CHAPTER 13 FLASH FLOODS – MANAGING THE RISKS

About the only thing floods have in common is water. They can be caused by rainfall, snowmelt, structural failures or ice jams. They can occur over days or in minutes, and take place in remote rural areas or in the middle of large cities.

Paraphrased from Susquehanna River Commission

13.1 Introduction

Flash floods represent a unique subset in the range of flood hazards. Flash floods rise quickly, frequently with limited or no warning, and giving rise to fast-moving and rapidly rising waters with enough force to destroy property and take lives. Flash floods are the most deadly of floods, and worldwide are responsible for the largest number of flood-related deaths and high flood mortality rates (Jonkman, 2005). Although mitigation of flash floods risks is difficult, it is not impossible. This chapter describes the flash flood threat and steps that can be taken to reduce the risks from such floods.

As with all effective efforts to reduce risk, flash FRM must account for the hazards as well as changes that are occurring to those hazards (climate and demographic) and the potential interventions (engineered structures and nonstructural responses) that may reduce present and future consequences of such floods.

13.2 Drivers of flash floods

Flash floods typically result from intense rainfall over a short period of time in a limited area. The intensity of the rainfall reduces the ability of the land to absorb the precipitation, and increases the runoff into streams and rivers, resulting in rapid rise of the stream or river level (stage). Flows in one river may join other rivers in the region affected by the same meteorological event, adding to the rapid rise. In mountainous areas where topography causes the rainfall to accumulate rapidly in valleys and canyons, the rises in river stages becomes even more pronounced – the steeper the topography, the more rapid the concentration of flows. In a matter of minutes or hours a peacefully flowing stream can become a raging torrent. In areas with steep soil-covered slopes, the intense rainfall can cause massive mudslides, which can move with such force as to wash away whole communities and landscapes below.

In high-latitude areas, particularly in the northern hemisphere, ice jams are a frequent occurrence, blocking channel and control structures. They can under some circumstances create flash flooding when they break (Figure 89). In the case of ice jam breaks, inundation may contain not only flood waters from the river but large ice boulders which themselves can cause significant damage.

Figure 89: The town of Eagle, Alaska was suddenly inundated when an ice jam break occurred on the Yukon River and forced the river into the community

Source: US National Park Service.

Flash floods may also occur following failures of dams, sending the waters previously stored behind the dams downstream as walls of water. They may result from failure or overtopping of levees, opening previously protected areas to the onrush of flood waters. Such events may or may not be weather-related. Dams and levees have failed and caused massive downriver flooding or inundation of areas behind the levees as a result of structural conditions not directly related to rainfall events. In rare cases, deliberate human actions have precipitated such failures. Under other circumstances, significant meteorological events have created conditions that caused the failure of the dams or levees. Whether the failure has a meteorological or nonmeteorological cause makes little difference to those who are affected by the consequences of the failures.

13.3 Past flash flood events

The record of flash floods is lengthy. Many are significant in terms of their consequences, of both lives lost and property damage. The following are illustrative of such events and the disasters they brought with them:

AUGUST 2002, CHINA

On 8 August 2010, unusually intense monsoon rains triggered devastating landslides and floods which buried a densely populated area in the centre of Zhouqu City in north-west China. The slide terminated in a brown fan that extended into the Bailong River (Figure 90 and 91). Mud surrounded several of the buildings near the river's edge and branched into adjacent streets. Some of this mud may have been deposited by flood waters that gathered behind the slide as torrential rain continued to fall. More than 1,400 people were reported killed and several hundred were missing after this disaster.

Figure 90: Satellite photo of part of downtown Zhouqu City after the mudslide

Source: NASA (http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=45329).

Figure 91: Buildings in Zhouqu City surrounded by mud as rescuers attempt to locate missing persons

Source: GIWP.

OCTOBER 2010, WESTERN HUNGARY

In October 2010, the dam of a sludge reservoir in Western Hungary failed and sent a toxic concentration of heavy metals down a nearby river and through two villages, killing eight people and injuring 92 (Figure 92). The reservoir was built to contain the residue from alumina production in a nearby factory. Over 600,000 m^3 of sludge ran into the local rivers and eventually into the nearby Danube River, raising international concerns over potential significant pollution. There had been no indication of a possible failure and as a result there was no warning of the flood given to those in the nearby villages. In 2006, in the same region, another alumina sludge reservoir failed and caused a similar flood.

Figure 92: Red sludge covers a Hungarian city after a flash flood caused by a dam failure

Source: AP Photo/MTI, Gyoergy Varga.

JUNE 1972, USA

In the late afternoon of 9 June 1972, scattered thunderstorms began to develop over the Black Hills, a rugged mountain range to the west of Rapid City, South Dakota, USA. By 18.00, heavy rain had begun to fall as a line of thunderstorms moved over the area, sending rainfall into the numerous canyons and valleys of the Black Hills. At 19.15, as the heavy rainfall continued, the US Weather Service issued a flash flood warning for Rapid City, and Rapid Creek, which runs through the city, began to overtop its banks. At 20.45, a dam on the west side of the city failed, adding to the flow in Rapid Creek. By 00.15 on 10 June, a flood crest of 1,416 m^3/s moved through the city, killing 238 people and causing US$800 million (in 2011 terms) in damages in the city and the region, including the destruction of 1,335 homes and 5,000 vehicles (Figure 93). The flash flood resulted from 254 mm of rain falling over an area of 115 km^2 in six hours. In one area the rainfall exceeded 381 mm in the same period.

Figure 93: Cars piled up by the 1972 flash flood in Rapid City, SD, USA

Flood damage on East Blvd. at Omaha St. in Rapid City, June 10, 1972 (photo courtesy of the Rapid City Journal).
See: http://www.crh.noaa.gov/unr/?n=1972_Floo
Source: US Geological Survey.

13.3 Characteristics of flash flood events

Flash floods can be characterized by the uncertainty of their occurrence, the rapidity with which they occur, the size and velocity of their flows and the potential severity of the associated consequences.

PREDICTING THE OCCURRENCE OF A FLASH FLOOD OR LANDSLIDE

Flash floods can result from a number of causes, and forecasting their occurrence is extremely difficult. Intensive thunderstorms, dam break, ice jam break and levee failure are all impossible to predict with any degree of certainty in the context of a flash flood forecast, but of critical importance to consider. Thunderstorms develop rapidly, with chaotic processes that can only be forecast in probabilistic terms, and an associated high degree of uncertainty. Advances in radar technology and coverage in a number of developed countries are promoting the use of data-driven models to forecast thunderstorms with some success, but in many regions of the world more limited coverage and older technologies limit their usefulness. When water overflowed the levees in New Orleans, structure failure and breach rapidly followed. Similarly failure of a storm water system to be able to accept, store or convey storm rainfall can lead to local fast-rise flooding. Such failures result from the collapse of pipes and culverts and the blocking of entrances to storm sewers by debris picked up by the storm waters. Neither of these events is easily predicted but methods to help are now starting to emerge, including:

- uncertainty and levee and drainage failure with real time forecasts
- real-time monitoring of levee performance and structural condition to support a forecast of failure (floodprobe, www.floodprobe.org).

Prediction continues to be focused at identifying areas that are susceptible to flash floods and landslides. Such analysis relies on synoptic, topographic and geologic analysis, and provides good insight, but developing the probability of occurrence and more importantly, forecasts of forthcoming events, is far more complex.

VELOCITY AND DEPTH OF FLOODING

The intensity of rainfall or the suddenness of a levee or dam failure or an ice jam event creates high-velocity flows during flash floods, and the high velocities create significant threats to those in the path of the flood wave. Velocities of 10–20 km/hr are not unusual. Such speeds will move automobiles and knock humans off their feet, carrying them away. Depending on the nature of the event, flash flooding can generate fast, and occasionally deep, flowing water down a stream or river. Heights of 3 to 6 m can be expected and under dam break or extremely large rainfall events, rivers may rise as much as 20 or more meters carrying with the flows boulders, trees, cars, and debris (Figure 94).

Figure 94: Large boulder found in a river in western China following a flash flood

Source: GIWP.

FLASH FLOOD CONSEQUENCES

Flash floods frequently catch unawares those who live or work in the flood zone. Early warning can reduce the human consequences of a rainfall-generated flash flood event significantly, but it is difficult to provide early warning for structural failure that can occur without any warning, when the distance between the failure and the population is minimal. The capability of flash floods to carry large amounts of material in their flows, including soil and sand that buries people and destroys property in their paths, increases the destructiveness of these events. Similarly, mudslides may occur without warning, bring vast volumes of debris crashing down on those below. Flash flooding occurs quickly and water levels created by these floods fall equally as fast. As a result, areas subject to flash flooding are not generally subjected to the same extended periods of inundation seen in slow-onset riverine events. However the time of recovery can be slow. The sediment load in the flood flows and the destructive power can lead to damage that it can take a considerable time to recover from.

13.4 Managing flash flood risk – intervention options

The first and most important stage in developing a response to flash floods is to determine the potential flash flood hazards and the areas that would be affected should a hazard event materialize. This includes the potential for intense rainfall events and the associated meteorological conditions, but also the potential for mudslide, dam break, ice breaks, levee failure and so on. Once these factors are known, described, and potential hazard areas identified, steps can be taken to reduce the impact of the hazard on the affected population and property.

STRUCTURAL MEASURES

Given the extreme range of flash flood flows and their infrequent nature, use of structural measures frequently is not economically viable or environmentally acceptable. This does not mean structural measures have no role. Examples do exist where structural measures are used: for example in San Antonio in the United States embankment dams (dry for most of the year) are used to control the flow of the flash flood flows (alongside nonstructural measures). In Almaty (Kazakhstan) there is a known risk of flash floods/mud flows from nearby mountains, and dams are used to retain the mud flows. Structural measures are therefore typically used to redirect flows, stabilize slopes and strengthen properties rather than attempt to defend the floodplain. Nonstructural measures (see below) linked with good land use management (promoting run-off control – see Chapter 9) offer the primary response.

NONSTRUCTURAL INTERVENTION

Nonstructural measures can provide significant mitigation of flash flood consequences. These measures include the following.

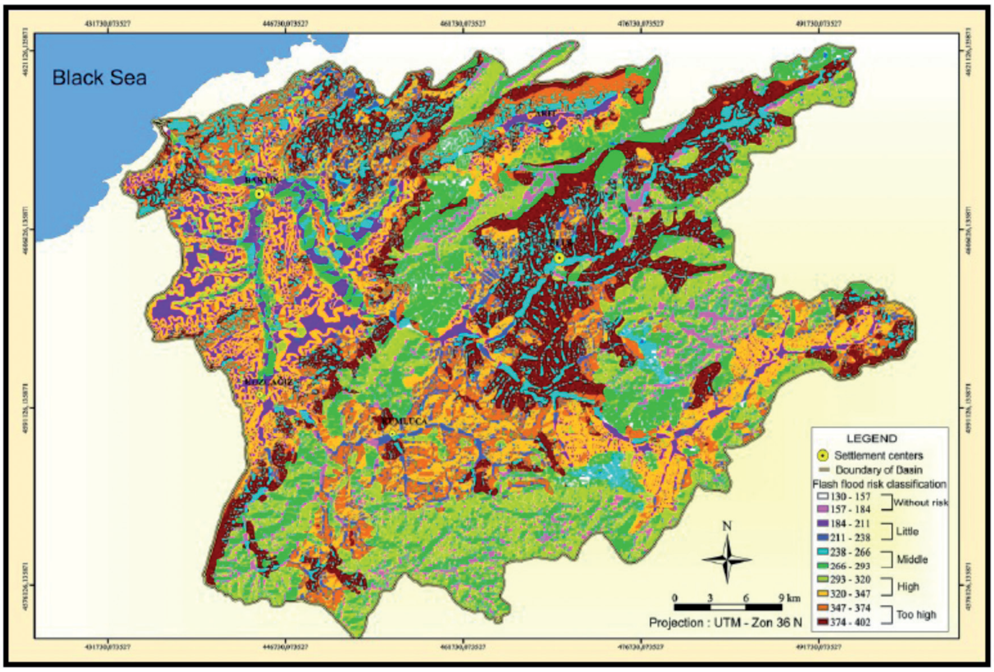
Building awareness and mapping of hazard zones

As with slow-onset flooding, calculations can be made of the areas that could be inundated by a variety of flash flood events, and these inundation areas mapped (Figure 95). The extent of historical flash floods provides a useful addition to such maps, but they need to be presented as historical maps and are not necessarily indicative of future floods. Depending on the quality of the data available, depths of inundation and flash flood velocities can also be indicated on the maps (see Chapter 12).

The extent of the inundation from the failure of a dam also can be estimated and mapped (Figure 96). Levee failures and ice jam flooding can occur at almost any place in a floodplain, and a combination of 'what-if' mapping (such as the rapid inundation zones mapping produced in England, which assumes a breach in the levee) and probability mapping (which maps the residual probability of flooding taking account of the chance of levee failure) can be useful additional outputs (see Chapter 12 for elaboration).

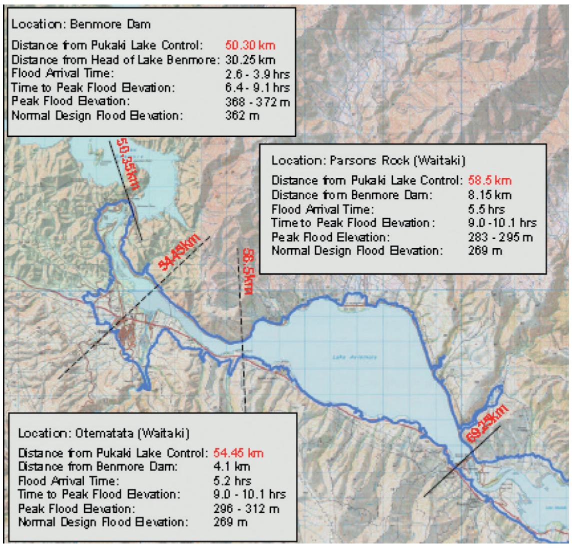
It is also possible to identify areas of potential mudslides (Figure 97) and, as with slow onset floods, maps can be developed to guide evacuation from flood hazard areas (Figure 98). As a result, in many areas of the world, when potential failure areas are identified, residents that might be in the path of the landslide are relocated to other less dangerous areas.

Figure 95: A flash flood risk map of the Bartin basin in Turkey based on analysis of the physical conditions of the basin



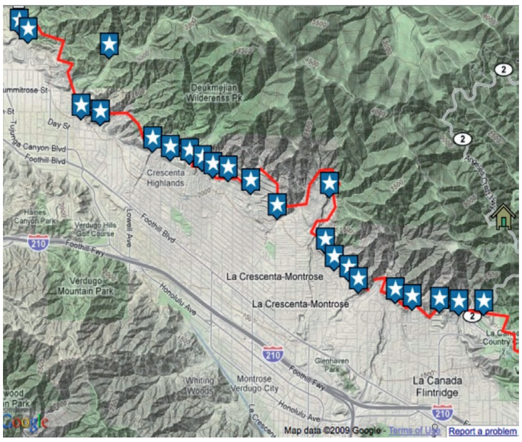
Source: H Toroglu, Istanbul University.

Figure 96: A section of a dam overtopping failure inundation map for Benmore Dam in New Zealand. Information in the boxes describes conditions concerning timing and extent of inundation at the selected cross sections of the river below the dam.



Source: Waimate District Council, New Zealand.

Figure 97: A Los Angeles Times map indicating areas subject to mudslides during storm events in August 2010.

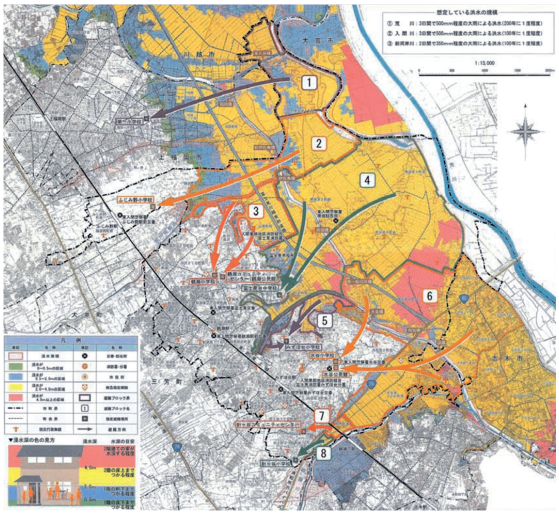


Source: These maps were based on US Geological Survey analyses of areas most at risk of mudslides (Los Angeles Times, 2010).

Better weather forecasting

Modern forecasting techniques permit the early identification of potential flash-flood-generating meteorological events. Dual-polarizing and increasingly sophisticated ground radar and satellite systems aid in the identification and tracking of storms and the accurate determination of their rain-producing capabilities – a capability that is starting to include the ability to track thunderstorms. Forecasts using a combination of physics and data-driven artificial intelligence techniques are now starting to increase the amount of time available to those in the path of major storms and potential flash floods.

Figure 98: Map showing safety areas and evacuation routes in Koriyama City, Japan



Source: EC (n.d)..

Better early warning systems

Once information on the potential for rainfall, dam/levee break or ice jam flash floods is developed or made known to responsible officials, wider dissemination should follow. Access to information on the probability of the event and its likely severity supports those who could be affected in taking actions to protect property and to evacuate when appropriate. Sirens and loudspeakers can be used to broadcast the message to populated areas. A wide variety of modern communication systems such as television, radio, cell phones and the internet provide near-instant communication of hazard warnings to those with such systems. In France, Cemagref and Meteo France have developed AIGA, a system that provides early flood warning information about French rivers. AIGA provides maps containing information on the rainfall and runoff risks across the entire country. The effort is expanding to include links to real-time hydrologic monitoring that is linked to near real-time displays of actual and potential streamflow changes.

Box 32: Identifying potential rapid response catchments – a national screening approach

Through 2004 and 2005 two small steep catchments in England (Boscastle, 2004 on the North Cornish coast and Helmsley, 2005 in the Yorkshire Moors) experienced flash flooding. In response new national-scale modelling was undertaken to identify those catchments with the potential to response rapidly to rainfall and produce a fast-flowing, rapid-rise flood event.

The study recognized that for small catchments the time between the rainfall event and the consequent flooding is short. This makes traditional flood warning systems that rely on monitoring river levels difficult or impossible to implement. There are characteristics of some catchments, however, that appear to place them at higher risk of flash floods than other catchments. In some locations this potential risk of rapid flooding will coincide with developed areas, which will mean that there is a risk to people and property. If such areas can be identified prior to any rainfall event, then the potential risk to people can be assessed and the appropriate response in these locations can be reviewed. In certain locations it might be possible to implement simple, quick warning systems, or information could be provided to raise awareness of the potential for flash flooding in these areas in order to reduce the risks to people.
A high-level method was applied nationally to:

- identify catchments that react quickly to rainfall events
- describe the severity of the resultant flooding
- assess the impact of the predicted flooding on people (using methods outlined in Defra, 2003).

Source: Environment Agency (2006).

The Boscastle flood arrived so quickly that owners did not have time to remove their cars. However the significant risk is to life and to fixed property (photo: Cornwall County Fire Brigade).

Example GIS image from the national application of the method showing peak flood depth during an extreme flooding event

Education

Unless people receiving the warning are aware of the risks and prepared to act, even the most sophisticated early warning systems will be ineffective. Individuals and organizations must understand the nature of the threat and what they should do in the event of receiving a warning. Community education and programmes in businesses and schools should focus on developing an awareness of the risks faced and the actions that must be taken when alerts are sounded. Education also should focus on actions that can be taken prior to flash flood events to mitigate potential damages. Such actions include relocation of utilities to upper levels of buildings and floodproofing/sealing of entrances and windows.

Preparedness exercises

In addition to individuals, organizations with responsibility for responding to a flash flood emergency must always be prepared. This includes undertaking periodic simulated exercises to practise and refine plans. Such exercises should be as comprehensive as possible, and include testing of the early warning systems, evacuation drills, and response and recovery training. (More details on the general aspects of emergency planning and management are given in Chapter 11).

Hazard identification signs

In association with education programmes, signs should be placed in flash flood hazard zones both identifying the areas subject to the hazard and providing instructions on the actions to take in the event of a flash flood or a mudslide (Figure 99). Although very simple, such signage can be powerful reminders of the risk posed.

Figure 99: Flash flood warning and instruction signs

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Land use controls

Damages from flash floods can be avoided by limiting development in areas subject to flash floods and mudslides. Where population pressures do not permit the prohibition of development throughout a potential hazard area, development in those areas deemed to be the most hazardous should be restricted or limited to activities that can sustain occasional flash flood damage (such as parking lots, sports fields and parks).

Building codes

Both retrofitting and new design offer an opportunity to increase the resistance and resilience of buildings to flash floods. Where development will take place in areas that could be subject to flash flooding, new structures should be built according to standards that dramatically reduce the damages that would be sustained in a flash flood or a mudslide. In some cases, it may be necessary to mandate elevation of structures that will be subject to frequent flash flooding.

13.5 Flash flood risk management planning

The techniques and procedures described in earlier chapters for flood risk planning for slow-onset floods apply equally to planning for management of flash floods and related mudslides. Because of the nature of a flash floods, such planning, while it must take into account national and regional policies, goals and objectives, places an increased onus on clear identification of local issues and unique physical factors. It must also integrate the actions that need to be taken by individuals and businesses as well as the local emergency management structures charged with development of the pre-event planning, response during the event, and post-flood recovery. The lack of long warning periods before flash floods makes it unlikely that those on the scene can plan on support from higher levels of government prior to and immediately following the flood.

As a first step in the planning process, heavily populated urban areas that are subject to flash flooding must be identified and the hydrologic characteristics of the region closely examined. Knowing these details permits the identification of the flood forecasting and early warning tools that are most needed and where they should be located. This initial analysis also permits the development of structural and nonstructural portfolios of flood risk reduction measures. In addition to the need for more accurate and timely forecasting methods and enhanced early warning systems, considerable effort needs to be focused on educating the population at risk about what to do both if a potential flash flood is announced and during the event should it occur.

Following the 1972 Rapid City, North Dakota, USA flash flood, federal, state and local officials worked closely together to develop an integrated approach to reduce the threat of flash flooding to the community should another major event occur. Following a detailed analysis of the physical characteristics and development of the 1972 flood and an examination of land-use patterns in the Rapid City area, officials initiated a number of actions designed to address the shortfalls identified in the post-flood analysis. The size of the National Weather Service staff in the region was increased and more modern forecasting equipment was brought on site. Increased reliance was and is being placed on use of new observation systems such as satellites to provide a more rapid understanding of weather systems as they develop. Communication systems that were used to notify local officials of impending weather events were also modernized. As part of a national improvement in early warning of weather events, radio and television stations were integrated into an early warning network that permitted special alarms to sound on receivers in homes and businesses. Similar alarms are now able to be transmitted to the wide variety of personal telephones and communication devices. The four warning sirens in the region in 1972 have been supplemented by additional thirteen devices (NOAA, 2011; USGS, 2011).

Consideration was given to development of structural measures to deal with potential flash flooding, but those alternatives analysed were either not feasible from an engineering standpoint or too costly. As a result, the city, working with the state and federal government, chose instead to develop a green way –open space – along the river to reduce the potential exposure of the community to flooding and provide room for the river to pass through without causing significant damages. Extensive education campaigns have taken place in the community to remind residents of the earlier tragedy and to inform them of the actions they need to take in the event the future threat (USGS, 2011).

Similar efforts were undertaken after other flash flood events around the globe, and these have succeeded to varying degrees. Considerably more success has been obtained in improving the quality of weather forecasting, early identification of potential significant events, and development of early warning systems that educate the public about appropriate actions in the face of flash flooding. In developed areas, in spite of considerable media attention to the threat, the highest casualty rates occur as a result of vehicles being caught in floodwaters. Receipt of information about a threat does not necessarily enhance people's safety unless they are willing to modify their behaviour in response to this information, or governments are willing to move to involuntary evacuation (Montz and Gruntfest, 2002; Staes et al., 1994; Duclos et al., 1991). Efforts to better manage areas most prone to flash flooding are hampered by pressures for development in the same areas. Following the flash flood deaths of 137 people in the Big Thompson Canyon in Colorado in 1976, plans were made to limit occupancy of high-risk areas; however, in the decades since, development has gradually moved back to take advantage of the canyon's amenities.

Following major flash floods in many large Asian cities such as Kuala Lumpur, Manila and Seoul, efforts were undertaken to improve forecasting services and warning systems, but the concurrent growth in population, interior drainage problems and lack of public understanding of what actions should be taken during flood events created conditions that continued to generate flood casualties. The need for public education was found to be of critical importance (Sehmi, 1989). The experience of Aude, France in dealing with flash floods is highlighted in Box 33.

Box 33: Aude, France – reducing the risk from flash floods

The Aude is a region in France exposed to severe flash floods. These examples illustrate the fact that, except for camping places, evacuation is generally not recommended in France and is considered as a very last resort. A suggestion was made after the 2002 floods in the Gard region to build refuges on the roof of some houses if they are below the maximum water level so that the occupants have a place to take shelter before being rescued. If evacuation is considered necessary, the procedure is described in the municipal safeguard plan (*Plan communal de sauvegarde*). The typical procedures are described in regulation 2005-1156 of 13 September 2005, including:

- First provide a pre-alert message to the affected population to give information about a possible evacuation and explain the procedure. A second message is given at the start of the evacuation. Both messages have to be clear.
- Teams are created to organize the evacuation, with one team per area to be evacuated. If necessary, specific means are prepared to evacuate schools: for example, transport can be requisitioned. If some of the residents refuse to evacuate their location should be noted. If the situation becomes dangerous they should be forcibly evacuated. People with reduced mobility have to be identified and helped. After the evacuation, every building must be checked to be sure that there is nobody remaining in the area.
- A safe place must be designated and prepared for the evacuated people to take shelter. This is typically a public building like a school or a gymnasium. This place must be located as close as possible to the evacuated areas.
- The evacuated areas must be policed to avoid looting and vandalism.


L'évacuation

La mise à l'abri dans un refuge sur place est souvent préférables à une évacuation, notamment pour toutes les habitations qui ne sont pas fortement exposées lors de la montée des eaux.

Si l'évacuation apparaît comme l'ultime solution,

- *évacuer rapidement,*
- *gagner un point en hauteur ou le refuge indiqué,*
- *suivre strictement les consignes données par les autorités.*

About Evacuation

Taking shelter on the spot is often preferable to an evacuation, particularly when the buildings are not exposed to potentially destructive flood flows. If evacuation is the only option then:

- Evacuate without delay
- Move to high ground or an designated refuge
- Follow the orders of the authorities


Prévoir

- *l'installation au-dessus du niveau des plus hautes eaux (dans les étages supérieurs, les combles ou sur le toit de l'habitation), d'une zone refuge accessible de l'intérieur et de l'extérieur (pour les secours).*
- *sur les ouvertures, des dispositifs mécaniques destinés à ralentir l'entrée de l'eau.*
- *les moyens de surélever le mobilier ou de le monter dans les étages,*
- *la mise en sûreté des véhicules avant l'inondation.*

Before the flood

- Install a refuge, above the highest known flood water level which is accessible from both inside and outside the house
- Slow down entrance of water through the openings
- Raise the furniture above the flood water or move upstairs
- Put vehicles in a place safe before the onset of flooding



Ne pas...

- *Ne pas s'engager à pied ou en voiture dans une zone inondée: une voiture n'est plus manoeuvrable dans 30 à 50 cm d'eau; ne pas forcer les interdictions. Reporter ses dépalcements à plus tard.*
- *Ne pas prendre l'ascenseur...pour éviter de rester bloqué.*
- *Ne pas aller chercher ses enfants à l'école...l'école s'occupe d'aux.*
- *Ne pas téléphoner...afin de libérer les lignes pour les secours.*

Do not...

- Do not walk or drive in a flooded area. It s not possible to control a car if the depth of water is between 30 and 50 cm.
- Do not force pass through roadblocks. Postpone your travels.
- Do not take the lift as it may get stuck
- Do not go and fetch your children at school. The school will care of them

Do not use phone as the lines need to be left free for the emergency services




Agir

- *Fermer les portes, fenêtres, soupiraux, aérations...pour ralentir l'entrée de l'eau et limiter des dégats.*
- *Couper l'électricité et le gaz...pour éviter l'électrocution et l'explosion.*
- *Monter dans les étages avec: eua potable, vivres, papiers d'identité, radio à piles, lampe de poche, pile de rechange, vêtements chauds, médicaments...pour attendre les secours dans les meilleures conditions.*
- *Ecouter la radio...pour connaître les consignes à suivre.*
- *Se tenir prêt à évacuer les lieux à la demande des autorités, prendre ses papiers d'identité et si possible fermer le bâtiment.*

Act

- Close doors, windows and other openings to slow the entrance of water and limit the damages.
- Switch off the electricity and gas to avoid electrocution and explosions
- Go upstairs with: drinking water, supplies, identity papers, radio, torch, batteries, warm clothes, medicines and wait for assistance under the most favourable conditions.
- Listen to the radio to get the latest instructions
- Be ready to evacuate when requested to by the authorities' request. Take your identity papers and if possible lock your home.

Source: adapted from Mens et al. (2008).

13.6 A summary of recommendations – learning the lessons from flash flood events

Flash flood events are common to all regions of the globe, and perhaps the most important lesson is that, where possible, development in flash flood risk areas should be avoided. This of course relies upon understanding those areas potentially at risk.

Success in dealing with these events rests on pre-flood identification of the potential risk in terms of magnitude and location, development of techniques to provide forecasts of events as they develop, education of those that might be affected, and implementation of early warning systems that permit those at risk to move out of harm's way. Development of plans to deal with flash floods and to respond to their occurrence will require use of the same procedures employed to deal with slow-onset floods.

CHAPTER 14
INSURANCE AND FLOOD RISK

14.1 Aims

Flood insurance is a major and legitimate activity in managing flood risk. For those insured, flood insurance provides a mechanism for them to transfer part of their risk and reduce their vulnerability to flooding; to those providing the insurance (and reinsurance) it provides a commercially viable means of generating income.

Flood insurance, when seen as part of a portfolio of measures to reduce or manage flood risk, has four main roles:

- **reimbursing** those who suffer damage, and thereby restoring them to their pre-flood financial situation
- **spreading** the costs of flooding across communities (and clients) , given that floods may affect only some communities at a time; and for individuals through time by spreading the potential costs of flood damage over many years in relatively small payments rather than having a single large cost if and when a flood actually occurs
- **reducing** the costs to the government of post-event recovery since the insured will receive insurance funds (note: where a private insurance sector exists only)
- promoting a **change of behaviour** with regard to exposure to flood risk, by giving a signal of the hazard that people face and providing incentives for 'good behaviour' – joining automated warning schemes, floodproofing properties and so on.

Only the fourth of the roles listed above seeks to reduce risk; the first two simply transfer the risk from the insured to the insurer, and the third reduces government expenditures.

The way in which each of these roles is approached determines the nature of the flood insurance arrangements that are effective and commercially viable. In descending order of general incidence, insurance policies can be bought for:

- **property damage loss**, when floods cause damage that requires the repair or replacement of buildings and their contents
- **loss of business income and profits,** for example when operational days occur or stock is lost
- **loss of agricultural production**, for example when crops are destroyed
- **loss of life and injury** during floods (life insurance).

Insurance against flood damage is a central component of a well-considered portfolio of FRM measures, but there are dangers. Many private insurance companies failed in the United States in the early parts of the twentieth century when confronted with massive claims during major floods. This failure occurred for a number of reasons:

- Few legitimate insurance companies in the early part of the twentieth century underwrote flood losses, as few considered flood catastrophes to be a natural hazard. (In part this was because the insurer had limited ability to properly access catastrophic risks – that is, those affecting many insured at once – in terms of frequency and severity, and hence premium levels and reserves were often insufficient.
- Many illegitimate insurance companies existed at the turn of the twentieth century as insurance products became increasingly popular. Because of the lack of associated regulation fraud, scandal and mismanagement were commonplace. Many of the issuing companies did not actually have the capital to pay claims, whether these claims related to flood, fire or loss of life.
- Many companies went bankrupt and the claimants did not receive their compensation.

In response the US government had to intervene to make many of these payments, so as to restore faith in insurance generally. A much tighter and more regulated industry followed to try and curb future problems.

14.2 State or private? A key decision

Any organization promoting flood insurance must be large, as claims totals can be substantial. There are basically two alternatives:

- flood insurance provided by the state, and sold to communities or individuals
- flood insurance provided by large private companies, and sold as profit-making services just like motor and other typical insurance products.

Each has advantages and disadvantages. For example, a state system requires a long-term commitment which may not fit with changing political agendas. It also requires a commitment by the government to meet periodic large claims. Private companies may fail, or may withdraw cover when it becomes unprofitable. Governments should decide for their country where the balance of advantage lies, or could decide (like most of the Netherlands) to have no flood insurance at all.

14.3 Necessary conditions for successful insurance

There are five conditions that need to be in place to ensure the sustainability of any insurance scheme, not just flood insurance (Arnell, 2000). These are:

- It must be possible to estimate the **likelihood and magnitude of possible losses**, so that premiums can be calculated that reflect this loss potential. If this is not possible, the premiums become arbitrary and the insurance agency (private or governmental) is at risk.
- Losses from individual claims must be **independent**, and no single event such as a major flood should affect the majority (or even a large number) of those insured. If this is not the case, then the insurance agency might be faced with an overwhelming claims total, and fail.
- The occurrence of any event leading to claims **must not be predictable** in deterministic terms (for instance, the dam will fail tomorrow and my house will be lost), or else those purchasing policies will only do so when they know that a claim is certain/likely.
- There must be sufficient **demand** for insurance coverage to make a large enough market that a single event such as major flood does not lead to claims that exhaust the insurance agencies' resources
- The **premium** charged to the insured must be acceptable so that coverage is purchased.

The problem with flood insurance (compared, say, with motor insurance) is that not all these conditions are met. In particular, flood losses are not independent; a major flood affects hundreds or thousands of adjacent properties, all of which may claim at once. Regional floods may affect properties across different catchments, or even in different countries. Equally a flood event could coincide with an earthquake and /or hurricane and wind damage. Although there always will be some correlation between risks, for the most part one flood event will not affect everyone. Flood is not alone in this: brush fire, windstorm, freeze and all other natural perils have some degree of dependence and can impact multiple policy holders. A regional company might have greater exposure to dependent risks than a well-diversified international or national insurer. The potential for large single-event claims however puts insurance companies or even governments at risk. This pressure has led to the development of an active reinsurance market for natural perils, which seeks to further transfer this risk – see below.

HOW BEST TO MEET THE FIVE CONDITIONS

Failure to meet the above conditions is liable to render any insurance system fragile, and to cause it to fail periodically. This can be avoided by careful attention to information on flood risk and the nature of the insurance scheme, as discussed below:

Having adequate information on which to base premiums

What are required here are flood maps and flood probabilities. This in turn will require a hydrological database of past floods, from which to predict future flood probabilities for locations where insurance premiums are to be sold, as these premiums should ideally be related to the risk of flooding and hence of claims. This database should extend back as far as possible (say fifty years) and is likely to include, for each catchment or locations within catchments:

- rainfall records
- runoff characteristics
- river flow records
- coastal tidal gauge and surge records
- historical flood extents (for model calibration)

- structure elevations
- adequate topographical information.

The simplest way of presenting information from the analysis of this data is as insurance 'rate maps', showing where properties are located, and the extent of the 10, 20, 50 and 100-year floods. With climate change affecting the behaviour of the flood system and hence probabilities, this can be a complex operation, and modelling is usually required to produce the flood extent data, which cannot solely rely on historical records.

Insurance premiums should reflect risk, although they do not always do so. Risk incorporates the probability of flooding, and the consequences of that flooding. This means that the insurer must also know the susceptibility of the insured to flood damage, as compensation will obviously be a function of that damage. For this, data needs to be collected on:

- the nature of the property insured (for instance domestic, industrial or commercial)
- the size of that property or group of properties
- the potential damage that would result from a range of flood events (to establish an expected annual loss).

In this way the insurer can calculate an appropriate annual premium to charge which over the long term will compensate the insured for the flood losses they will incur and create sufficient profit (and hence reserves) for the insurer to be safe from failure.

Assessing exposure of individual premium payers, communities and hence the total portfolios

Given the data collected as above, the insurance company needs to set the premium to charge. If this is done correctly total claims should not exceed total premium income, over the long term.

But the exposure of the insured to risks changes over time. This might result from increased runoff from an urbanizing catchment, or increased flood flows resulting from climate change. It might also result from the changes in property characteristics, when the owners extend their buildings or purchase more valuable contents. This means that exposure needs to be monitored continuously, and premiums recalculated on a regular basis (say, every year).

Any insurance company will also need at the same time to assess its total exposure to risk, by cumulating all possible simultaneous claims within its portfolio of policies. This is necessary to ensure that the company can meet its obligations of paying compensation totals that cover its entire portfolio. It will also alert the company to excessive risk and encourage it to spread its portfolio of cover over many communities and/or catchments.

This way makes it very less likely that all policy-holders will claim at the same time, and thus threaten the company, by ensuring that claims to the insurance company are matched by (or at least paid partly from) income from others who are not making these claims either at that time or at all.

Having adequate financial reserves to meet all claims

In a properly run flood insurance scheme total claims should not exceed total premium income, over the long term. But the scheme might be faced with many claims early in its life, or claims in any one year that far exceed its annual premium income.

This means that the scheme must have reserves (through reinsurance or capital market securities) or be backed by the country's government as the 'insurer of last resort'. The extent of these reserves will depend on the nature of the portfolio of policies the company has 'written' (that is sold) and the chance that premiums in any one period will exceed income, and by how much. There are no simple rules here, but insurers at Lloyds of London (a marketplace in which insurance is traded) are required by the UK Government to be able to cover all the claims from a 1:200-year event.

These reserves also need to be liquid. That is, they need to be available at short notice, to respond to a flood event and the claims that rapidly follow, so they cannot include valuable property that could not be sold easily or quickly. Generally they comprise government bonds that are traded regularly and are relatively risk-free investments. Holding these liquid reserves – which generally yield a low income – is an expense that the insurers must be able to cover.

Promoting a sufficiently large market to ensure the safety of the insurers

Any small market in flood insurance is liable to suffer from claims that overwhelm its income and reserves. Therefore the market for flood insurance needs to be large, so as to include at any one time far fewer claimants than the numbers that are insured. Ideally any insurance scheme will, say, have many thousands (or millions) of premium payers but only a few hundred or a few thousand claims in any one year (or any other such period).

How this is achieved is not easy in flood insurance, as property owners might only seek and therefore buy insurance if they feel that their individual risk of flooding is high (which is known as adverse selection). Most governments make it compulsory for vehicle drivers to insure against accidents. This is generally not possible for flood insurance, as the owners of risk-free properties well outside flood plains would justifiably complain, and in a free market they will decline to buy cover or simply refuse to pay. Either incentives for insurance need to be provided (by governments generally) or other ways found whereby insurance is bought by people unlikely to claim, as in the United Kingdom (see below). In any case the market must be large, or it is vulnerable to large simultaneous claims which will lead to its collapse.

Governments have an important role here. They can either be the agency of insurance themselves (that is, act as an insurance company in insuring individuals or communities) or they can promote a private insurance market (see above). If the latter, they will need to regulate it in such a way as to minimize the risk of failure by requiring the companies to hold sufficient reserves to meet multiple claims. Often the critical tension between the regulator and the private insurers is a desire for affordability for all and a fear that regulation will suppress risk-based rates to a level where premiums would never cover losses, and hence the private insurance sector would fail to function.

Importantly, the ratio between reserves and the extent to which the companies can provide insurance cover needs to be controlled, using fixed ratios based on modelling of catastrophic floods or by some other means, so as to disallow the companies from writing excessive numbers of policies that could lead to failure if claims all come together. (Note: rating agencies routinely do this for hurricane and earthquake, and are likely to increasingly do so for flood).

14.4 The nature of reinsurance

Individual insurance companies can become unsafe or even fail if they are faced with an overwhelming claims total. Anticipating these circumstances, the company can reinsure part of its liability with a specialist insurer, which will reimburse them if the liability exceeds a certain sum (typically billions of dollars). The premium might be quite small per sum insured, given that the probability of a claim is inherently low, but it means that the insurance company is rendered fit to write more policies than would otherwise be the case.

Reinsurance companies are typically regulated with capital ratios, and to be profitable and safe they tend to be large, so they can bear the losses when claims are made, and have an international rather than just a national marketplace to realize the benefits of a diversified portfolio covering many disparate circumstances.

As pressure mounts for insurance payouts to be delivered as rapidly as possible, some reinsurance products release the insurance compensation payment based on the occurrence of a (precisely defined) catastrophic event without a detailed assessment of the actual damage caused. This allows for speedy processing of insurance claims; the event itself can be verified in a matter of hours, whereas damage assessment can take months or years.

14.5 'Nonstationarity': a real threat to insurance?

The world is changing, in both its climate and its social and economic fabric. The past is no complete guide to the future. Insurance arrangements and premiums that are based on the past hydrological record can be unsafe, and fail if there is a 'run' of serious floods requiring huge insurance payouts.

There are several ways out of this dilemma:

- One solution is for insurers not to offer long-term policies, but to restrict them to annual cover. In this way losses one year can be recouped the next (provided as the insured can afford the higher premiums that will probably be required).
- Another strategy is more risk sharing. The insurance policy can require that the insured pays the first slice of the flood damage costs (termed an excess or a deductible), particularly for high-risk areas. In this way the liability of the insurance company is reduced.
- Insurance for floods is not offered by the private sector: this is a real option, and can bring dilemmas for the governments of the countries concerned, as they are then liable to pick up a substantial element of the bill for flood damage if they want the areas affected to recovery quickly.

Clearly, insurers need to monitor very carefully indeed the state of flood risk in the areas in which they provide cover, so as to avoid the dangers that come with unanticipated change in risk and hence liability.

14.6 Example insurance regimes

FLOOD INSURANCE IN THE UNITED KINGDOM: INSURANCE FOR ALL, IRRESPECTIVE OF RISK

Flood insurance is very common in the United Kingdom, for some internationally unique reasons. Based on the government's Household Expenditure Survey and evidence from its own members, the ABI estimates that the take-up of insurance in the United Kingdom is such that 93 per cent of all homeowners have buildings insurance that covers their home (where this insurance is a standard condition of a UK mortgage), although this falls to 85 per cent of the poorest 10 per cent of households purchasing their own property. Some 75 per cent of all households have home contents insurance, although half of the poorest 10 per cent of households do not have this protection.

This internationally unusual situation is a product of history. Following severe floods in the south-west of England in 1960, the insurance industry agreed in 1961 to make flood insurance more widely available to private households and to commercial and industrial properties. Members of the British Insurance Association, the forerunner of the ABI, reached a 'gentleman's agreement' with government. The agreement was that they would offer flood cover to any domestic residence or small shop in Britain at an additional premium not exceeding 10 shillings (£0.50, or approximately $0.60). But there was a key condition: this cover they would charge to all properties, irrespective of risk, as part of a general household insurance package.

Thus, the pattern of compensation for flood damages being the responsibility of individual householders and businesses provided through the market was set, as was the role of private insurance. In the 1990s, as data and techniques for mapping and modelling flood risk improved, the insurance industry focused attention on identifying properties at greatest risk; and thereby on endeavouring to ensure that the premiums charged reflected that risk, and on assessing the overall level of liability it might face in a major flood event.

This provided the industry with an argument for increased investment in flood defence. In this way, the ABI began to contribute to the debate about funding for flood and coastal defence. The flood event of 1998 also served to increase the industry's level of concern about the potential frequency, and cost, of floods in the United Kingdom, but it was the events of autumn 2000 that confirmed the industry's predictions on inland flooding. It was clear that significant flood event could result in insurance costs of between £1 billion and £2 billion (approx. US$1.2–2.4 billion): a dangerously large sum from the industry's perspective.

In January 2001 the industry, through the ABI, agreed voluntarily that it would be a general policy to maintain flood cover for domestic properties and small businesses, but just for a period of two years. During these two years the ABI was active in putting pressure on the government, through a variety of means such as direct discussions and responses to consultation documents, to ensure that sufficient funds were made available to allow flood defences to be improved, thus reducing the potential liabilities.

The ABI was also a key actor in processes to secure a strengthening of the control of development in floodplains through changes to planning policy guidance/statements and the planning system. In 2005 it issued a 'Statement of Principles' (ABI, 2005) on the provision of flooding insurance', indicating that flood cover would be maintained for domestic properties and small businesses where properties were currently protected to Defra's minimum indicative standard or 1 in 75 years, for urban areas, or better where improved defences to at least that standard were planned by 2007.

In other locations, where risks were unacceptably high, and no improvement in defences was planned, flood cover could not be guaranteed but would be considered on a case-by-case basis. The implementation of the principles in the Statement was conditional upon specific actions from government being carried out, on funding, development control and other matters.

In summary, the UK flood insurance arrangements are designed to make the insurers safe and profitable, without which there would be no private market for compensation against loss through flooding. The consequence is that some individuals who are insured, and pay for it, do not need that insurance, and the government is required to spend more on flood defence than it might otherwise do. The merits and demerits of these characteristics continue to be debated.

FLOOD INSURANCE IN THE UNITED STATES: CARROT AND STICK

Standard US homeowners' insurance does not cover flooding. It is therefore important for those at risk to have extra protection from the floods associated with hurricanes, tropical storms, heavy rains and other conditions that impact the United States.

In 1968, Congress created the National Flood Insurance Program (NFIP) to help provide a means for property owners to protect themselves financially from unaffordable flood damage. The NFIP offers flood insurance to homeowners, renters and business owners if their community participates in the programme. Participating communities agree to adopt and enforce ordinances (zoning of land use) requiring that all new homes built after the community joined the programme to have their first floor elevation at or above the 100-year flood elevation. Communities must also meet or exceed other FEMA requirements, such as control of construction in that portion of the floodplain that passes the 100-year flood in order to reduce the community risk.

The NFIP has the following three aims:

- to provide flood insurance at affordable rates (that are reasonable given the risk faced)

- to reduce federal disaster aid by replacing such aid with the insurance system
- to slow the rate of increases in flood losses through community actions that control development in the 100-year floodplain.

In this respect the NFIP supports local communities in their efforts to reduce the risk and consequences of serious flooding. In order to participate in the NFIP, a community must agree to adopt and enforce sound floodplain management regulations and ordinances. In exchange for these practices, FEMA makes (government-subsidized) flood insurance available to homeowners, business owners and renters in these communities. Those who joined the programme in its early days and who lived in the 100-year floodplain were offered reduced or subsidized rates. Today, approximately 25 per cent of the FEMA policies are subsidized (so they are provided at a rate lower than actuarially expected).

Because relatively few homeowners purchased flood insurance early on, the US Congress established a mandatory purchase requirement (MPR) in 1973. A property owner in an area at high flood risk (defined as having a first floor below the elevation of the 100-year flood) is required to purchase flood insurance if the property is mortgaged with a federally regulated lender. The lender is required to ensure that the property is covered by flood insurance for the term of the loan, and to purchase flood insurance on behalf of the property owner if the property owner fails to do so, although this is not frequently done. Homeowners who live in a hazard area that is protected by a levee that provides protection against the 100-year flood and has been recognized by FEMA as providing that level of protection are not required to purchase insurance.

Box 34: Floodplain development and flood insurance in the United States

US Federal policy has not prevented development in high-risk areas. Since 1980 coastal county population growth rate (at 28 per cent) is consistent with the nation's average rate of increase, but the density is much greater (17 per cent of the land area holds 53 per cent of the total population). However, only about 3 per cent of the US population live in a coastal flood hazard area.

Flood insurance is available in over 21,000 participating communities nationwide. There are over 1100 communities participating in the financial-incentive-based Community Rating System implementing 'higher standards', and accounting for 66 per cent of policies in force.

There are over 80,000 insured repetitive loss properties (a number that is growing) and over 8000 severe repetitive loss properties (also growing). There is $1.2 trillion in insurance cover, and 5.6 million flood policies are in force. About 25 per cent of the 5.6 million policies are rated at less than actuarial rates

Outstanding Treasury borrowing (debt) is $18.7 billion.

Source: FEMA www.fema.gov accessed 1 December 2011.

Rather than purchase insurance through the NFIP, lenders and homeowners can purchase flood insurance from private insurers. In contrast to the NFIP market, in which the private sector sells the policies but the federal government underwrites them, in the private-sector market insurers both sell and underwrite the policies. Such policies must meet or exceed the coverage provided by NFIP policies to satisfy the MPR.

At present, coverage of residences under the NFIP is limited to $250,000 and $500,000 for businesses. Those seeking coverage above the FEMA maximum must turn to the private market.

FLOOD INSURANCE ARRANGEMENTS IN FRANCE: 'BUNDLED' WITH FIRE COVER

In France, a different model of compulsion has been developed. Since 1982 the French government has required communities to produce plans to reduce risk – not just from floods – in the form of plans d'exposition aux risques (PER), termed plan de prevention aux risques (PPR) since 1995. The insurance element is provided by requiring all those insuring against fire to pay a compulsory levy of 9 per cent of their premium for flood insurance. Insurance companies can buy reinsurance from the state's Caisse Central de Reassurance.

At the same time, mitigation was incorporated in the arrangements. A commune has to produce a plan of its floodplain areas, and divide this into zones with different levels of risk. New development is subject to conditions that are designed to reduce the build-up of risk, and existing developments must be adapted to minimize risk, paid for by the owners. Reimbursement for flood damage is only paid if the property affected meets the requirement of the PPR: new development in contravention to the plan is not covered, nor is property that had not been adapted as above.

There are similarities with the US NFIP, but suited to French circumstances. There is no need to incentivize compliance with zoning and mitigation measures, as in the United States through subsidized flood insurance, because in France these plans and measures are required by law. This more dirigiste regime does have its own limitations, in that enforcement of the mitigation measures has not always been straightforward, and this threatens to undermine the whole arrangement.

INSURING THOSE RESPONDING TO FLOOD EVENTS

As well as those directly impact by floods, local governments can incur significant additional expenditure in responding to flood events. Various 'insurance' mechanisms exist to reimburse local governments for this additional expenditure from central funds. For example the Belwin scheme in the United Kingdom provides a central government fund that local authorities can apply to for emergency financial assistance following a major emergency in their area. If a local authority incurs costs from responding to a major incident, it can apply for a grant to recoup up to 85 per cent of the costs (over a given threshold).

The scheme is applicable where an emergency or disaster results in destruction of or danger to life or property, and a local authority incurs expenditure on, or in connection with, taking action to safeguard life or property or preventing suffering or severe inconvenience in their area. Local authorities are not automatically entitled to this financial assistance, and the grant does not cover insurable or capital costs. The decision to award a grant is taken by central government after deliberating on the disaster circumstances.

14.7 A summary – the key components of an effective flood risk insurance sector

For flood insurance to form a component of the FRM it must:

- have access to sufficient financial reserves (either directly or through reinsurance) – reflecting a good understanding of the interconnectivity and the spatial and temporal coherence of the major flood events (and associated perils) to which a country is exposed
- form part of a more comprehensive and large private insurance industry, or be run by the state
- compel individuals and businesses to take insurance (or at least in part)
- be well regulated to ensure substantial financial reserves are maintained (particularly if operated through private companies)
- set premiums that are affordable (to promote take-up) yet commercially reasonable given good data on risks faced
- promote and regulate reinsurance arrangements; ensuring providers have appropriately diversified their exposure
- promote 'good behaviour' but build flood risk mitigation actions into the conditions for cover to be provided
- link private and government funding with individual and business financing to promote betterment of reinstated properties (to be flood resilient)
- provide access to central government emergency funds to insure the additional costs incurred by local governments in responding to flood events.

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Flood risk management
A Strategic Approach

Over recent decades the concept of flood risk management has been cultivated across the globe. Implementation however remains stubbornly difficult to achieve. In part this reflects the perception that a risk management paradigm is more complex than a more traditional standard-based approach as it involves 'whole systems' and 'whole life' thinking; yet this is its main strength and a prerequisite for more integrated and informed decision making.

This book results from an international collaborative effort to explore and distil best practice approaches to flood risk management in challenging large scale and inter-related environments. Part A provides a historical perspective on the flood events that have shaped modern approaches. Part B describes emerging good practice, including (i) the purpose and characteristics of strategic flood risk management, (ii) the goals, objectives and outcomes sought, (iii) the necessary governance frameworks, (iv) the development of adaptive strategies, (v) the relationship with ecosystem services, (vi) the barriers to, and enablers of, implementation, and, finally, (vi) the 'nine golden rules' that underpin good flood risk management decision making today. Part C presents particular techniques in more detail, including (i) risk and uncertainty analysis, (ii) spatial planning, (iii) infrastructure management, (iv) emergency planning, (v) flood hazard and risk mapping, (vi) the management of flash floods and (vii) insurance.

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