Responsibilities for adaptation to different types of flood hazard at various scales.

Ian Douglas
Emeritus Professor, School of Environment and Development, University of Manchester, M33 5DD, UK.
ian.douglas@manchester.ac.uk

Resumo:

Responsabilidades para adaptação a diferentes tipos de risco de inundação em várias escalas.

Os danos causados pelas inundações, nestes primeiros 12 anos do século 21, foram cada vez mais graves na Europa, tendo levado a uma maior resiliência e melhor capacidade de adaptação a futuras inundações, bem como aos efeitos decorrentes das mudanças climáticas. Embora as medidas estruturais continuem a desempenhar um papel importante, estão a ser desenvolvidas combinações de obras de engenharia pura, com medidas não-estruturais, tais como: seguros, preparação das famílias, ou estratégias e sistemas de alerta da comunidade local. No entanto, alguns tipos de inundações rápidas, particularmente associadas a águas superficiais e a colectores de águas pluviais que transbordam em áreas urbanas, parecem estar a aumentar e a apanhar de surpresa as pessoas. Assim, é importante identificar onde, quando e como deve ser a preparação para inundações. Estudos de caso relacionados com pluviosidade intensa e rápida fusão das neves, tanto em pequenas linhas de água urbanas como em grandes rios, ou associados a inundações costeiras, mostram que todos nós, das famílias aos órgãos de governo (autárquicos e nacional) têm responsabilidades e podem ajudar na prevenção de inundações, mas, muitas vezes, a falta de comunicação e de coordenação significa que as políticas que funcionam de cima para baixo não são eficazes e que as comunidades locais não conseguem agir de forma colaborante. Por isso, alguns organismos já dispõem de planos de inundação bem desenvolvidos, enquanto que outros não. As chuvas torrenciais ainda causam inundações frequentes nas cidades tropicais, independentemente de terem sido realizadas, ou não, obras de engenharia de grande porte, pelo que, nessas cidades, o risco de morte por inundação ainda é, provavelmente, o mais elevado.

Palavras-chave: Inundações. Adaptação. Responsabilidade. Escala. Pobreza.

Abstract:

Increasingly severe flood losses in Europe in the first 12 years of the 21st century have led to demands for improved flood resilience and ability to adapt to future flooding and associated effects of climate change. While structural measures continue to play a major role, combinations of both hard engineering works and non-structural measures, including insurance, household preparedness, community strategies and local warning systems are being developed. However, some types of flooding, particularly local pluvial flooding from surface water and overflowing drains in urban areas, appear to be increasing and catching people unawares. Thus it is important to identify where, how and when to prepare for flooding. Case studies of pluvial, small urban stream, major river, snow-melt and coastal flooding show that all parties, from households to state and national governments have responsibilities and can help in flood prevention, but often the lack of communication and co-ordination means that top-down policies are not effective and local communities fail to act collaboratively. Some agencies have well-developed flood plans, others do not. Torrential downpours still cause frequent flooding in tropical cities, whether or not large-scale engineering works have been undertaken. It is in such cities that flood fatalities are likely to be highest.

Keywords: Flooding. Adaptation. Responsibility. Scale. Poverty.

Introduction

In the 20th century, flood deaths across Europe averaged less than 250 per year. From 1970-2006 average annual flood loss in Europe was US $ 3.8 billion (Barredo, 2009). In the first decade of the 21st century severe floods mainly caused by heavy rain affected much of Europe. The deluge in August 2002 affected five countries (Czech Republic, Germany, Austria, Hungary, and Romania) causing 55 deaths and material damage costing US$ 20 billion. The next month, another major flood caused 23 fatalities and US$ 1.2 billion in material damage in France. Heavy rains led to destructive floods in Romania in 2005 with dozens of fatalities. Two years later (in June and July 2007) several waves of intense precipitation produced damaging floods in many parts of the UK (Lugeri et al., 2010). The Interim Report of the Pitt Review of the 2007 UK flood events described low levels of prior flood risk awareness and personal preparedness among those affected (Pitt, 2007). Subsequent measures in the UK have emphasised community preparedness, the role of insurance, better planning policies and collaboration between Department of Environment, Food and Rural Affairs (DEFRA) and the Environment Agency, Natural England and water utilities to establish Catchment Flood Management Plans and Shoreline Management Plans (Keskitalo, 2010). The aim of such policy initiatives is debatable. Should they be to ensure the best value for taxpayers in general, or to fairness for those potentially facing a flood hazard? Should funds be concentrated on emergency relief and post-disaster assistance, or be used to promote adaptation to flooding, flood mitigation and flood preparedness?

To find answers to these questions, the roles of different parts of society, households, communities, the corporate sector and governments at various levels in dealing with and adapting to floods need to be clearly established for particular types of flooding. The task of this contribution is to look at five major types of flooding and how six different scales of decision-making about floods attempt to cope with each type. After examining the broad responsibilities of each of the six levels in general terms, how each level performed for each type of flooding is developed through case studies from a wide range of geographical settings to emphasise how social, economic and physical geography all influence how people deal with floods. The five key types of flooding are discussed first (Table I), then the six levels of decision making are outlined (Table II). Subsequently examples of actions in response to flooding are drawn from case studies (Table III) to show how each type of flooding involves multi-level actions and adaptations.

Types of flooding

Human settlements may be affected by five types of flooding (Table I):

- localized pluvial flooding due to inadequate drainage;
- flooding from small streams flowing almost entirely within built-up areas;
- flooding from major rivers on whose banks the towns and cities are built;
- snow-melt flooding triggered by heavy spring rains as occurs in both Polar regions and mountainous areas such as the Alps;
- coastal flooding from the sea, or from a combination of high tides and high river flows from inland.

The conditions giving rise to flooding are constantly changing as a result of environmental change at different scales, from global climate trends to local impacts of urban development, more impermeable surfaces, reduced channel capacities, built-up flood plains and waste dumping in stream channels and drains. Such human activities affect most modern urban floods. However, the most extreme rain events will so saturate the ground and any vegetation that the entire surface of a river catchment area may have negligible storm water detention capacity. Such extreme floods are so rare that human efforts are usually concentrated on avoiding more frequent annual and decadal damaging flood events. However, flood magnitude-frequency relationships are changing: what used to be a 1 in 50 year event, may now be a 1 in 20 year happening. Urban development may so alter rainfall- runoff relationships that floods begin to occur in localities with no previous record of flooding. Identifying what may happen and what needs to be done at different scales is therefore important (Table I).

Table I
Examples of different types of flooding and their effects in different countries and regions.

Country	Increasing scales of river flooding	Special cases			
	Pluvial/ surface water	Small stream	Major River	Snow-melt	Coastal
Portugal	Lisbon Porto	Many towns, e.g. Águeda (Figueiredo, *et al.*, 2009)	Douro, Mondego, Tagus Floods of 1739 and 1978 (Alcoforado and Nunes, 2009)	Rare	Occasional e.g 1755 Tsunami
UK	Many cities, e.g. Greater Manchester (Douglas *et al.*, 2010)	Many cities, e.g. Sheffield	Thames Severn e.g. 2007 floods 4 people died	In Scotland and Wales	Localised, but also storm surges e,g. North Sea 1953
Scandinavia	Problem in many cities: existing drainage often inadequate	In Sweden: Fulufjäll 1997, Hagfors 2004 and Ånn 2006	Can be severe, e.g. Fyris River at Uppsala, April 2013; linked to snow melt	Every Spring, but may be severe when sudden temperature increases occur	Urban areas in Skåne county and Göteborg located in Västra Götaland
Alps	Likely in any city	Risk accentuated by steep slopes; 40 people died in the 2005 Alpine floods	Rhine, Rhone, Danube and Po tributaries all flow past major towns	Annual, but occasionally severe e.g. Guil Valley, 1957 (Arnaud-Fasseta *et al.*, 2005)	n/a
Nigeria	Frequent due to thunderstorms and drains often clogged with debris	Many urban streams have inadequate Capacity; 25 deaths in July 2011	Major floods along Benue and Niger Rivers as in July to October 2012	n/a	Niger delta particularly susceptible with loss of mangroves

Localized pluvial, surface water flooding. So-called because it is often caused by direct surface runoff from impermeable surfaces or overflowing sewers or drains on to streets and surface car parks, localized surface water, or pluvial, flooding usually arises from short-duration, high intensity, wet season thunderstorms in the tropics and summer cumulus cloud development in higher latitudes. In many tropical cities it occurs several times a year, with particularly severe effects in slum areas which have few drains, but pathways between dwellings that become streams during storms. Existing drains and culverts are often blocked with waste and plastic debris due to inadequate garbage collection and cleaning services.

Flash flooding/ small streams. The small streams in urban areas rise quickly after heavy rain, but often pass through small culverts under roads. Although adequate enough to deal with the existing flood flows when they were designed, changes in urban areas and in storm intensity now produce flows that exceed the capacity of the culverts. Intense rainfall, rapid filling of stream channels, and inadequate culverts lead to flash floods that inundate highways and adjacent properties. The stream channels themselves may contain so much debris and urban waste that their channels are effectively smaller than they were two decades ago. These changes combine to make flooding more frequent.

Major rivers. Large rivers flowing through urban areas are affected by land use changes and engineering works upstream. Dams modify river flows and trap sediments, often causing river bank erosion downstream to accelerate. Although dam operations regulate flows, they may lead to high flows when stored water is released suddenly to prepare for incoming stormwaterm. Natural and artificial river levees provide some protection to the towns and cities. However, urban growth has often spread over floodplains restricting their flood water storage capacity and creating parts of the city below flood level. Levees may be breached and cause devastating urban flooding with severe losses and disruption over large areas of the city. Depending on the size of the river, they may last several days or several weeks.

Snow-melt flooding. In polar and alpine regions when abundant snow lies on the mountains late into the spring or early summer, rapid temperature increases and sudden heavy rainfall may trigger major floods. The water from the rapidly melting snow is added to the storm runoff to create exceptional flood peaks that cause braided gravel rivers to develop into huge torrents capable of causing great damage. Frequently side streams, which usually occupy small channels across their alluvial fans where they enter the main river valley, burst their banks and spread across the whole alluvial fan, sweeping away many of the buildings in settlements occupying those fans. A well-documented example of this type of flood and its consequences is the 1957 flood in the valley of Guil in the basin of the Durance River, France (Tricart, 1958, 1961a, b).

Coastal flooding. Over 600 million people, about 10 per cent of the world's people live in floodable coastal zones. In coastal cities, such as Lagos and Port Harcourt in Nigeria and Banjul, The Gambia (Douglas et al., 2008) many poor people living on former swamp land or in dwellings built on stilts in tidewater areas are particularly vulnerable to increased storminess and rising sea levels. Dumping of waste beneath dwellings on these wetlands helps to raise water levels further. Storm waves can also flood these areas. In tropical lowland and coastal cities, wet season flooding may affect some areas for two or more months because rain and river water combine to raise water levels in swamps that would naturally have been inundated at certain times of the year.

Responsibilities for adaptation to different types of flood hazard at various scales.

Responsibilities for flood responses and adaptations

Responsibility for all aspects of flooding is shared across different spatial and social scales (Table II). Individuals respond to flooding in varied ways, but they can also prepare for flooding and take steps to safeguard their property, including physical resilience measures. Local communities can involve neighbours helping one another and groups working together in emergency procedures, and combined efforts to clear drains and blocked culverts. Local authorities have great official responsibilities, even though in some countries, central governments try to reduce their ability to act independently to adapt to local conditions and prepare for local events. Catchment area authorities of all sizes potentially have important roles, but in many jurisdictions, local political and administrative boundaries do not coincide with catchment area boundaries and special organisations, such as the Mersey Basin Campaign in the UK or the Murray Darling Commission in Australia, are needed to bring the relevant parties together to plan land and water management and sponsor local action. National governments have major responsibilities but can link appropriate departments and ministries together to achieve integrated water resources development and flood management. International river basin organisations, such as Mekong River Commission and the International Commission for the Protection of the Rhine, have specific responsibilities, but can ensure that river flows are well managed, flood plains are protected, channel sedimentation is regulated and data is shared throughout the basin.

Table II
Examples of the general responsibilities of different levels of society and governance for flood management

Households/ Corporations	Communities	Local Governments (LGAs)	River basin authorities (multi-LGA)	National Governments	Supra-national river basin bodies
Individual proper-ties; On-site stormwater management; Flood resilience; Insurance	Care of group spaces; Local sustainable drainage and waterways	Planning for floods; Emergency plans and leadership; Waste removal; Storm drains;	Integrated river basin management; Reservoir flood capacity; Flood hazard and risk maps; Warnings	Overall flood policies and oversight of responsibilities of agencies; fair insurance and emergency relief systems	E.g. Mekong River Commission; International Commission for the Protection of the Rhine; floodplains; water storage and release; monitoring and data

Lessons from case studies

People of different countries, cultures, ethnicities and socio-economic well-being inevitably respond to flood hazards if differing ways. Similarly, responses to flooding are affected by the type of flood, its severity and its duration. To explore this, case studies of the different types of flooding drawn from different parts of the world (Table III) will now be examined.

Pluvial flooding: Heywood, UK

In both 2004 and 2006, around 200 properties experienced flooding, with about 90 properties being flooded internally with up to 900mm of sewage contaminated water for up to two to three hours. Half the affected local residents had to be evacuated twice to permit post-flood renovations. All six areas which experienced severe flooding are located along two streams now buried and partially incorporated into a combined sewer system. Not having suffered internal flooding previously, Heywood residents were unprepared for the August 2004 and June 2006 floods. Victims were confused as to who does what and who is responsible for flood risk management, and they were ill-informed about how best to protect their properties. None of the agencies responsible for flood management provided personal counselling or advice on flood mitigation methods to either the flood victims or the local community (Douglas *et al.*, 2010). Subsequently the community, led by their Member of Parliament, made great efforts to improve flood awareness and preparedness. However, at the individual household level, insurance premiums and pay-outs varied more with different companies than with the actual flood risk. The Heywood case showed that the plethora of agencies, together with many public services now being in the private sector, creates a lack of cohesion and invariably constrains effective responses to urban pluvial flood events. Clear lines of leadership and responsibility are needed.

Flash flooding from small streams: Kuala Lumpur, Malaysia

The centre of Kuala Lumpur is at the confluence of three rivers whose headwaters are in the 2000m high forested main range of the Malay Peninsula. Descending rapidly from the hills the rivers emerge on to an alluvial plain which is now almost entirely built-up except for parks and golf courses. The roof of every house is part of a surface stormwater drainage system, water from the roofs going into concrete drains around the house which feed into roadside drains which in turn are connected directly to local streams and thence to the rivers. So intense are some thunderstorms, that water spills out of drains onto roads causing flash flooding across major roads several times a year. Major floods occurred in 1926 and 1971. 32 people dies in the latter event, but relatively few deaths have occurred in subsequent events (Jamaluddin, 1985).

Relief is essentially obtained by building larger culverts and enlarging the channel of the main rivers, especially that of the Sungei Kelang downstream of the city centre. These hard engineering solutions are seen to be the most effective way of coping with rapid stormwater runoff from a growing, increasingly densely built-up metropolis. Perhaps the most innovative of these is the Stormwater Management and Road Tunnel (SMART), a 13.2 m diameter tunnel comprising a 9.7 km storm water bypass tunnel, with a 4 km dual-deck motorway within the storm water tunnel (Figure 1). The tunnel diverts storm water before it enters the city centre and acts as a motorway link during drier periods relieving traffic congestion on the city’s main highways. The tunnel can hold up to one million cubic meters of water, which is released into the river downstream of the city after the flood peak. In extreme floods the traffic section of tunnel is closed to maximise the diversion of stormwater (Figure 2). Nevertheless, local flooding persists. Major roads are inundated for short periods, sometimes affecting many intersections around the CBD, as on 10th April 2013. Thus, although numerous flood mitigation projects and programmes have been carried out, the flood problems of the Kelang River Basin still exist. New drainage guidelines were proposed after 2000, but there is still insufficient flood reduction.

Responsibilities for adaptation to different types of flood hazard at various scales.

Table III

Responsibilities for flood adjustments for each flood type at the six different decision-making levels.

Type of flooding	Household	Community	Local Government/ water utilities	Catchment/ Watershed	State/ National Government	Supra-national agencies
Pluvial (case: Heywood, Greater Manchester: Douglas *et al.*, 2010)	Sealed doors; air-brick covers; door covers; raised electricity points; pumps; sand-bags; insurance;	Flood warning; sharing experiences of mitigation and disaster relief; adopt flood resilient construction	Using local knowledge of storm sewer network; clearing drains and sewers; removal of blockages; advice to public	Consider consequences of upstream land use change; Manage increased storm-water runoff to storm drains due to increased urbanisation	Ensure home information packs include histories of pluvial flooding; clarify responsibilities of agencies and local government	Climate change advice; Hyogo declaration on flooding
Flash/ small stream (Case: Kuala Lumpur, Malaysia: Douglas, 2005)	Barriers across doorways; removal of belongings from ground floors to higher levels	Respond to warnings by experienced neighbours. Use of local community buildings as refuges; Political campaigning	Clearing drains, enlarging culverts, construction flood diversion canals and tunnels; raise embankments	Catchment land use guidelines: flood detention ponds; stormwater diversion around city	National flood warning system and on-line flood information (info-banjir); flood hazard mapping	Climate change advice; Hyogo declaration on flooding; WMO advice and standards
Major catchment (Case: Namoi and Gwydir Rivers, NSW, Australia: Douglas, 1979)	Personal checks on river levels; Household flood resilience: good preparation, reaction to flood warnings	Ensure evacuation paths and assembly points ready; ensure past flooding and local flood risk information is shared	Develop flood levees to protect towns; provide adequate warning systems and evacuation strategies	Clear river channels of debris; use flood capacity of up-stream reservoirs; create flood storage; monitoring; warnings	Provide local flood with flood history and risks clearly set out; flood forecasting and warning systems,	Where appropriate international river basin management
Snowmelt (Cases: Ringebu and Skedsmo, Norway: Naess *et al.*, 2005; Ivalo, Finland: Tennberg *et al.*, 2010)	Check river height personally; listen to TV warnings; lift all valuables to the table; evacuate;	informal networks between community members provided unofficial information on approaching flood	Ensure good working between agencies; flood emergency plans; prevent ingress of water through drains; temporary flood protection and raising roads, water and electricity infrastructure..	Changes to land use: avoidance of areas prone to landsliding that supply debris to floodwaters	Flood warnings national level assessments of flood impacts and the government flood commission;	International snow pack assessments and shared warnings for major rivers. Weather forecasting, especially of warm air masses
Coastal (Case: Lagos, Nigeria: Douglas *et al.*, 2008)	bailing water out of the house with buckets; pumps used by the wealthy; block water inlets with cloth; lift goods to tops of cupboards	Move out to family members houses on higher ground; little collective action	Clear drainage channels and prevent blockage by waste and dumping on floodplains; prevent encroachment on coastal wetlands	Create upstream storm-water storage; develop SUDS; reduce stormwater runoff peaks; develop a flood plan.	Lagos State government issues advisory alert; closes schools; warns people to keep off roads; needs water management strategy.	International tsunami and storm surge warnings; Action to mitigate sea-level rise; Protect coastal mangroves

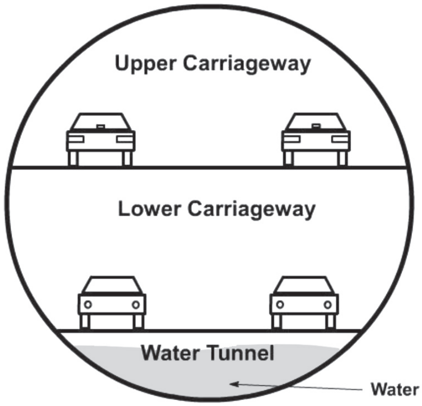

Figure 1
Schematic cross-section of the SMART tunnel in Kuala Lumpur.

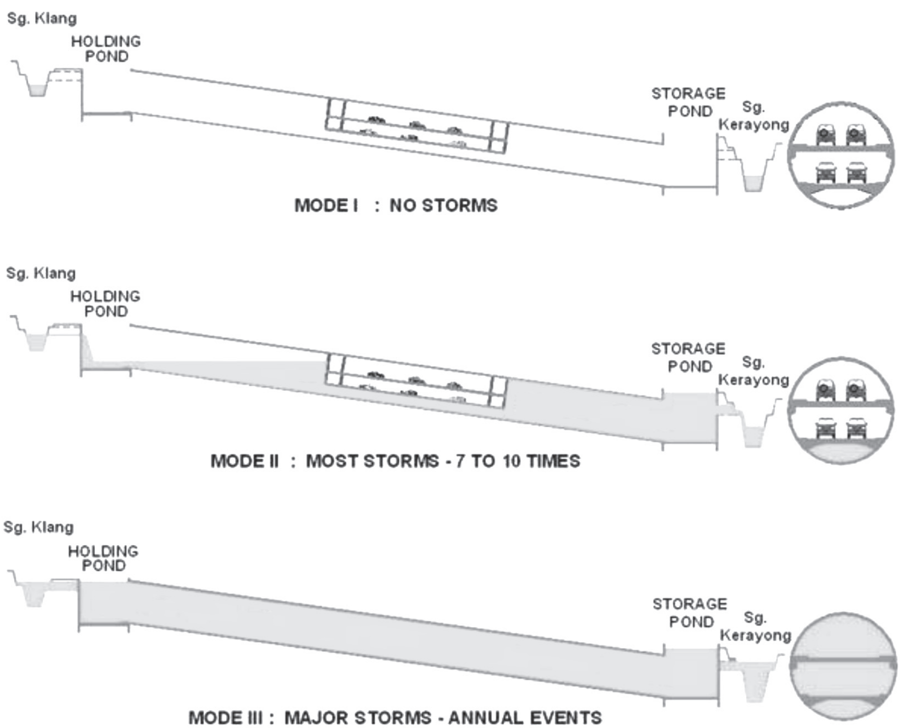

Figure 2
Schematic diagram to show different modes of stormwater flow in the Kuala Lumpur SMART tunnel according to flood frequency.

Major river flooding: Namoi and Gwydir Rivers, NSW, Australia

The 42,000 km^2 Namoi and 26,600 km^2 Gwydir catchments in northern New South Wales are part of the Murray-Darling basin, Australia. As they emerge from the uplands on to the western plains, the rivers divide into distributary channels associated with semi-permanent wetlands that develop their aquatic characteristics when floodwaters escape from the river channels. Such flood events occur irregularly but may form extensive sheets of water that take many days, or weeks, to flow downstream to the Darling River. Although essential for ecosystems and farming, this flooding greatly affects riverine urban settlements, such as Narrabri or Moree. Normally there is several hours warning of the passage of a flood downstream to these towns, but the construction of reservoirs to hold water for irrigation has altered natural flooding patterns. These reservoirs are sometimes required to release water for environmental flows to help maintain the ecosystem services of the semi-permanent wetlands. At other times they regularly supply irrigation flows. Thus at any particular time they may have ample storage for flood flows, or may be relatively full as an environmental or irrigation release is due to be made within a few days. This means that the ability of the reservoirs to mitigate flooding of riverine towns may be constrained. The towns sit on the flat plains around the distributary channels and may be at least partially inundated by a 1 in 20 year flood. Warning systems and flood plans are well developed and usually there is good collaboration between state and local authorities and community organisations. In local detail however, small works, such as earth barriers that divert irrigation water, or raised tracks across easily flooded land, may send floodwaters from one property to another causing uneven damage patterns, because flood protection works only shift the floodwaters to another location. Careful collaboration across the whole urban, and the surrounding rural, community is needed to adapt to floods effectively.

Snow-melt flooding: Ringebu and Skedsmo, Norway and Ivalo, Finland

Skedsmo and Ringebu municipalities were severely affected by the 1995 floods in Southeastern Norway, which, in some areas, were the largest in 200 years. They led to evacuation of 7000 people and caused damage costing € 240million (Naess *et al.*, 2005). At Ringebu the 1995 flood submerged the main road through the valley. The railway was closed, and the township of Ringebu was effectively isolated during the flood peak. Similarly, large areas of Skedsmo municipality, including parts of the town, Lillestrøm, were flooded. Many Lillestrøm residents had to be evacuated during the floods. The emergency responses in both municipalities demonstrated a high degree of coordination between institutions at different levels, including relevant offices in the municipality administration, the regional waterworks, fire departments, the Civil Defence authorities, and the county administration. In both municipalities, technical measures were a dominant decision outcome in vulnerability reduction, often favouring economic interests at the expense of environmental interests. Protection of property assets was given high priority (Naess *et al.*, 2005). In reactions to the floods, national, regional and municipal technical concerns were dominant and soft engineering and non-structural flood mitigation methods appear to have been little considered.

In northern Finland, snow-melt floods occur every spring. That of 2005 on the Ivalo River had a peak discharge of 1,045 $m^3 s^{-1}$ making it a “major” flood by local standards (Tennberg *et al.*, 2010). On the Ivalo River, spring floods normally start in the end of April, and the discharges are at their biggest during the latter half of May. The town of Ivalo is located on both banks of Ivalo River in Inari municipality. The 2005 flood was caused by a combination of special conditions: warm temperatures, high water content of snow, fast snowmelt together with spring rain upstream. It was not a typical spring flood as in previous years, because downstream ice had melted away days before. In Ivalo town, rescue organisations were informed of the flood risk, but the locals were not aware of the situation because it was the middle of the night. Eventually the flood came as a surprise early in the morning to the Ivalo inhabitants. Some residents observed the rising river and took action, but others did not know they were expected to take flood defence measures until it was too late. Despite past experiences, the particular circumstances of this flood made it worse than expected.

Coastal flooding: Lagos, Nigeria.

On the coast of Nigeria, mangroves once protected most of the shoreline. Around the 21 million population megalopolis of Lagos, coastal wetlands have been filled and waterways diverted to accommodate urban development. Many poor people have built dwellings on stilts above the tidewater. During severe flooding on 10-11th July 2011 25people including 11 children died. Over 27% of the land surface was covered by floodwaters for over ten hours. Over 38% of area, roads and drains were indistinguishable. Many people had to salvage household goods from the floodwaters, and local schools were closed the following day because of the total disruption of traffic. Reactions in 2011 showed that people knew that uncontrolled disposal of waste, particularly plastic bags and sachets, into drains had aggravated the flooding. Residents of the low-lying coastal slum settlement of Iwaya/Makoko in Lagos argue that the climate is changing and flooding is becoming more frequent. Local people are concerned about property damage and the impact on child health in an area with totally inadequate sanitation. Floodwaters can carry all sorts of organic waste into people’s homes. Many recognise that in Lagos, while the municipal government should take the lead and implement a flood plan, the commercial sector and local communities and landholders should work together to ensure that neighbourhoods take care of local drainage and keep channels clear and that their activities do not aggravate floods (Aderogba, 2012).

Managing flooding at the appropriate level

Analysis of flood risk at the European level suggests that Eastern Europe as well as Scandinavia, Austria and the U.K., along with some regions in France and Italy, appear to be under significant threat, especially in terms of regional GDP (Lugeri *et al.*, 2010). Over continental Europe, flood management often requires international collaboration, but the principle of local, regional or national action at the appropriate scale applies to managing urban flooding. Where the problems are essentially internal to a specific community, then that community should manage them. Where they lie totally within the boundaries of a single local authority, then the local authority should manage them. Where they cut across many administrations, then national governments, or even international consortia, should manage them. Applying this principle of management as close to the communities as possible, the management of localized flooding as a result of inadequate drainage should be undertaken by the local communities themselves but in the context of overall river basin management plans. This is where local voluntary groups, assisted by national or international NGOs and with support from both local government and national disaster reduction organizations, could be highly effective. Local communities are stakeholders in the good drainage of and the rapid water removal from their own areas. They would benefit from improving and maintaining drainage channels, thus preventing the blocking of waterways and culverts by waste, from installing roof rainwater collection tanks for their own use, and avoiding construction on drainage lines. They could also organize local shelter for the people in their communities who are most affected by flooding.

Local authorities are best placed to cope with flooding from small streams whose catchment areas lie almost entirely within the built-up area. They administer regulations and by-laws concerned with land use planning and should be involved in local disaster management. In Asian cities like Kuala Lumpur, responsibility for stormwater control has to involve both government agencies and individual property owners. The tradition has been to evacuate all stormwater as quickly as possible, mainly because of the high intensity of rain during thunderstorms. However, this requires ever increasing downstream channels and culvert capacity to cope with the increase in impermeable areas and highly efficient concrete channels upstream. Ways of retarding the flow of stormwater on individual properties and in every subdivision of new development have to be found and have to be hydraulically integrated into a basin-wide stormwater management plan. Unfortunately, many African local authorities lack the human resources and financial power to carry out such responsibilities effectively. They may be able to form partnerships with NGOs but they should be supported by national governments and regional agencies to map flood risk areas, maintain urban stream channels, control building in flood channels and on floodplains and provide emergency assistance.

Where towns and cities are flooded by major rivers overtopping their banks, their flood protection has to be seen in the context of the entire river basin, which may include more than one state. Local shire flood plans for such rivers exist in New South Wales, for example for Narrabri Shire on the Gwydir River (State Emergency Services NSW, 2003). Such plans describe exactly how much of a town is likely to be flooded at different river levels and specify actions to be taken by different agencies during an emergency. Where a river basin lies within a single nation state, integrated river basin management principles should be applied by an agency cutting across ministries concerned with both rural and urban interests, to ensure that activities in upstream areas do not worsen the flood situation for towns and cities downstream. For large, international rivers, river basin commissions are required to manage the water resources of the entire basin for the benefit of all communities in the different nations occupying the basin. Individual urban authorities may campaign for, or act to build, extra flood protection embankments. However, such works only serve to direct the floodwaters elsewhere. The natural floodplain should be retained to hold floodwaters and should not be built upon.

Because gravel-laden rivers in mountainous areas naturally change their channels frequently, areas known, or predicted, to be affected by major floods as far as possible should be kept clear of buildings and other structures (Arnaud-Fassetta *et al.*, 2005). Structural measures, such as levees and strengthened raised highways can protect existing settlements on alluvial fans. In the Guil Valley, France, streams across such fans were diverted away from the settlements after the 1957 disaster and performed well during a 1 in 30 year flood in 2000. Key issues are ensuring that any structures across channels have adequate capacity for flood flows and that warning systems are known to, and accepted, by vulnerable communities.

Coastal processes include tidal patterns, wave height, wave direction and the movement of beach and seabed materials. Urban areas faced with coastal flooding from the sea, or from a combination of high tides and high river flows from inland, have to integrate both river basin and coastal zone management, ensuring that the natural wetlands can continue to function as flood storage areas as far as possible. Where settlements already exist, filling those areas to prevent flooding may be desirable, but the implications for adjacent areas need to be considered. Social factors may lead people to move on to other nearby wetlands. Adaptation responses to coastal flood hazards for urban areas include protection, accommodation, and retreat. Protection aims to manage the hazard with "hard" structures such as seawalls and groins or "soft" measures such as beach nourishment and wetland restoration. Accommodation allows human activities and the hazard to coexist through actions such as flood proofing of homes and businesses and evacuation planning. Retreat removes human activity from the vulnerable area which generally is accomplished by abandoning land as the sea rises. Each of these strategies has highly site-dependent technical, economic, social, and environmental impacts and policy implications. They are part of Shoreline Management Plans developed as large-scale assessments of the risks associated with coastal processes and to help reduce these risks to people and the developed, historic and natural environments. These measures provide important suggestions for clarifying responsibilities for action in flood preventions, mitigation and adaptation. Nevertheless, it is particularly important to have a social and cultural understanding of these limitations in order to facilitate adaptation of these vulnerable groups.

Conclusion

Recognising what different levels of society and administration can do is an important part of preparing for floods. Households need information on how to react to flood warnings, what they can do, what the flood risks are, and how they can help keep their local environment clean and capable of evacuating floodwaters. From Greater Manchester to Lagos, too many small urban streams and drains have their capacity reduced by waste and litter. Local communities can build up and spread knowledge about flood hazards and what to do when rivers overtop their banks. Local governments need to avoid development on flood plains, good flood plans and ways of communicating flood risks and warnings to their citizens. River basin authorities and regional organisations need integrated water resources management, good reservoir management and ways of storing flood waters in tributary streams before they reach the main river. State and national governments after ensure that agencies with responsibilities relating to flooding work together, even if some are privatised. More needs to be done to focus on the urban poor in international action on adaptation to flooding and climate change. As the

Lagos example shows, flood fatalities tend to be higher in the poorer tropical urban communities. Seldom do the needs of the urban poor feature in national responses to the National Adaptation Programme of Action on vulnerability to climate change. Steps are needed to create awareness and build capacity within city councils for the application of international and regional frameworks and other relevant protocols and conventions for the needs of the urban poor.

References

Aderogba, K. A. (2012) - "Global warming and challenges of floods in Lagos Metropolis, Nigeria". *Academic Research International*, 2 (1), pp. 448-467.

Alcoforado, M. J. and Nunes, M. F. (2009) - "Past analogs of recent climate anomalies and impacts in Portugal. Droughts, storms and heat waves". *EMS Annual Meeting Abstracts*, 6, EMS2009-162, 9th EMS / 9th ECAM.

Arnaud-Fassetta, G.; Cossart, E. and Fort, M. (2005) - "Hydro-geomorphic hazards and impact of man-made structures during the catastrophic flood of June 2000 in the Upper Guil catchment (Queyras, Southern French Alps)". *Geomorphology*, 66, pp. 41-67

Barredo, J. I. (2009) - "Normalised flood losses in Europe: 1970-2006". *Natural Hazards and Earth System Sciences*, 9, pp. 97-104,

Douglas, I. (1979) - "Flooding in Australia: a review". *In:* Heathcote, R. L. and Thom, B.G. (eds.) - *Natural Hazards in Australia*. Australian Academy of Science, Canberra, pp. 143-163.

Douglas, I. (2005) - "The urban geomorphology of Kuala Lumpur." *In:* Gupta, A. (ed.) - *The Physical Geography of Southeast Asia*. Oxford University Press, Oxford, pp. 344-357.

Douglas, I.; Alam, K.; Maghenda, M.; McDonnell, Y.; McLean, L. and Campbell, J. (2008) - "Unjust waters: climate change, flooding and the urban poor in Africa". *Environment and Urbanization*, 20 (1), pp. 187-205. http://dx.doi.org/10.1177/0956247808089156

Douglas, I.; Garvin, S.; Lawson, N.; Richards, J.; Tippett, J. and White, I. (2010) - "Urban pluvial flooding: a qualitative case study of cause, effect and non-structural mitigation". *Journal of Flood Risk Management*, 3, pp. 112-125.

Figueiredo, E.; Valente, S.; Coelho, C. and Pinho, L. (2009) - "Coping with risk: analysis on the importance of integrating social perceptions on flood risk into management mechanisms – the case of the municipality of Águeda, Portugal". *Journal of Risk Research*, 12 (5), pp. 581-602.

Jamaluddin, M. J. (1985) - "Flash flood problems and human responses to the flash flood hazard in Kuala Lumpur area, Peninsular Malaysia". *Akademika*, 26, pp. 45-62.

Keskitalo, E. C. H. (2010) - "Climate Change Adaptation in the United Kingdom: England and South-East England". *In:* Keskitalo E. C. H. (ed.) - *Developing Adaptation Policy and Practice in Europe: Multi-level Governance of Climate Change*, Dordrecht, Springer Science+Business Media B.V., pp. 97-147.

Lugeri, N.; Kundzewicz, Z.W.; Genovese, E.; Hochrainer, S. and Radzieiwski, M. (2010) - "River flood risk and adaptation in Europe - assessment of the present status". *Mitig Adapt Strateg Glob Change*, 15, pp. 621–639.

Naess, L. O.; Bang, G.; Eriksen, S. and Vevatne, J. (2005) - "Institutional adaptation to climate change: Flood responses at the municipal level in Norway". *Global Environmental Change*, 15 (2), pp. 125-138.

Pitt, M. (2007) – *Learning lessons from the 2007 floods, an independent review by Sir Michael Pitt*. London, Cabinet Office.

State Emergency Services NSW (2003) - *Narrabri Shire Local Flood Plan*, http://www.floodsafe.com.au/uploads/41/plan-narrabri-lfp-april-2003-lemc-signed.pdf [accessed 30 May 2013]

Tennberg, M.; Vuojala-Magga, T. and Turunen, M. (2010) - "The Ivalo River and its People: There Have Always Been Floods - What Is Different Now?". *In:* Hovelsrud, G.K and Smit, B. (eds.) - *Community Adaptation and Vulnerability in Arctic Regions*. Dordrecht, Springer Science & Business Media B.V., pp. 221-236.

Tricart, J. (1958) - "Étude de la crue de la mi-Juin 1957 dans la vallee du Guil, de l'Ubaye et de la Cerveyrette". *Revue de Géographie Alpine*, 4, pp. 565- 627.

Tricart, J. (1961a) - "Les modalités de la morphogénèse dans le lit du Guil au cours de la crue de la mi-Juin 1957". *International Association of Hydrological Sciences Publication*, 53, pp. 65-73.

Tricart, J. (1961b) - "Mécanismes normaux et phénomènes catastrophiques dans l'évolution des versants du bassin du Guil (Hautes-Alpes, France)". *Zeitschrift für Geomorphologie*, 5, pp. 277- 301.