Information Network Development and large flood report

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【Abstract】

Flood risk and vulnerability tend to change over many areas, due to a range of climatic and non-climatic impacts whose relative importance is site-specific. Several ongoing land-use changes, such as urbanization, deforestation, and reduction of natural storage (floodplains, wetlands), can be regarded as adverse from the viewpoint of flood safety. In order to understand the best flood management policy practices and lessons learned, ICHARM has been launched a project focuses on the experiences of the past large scale floods mainly in recent years. The target groups and audiences of the project's outcome are policy makers and flood risk managers, particularly those who are involved in decision making to deal with large-scale floods with national and regional impacts. The outcomes of the project will be publicized in various formats by ICHARM using its strong worldwide network. In total 10 original reports to cover large-scale floods o in the recent years have been collected as follows:

- Red River Basin Flood in Canada and US (April 1997) by Slobodan P. Simonovic
- Central European and Elbe River Flood in Germany (August 2002) by Erich Plate
- Flood Caused by Hurricane Katrina (August 2005) extracted from USACE reports by Ali Chavoshian
- UK Summer Flood (2007) extracted from UK Environment Agency by Ali Chavoshian
- Flood caused by Cyclone Nargis in Myanmar (May, 2008) by Tun Lwin
- Cyclonic Floods in Bangladesh (2007-2009) by Abu Taher Khandakar
- Typhoon Morakot Flood in Taiwan (August 2009) by National Centre for Dissater Reduction of Taiwan
- Flash Flood in Metro Manila of the Philippines (September 2009) by P. Nilo & Susan Espinueva
- Large- scale Floods in China (1998 and 2010) by Ao Tianqi and Wang Quchaing

Where applicable, the best practices described in this document should be taken into account, in particular on: a) Flood preparedness and warning systems, b) Structural and non-structural measures, c) Environmental considerations, d) Social aspects & resiliency at commune level, e) Financial considerations, f) Land use planning, and g) Climate change impact.

Keywords: Large-scale flood, Flood Management Policy, Climate Change, Flood Risk Management, IFRM

1. Introduction

This project deals with the risk of river flooding and risk management, in the context of global change, with particular reference to observations over the last two decades and projections for the future. The term “river flooding” describes destructive abundance of water, inundating normally dry locations outside of the river channel, where damage potential is present. Floods are intermittent events, possibly of rare recurrence in a given location. However, at some sites floods are commonplace events, e.g. occurring every spring when the abundant snow cover melts.

Floods continue to be an acute problem, causing high material damage worldwide and considerable death toll. This, in fact, pertains in general to weather extremes. The costs of extreme weather events (among which floods are a major category) have exhibited a rapid upward trend. Yearly material damage from large events has increased globally by order of magnitude within four decades, in inflation-adjusted monetary units. Damages caused by natural disasters, mostly weather and water-related have increased much more rapidly than population or economic growth (Mills, 2005). Hence, the climatic driver behind the increasing flood risk has been vigorously sought.

Many flood fatalities have been in Asia. Indeed, destructive floods are quite frequent in China, India, and Bangladesh. The highest material losses, of the order of 30 and 26.5 billion US$ (with over 3600 and appr. 2700 fatalities) were recorded in China in the summer 1998 and 1996 floods, respectively.

2. Global change and flood generation mechanisms

Several factors may be responsible for increasing flood worldwide, such as changes in socio-economic, terrestrial, and climate systems. Relevant socio-economic changes include increasing exposure and damage potential due to population growth, increasing GNP, economic development of flood-prone areas, land-use change leading to land-cover change (e.g. urbanization, deforestation), and changing risk perception. Changes in terrestrial systems include changes in hydrological systems and ecosystems, therein: land-cover change, river regulation – river straightening and shortening, channelization, constructing embankments. Conditions of transformation of precipitation into runoff in hydrological systems are subject to change, leading to reduction of water storage area and volume (drainage of wetlands and elimination of natural vegetation; increase of impermeable areas), increase of the value of runoff coefficient, increase of the flood peak and decrease of the time-to-peak. Last, but not least, changes in climate are important, such as increase of water holding capacity and water contents of the atmosphere in the warmer world increase of frequency of heavy precipitation, changes in seasonality and in circulation patterns.

On average, 2% of agricultural land has been lost to urbanization per decade in the European Union. Direct urbanization effects are particularly visible in small or middle size floods, which often constitute a substantial contribution to flood losses in the longer term. Van der Ploog et al. (2002) attributed the increase in flood hazard in Germany to climate (wetter winters), engineering modifications, but also to intensification of agriculture, large-scale farm consolidation, subsoil compaction, and urbanization. For example, the meadowland area in former West Germany decreased between 1951 and 1989 from 15.7 to 10.8%. Simultaneously, the small grain acreage grew from 18.5 to 22.3%. Additionally, nearly 20% of the agricultural land area was drained artificially during this period. The urbanized area in West Germany more than doubled in the second half of 20th century. The timing of river conveyance has been altered by river regulation (channel straightening and shortening, construction of embankments).

Human encroachment into floodplains appears to be the major cause for increased flood-related damages in most areas. It may grow as people become wealthier and more exposed. Technology helps populate more “difficult” areas. Many wrong local decisions have been taken, which cause the flood loss potential to increase. According to assessment reported by Newson (1997), one sixth of all urban land in the USA lied within the 100-year flood area and around ten per cent of population of the USA lived there. In Japan half the total population and about 70% of the total assets are located on flood plains, which cover only about 10% of the land surface. In some less developed countries, this portion is very much higher. Hope to overcome poverty drives poor people to migrate to informal settlements in endangered, flood-prone, zones around mega-cities in developing countries, which are left uninhabited on purpose, since effective flood protection cannot be assured. In Bangladesh, during the 1998 flood two thirds of the country area were under water.

An important factor influencing the flood risk is an unjustified belief in the absolute security provided by structural defenses. Further, a short memory syndrome can be observed. During a flood-free interval, decision makers gradually reduce the funding of flood preparedness systems, and citizens become increasingly less risk-aware. This occurs in developing and developed countries alike, including the United States, where the Katrina event unveiled the inadequacy of the emergency preparedness system.

Although land use controls flood risk, it is less so in case of very high-intensity rainfall, which causes high surface runoff in both urban and forested basins. There is a potential for floods becoming much higher than ever observed, e.g. if record-high precipitation occurs in areas with high (and dynamically growing) damage potential. The records (cf. WMO, 1998) of highest observed point precipitation for different time intervals are, for instance, 1340 mm in 12 hours, 1825 mm in one day (this happened on Réunion, a humid-climate island on the Indian Ocean), and 3847 mm in eight days. If precipitation of a record size occurs over a large city, consequences are utterly destructive.

3. Climate change: issues and policies

3.1. Climate change observations

The Fourth Assessment Report, AR4, of the Intergovernmental Panel on Climate Change (IPCC, 2007) concludes that warming of the global climate system is unequivocal. This is now evident from observations of increases in air temperature at a range of scales. Moreover, recently observed climate change has not been limited to temperature, but also embraced other variables, leading to a range of impacts.

While observed temperature increases are quite regular, precipitation changes are less regular. Nevertheless, precipitation increases over land north of 30°N over the period 1901–2005 and decreases over land between 10°S and 30°N after the 1970s were observed (Trenberth et al., 2007).

Globally, results of a change detection study of annual maximum river flows (Kundzewicz et al., 2005) do not support the hypothesis of a ubiquitous increase of annual maximum river flows. However, out of 70 time series of river discharge in Europe it was found that the overall maxima (for the whole 1961–2000 period subject to study) occurred more frequently (46 times) in the second 20-year sub-period, 1981–2000, than in the first 20-year sub-period, 1961–1980 (24 times). A regional change in timing and nature of floods has been also observed in many areas of Europe, and less snowmelt and ice-jam-related floods were recorded. Among observed climate-related phenomena impacting on floods in Europe are increase in precipitation intensity; increase in westerly weather patterns during winter; and shrinking snow cover.

3.2. Causes of climate change – climate policy

The climate projections (without mitigation policy) for the future indicate considerable further warming. Changes in river flows due to climate change depend primarily on changes in the volume and timing of precipitation and, crucially, whether precipitation falls as snow or rain. A robust finding is that warming would lead to changes in the seasonality of river flows where much winter precipitation currently falls as snow, with spring flows decreasing because of the reduced or earlier snowmelt, and winter flows increasing, possibly with consequences to flood risk. In regions with little or no snowfall, changes in runoff are much more dependent on changes in rainfall than on changes in temperature, and studies often project an increase in the seasonality of flows, with higher flows in the peak flow season (Meehl et al., 2007) .

The expected increase in heavy precipitation has multiple adverse impacts, such as: increased floods, landslides and mudslides (possibly leading to flow obstructions), increased soil erosion; and increased pressure on government and private flood insurance systems and disaster relief.

Hirabayashi et al. (2008) developed projections of recurrence interval of river floods. The return period of 100-year floods with respect to the 20th century (1901–2000) simulation was found to change (Fig.). In many low-latitude regions and in eastern Eurasia, a 100-year flood in 20th century was projected to become much more frequent (with a return period of less than 30 years). In contrast, flood frequency was projected to decrease over central and northern North America, eastern Europe and western Russia.

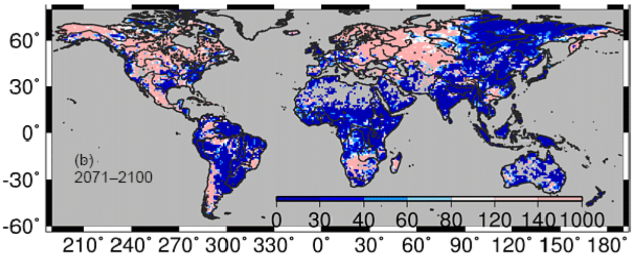

Fig. Projected return periods of the 20th century 100-year floods for 2071–2100, estimated by the Japanese MIROC model. Source: Hirabayashi et al. (2008).

4. Flood protection measures: structural and non-structural

One can never achieve complete flood safety in low-lying areas adjacent to rivers. Yet, the flood risk can be considerably reduced; if an adequate preparedness system is built, possibly consisting of a site-specific mix of measures.

There have been three basic adaptation strategies of coping with floods (cf. Kundzewicz and Schellnhuber, 2004):

1- protect (as far as technically possible and financially feasible, bearing in mind that the absolute protection does not exist);

2- adapt i.e. accommodation (prepare to living with floods); and

3- retreat (relocate from flood plains to flood-safe areas). This latter option aims to rectify maladaptation (inappropriate adaptation) and floodplain development.

Strategies for flood protection and management may modify flood waters and/or system susceptibility to flood damage and impact of flooding. They depend on the rate of recurrence of floods: natural measures are appropriate for frequent floods, engineering measures – for rare floods, while organization advances are essential for very rare floods (Kron, 2005). This latter category contains extreme, yet possible floods, also those beyond the limits of the so-far experience.

Site-specific adaptation may include some of the following components of holistic flood management. The pre-flood preparedness may comprise: flood risk management under consideration of all possible causes of flooding; construction of physical flood defense infrastructure; legislation; investment on research and development on floods; development control within the flood plains; increasing source control, infiltration and storage/retardation facilities in urban basins; land-use planning and management; building codes, flood proofing; implementation of flood forecasting and warning arrangements; public communication and education of the extent of flood risk and actions to take in a flood emergency; disaster contingency planning; maintenance of preparedness of community self-protection activities; and insurance schemes.

Operational flood management includes: detection of the likelihood of flood formation; forecasting of future river flow conditions from hydro-meteorological observations; warning issued to the appropriate authorities and the public on the extent, severity and timing of the flood; emergency protection of levees from breach and overtopping; strengthening of defenses; decision to operate reservoirs and retardation ponds; issuing prior warning on emergency spill to the people to be affected; and emergency rescue of lives and property from the flooded areas.

Finally, the *post-flood response* comprises such activity areas as: relief for the immediate needs of those affected by the disaster; reconstruction of damaged buildings, infrastructure and flood defenses; recovery and regeneration of the environment and the economic activities in the flooded area; review of the flood management activities to improve the process and planning for future events.

In several developed countries, costly structural protection facilities are in place, designed to withstand a high, rare flood. Reinforced dikes, or super-dikes of 300-500 meter width, play an important part in flood protection of major cities in Japan, where a very high level of safety must be assured (cf. Kundzewicz and Takeuchi, 1999).

Among non-structural flood protection measures are: source control (watershed management), laws and regulations, zoning, economic instruments, efficient flood forecast-warning system, system of flood risk assessment and management, awareness raising and improving information, e.g. via flood-related data bases, etc.

Source control modifies the formation of floodwater by “catching water where it falls”, enhancing infiltration, reducing impermeable area, and increasing storage in the catchment, hence counteracting such adverse effects of urbanisation as drop in storage potential, growth of runoff coefficient and flood peak, and acceleration of a flood wave. Important is enhancement of all forms of water storage capacity in the river system (floodplains, polders, washlands).

Existence of appropriate schemes of insurance, that is distribution of risks and losses over a high number of people and long time; and aid, that is capacity to compensate dramatic losses not covered by insurance, are important components of flood preparedness. Insurance and aid are needed in order to help flood victims recover after losses. Post-flood disaster aid, based on voluntary solidarity contribution, national assistance, and international help, is essential to restore livelihood and employment of survivors.

Despite some encouraging example (e.g. in the USA, after the 1993 flood), permanent evacuation of floodplains is virtually unthinkable in many countries. This is definitely true for Bangladesh - a densely populated and low-lying country, indeed the most flood-prone country of the globe. The people of Bangladesh, dynamically growing in number, have to live with floods. Most of the country area is constituted by floodplains and soil fertility depends on regular flood visits. In 1998, two-thirds of the country area was inundated. New flood embankments, even if they were affordable, would take scarce, and highly demanded, land. Thus, the options include reinforcing of the existing structural defenses and enhancing non-structural measures, such as the forecast-warning system. This example demonstrates that the optimum strategies for flood protection must be site-specific.

Considerable progress in reducing the number of flood fatalities can be achieved if flood risk awareness and management is improved. Efficient actions aimed at awareness raising can reduce flood losses. Many fatalities could have been avoided, were the awareness better. Most flood fatalities in several developed countries, e.g. the USA, are vehicle-related (e.g. car drivers who underestimate the danger and drive into water of unknown depth).

Important discussion of strategy of flood protection dates back to the mid-19th century USA (cf. Williams, 1994), when the US Congress looked into the problem of the Mississippi floods. One expert recommended that large areas of the Mississippi floodplains be used as flood storage and overflow areas, but the US Congress heeded another expert who recommended embanking the River Mississippi in a single channel isolated from its floodplain – attempting to control the floods. This decision has largely influenced the flood protection policy in the USA and elsewhere, leading to transformation of rivers and reduction of wetlands worldwide. In 1936, the US federal government assumed primary responsibility for flood damage reduction across the nation and over the next half a century embarked on a multi-billion programme of structural defences (Galloway, 1999). Yet, the great 1993 US Midwest flood proved that structural defences cannot guarantee absolute protection. In result, the US Interagency Floodplain Management Review Committee (cf., IFMRC, 1994, Galloway, 1999) recommended that the administration should fund acquisition of land and structures at risk from willing sellers in the floodplains and many vulnerable families have been relocated from risky areas (Galloway, 1999). However, this is not a universal attitude. In most countries, people who suffered in a flood. rebuild their houses (possibly - in a better, more robust way) and try to regain their livelihood in the same place, once devastated by a flood, rather than moving to another, safer, location. But the hazard may not have decreased and another flood may come again to this place, sooner or later.

Despite the critiques of structural flood protection measures like dams and levees, they are needed to safeguard existing developments, in particular in urban areas. An effective flood protection system is generally a mix of structural and non-structural measures. The latter approaches better conform to the spirit of sustainable development.

The principal flood protection and flood preparedness measures in Europe include: technical flood protection (e.g. dikes, dams, relief channels); and non-technical measures: natural storage of flood water; restriction of settlement in risk areas; standards for building development; forecasting and warning; insurance schemes, awareness raising. Upgrade of structural defenses (e.g. increasing the height and strengthening of levees, enlarging reservoirs etc.) and revision of the management regulations for water structures are carried out. Upgrade of drainage systems (in particular of urban drainage) for a future wetter climate is also found necessary. The need for costly defense and relocation measures, e.g., relocating industry and settlements from river flood plains, is being envisaged. A small-scale structural action is flood-proofing on the site, i.e. adapting existing building codes to ensure that infrastructure with a long life time will withstand future climate risks.

In general, countries of Europe have been increasingly acknowledging the importance of not relying only on technical flood protection. Land-use planning measures are regarded as efficient and allow to combine flood management and nature protection. One of the options is watershed management ("to keep water where it falls" and to reduce surface runoff and erosion). Restoration of wetlands and floodplain forests and re-connection of old river arms are being considered. There is a call (e.g. in Germany and the Netherlands) to „give more space to the rivers", to designate flood areas ("dry rivers", "compartmentalization") and to devise flood plain protection measures. Further, legal regulations are implemented/envisaged related to use of flood-plain areas, possibly assisted by flood risk maps. Flood—risk maps also facilitate estimation of insurance premiums for properties (e.g. in the UK). There are restrictions on new infrastructure and on handling substances dangerous to water (e.g. ban on use of oil-fired heating systems).

However, some non-technical measures based on land-use planning face difficulties in implementation. They may bring results in a longer term and they involve complex changes in the socio-economic system. A study by Daniel et al. (2007) shows that in the Netherlands, the announcement of an area designation for emergency inundation, resulted in decrease of the prices in the local housing estate market. Despite compensation schemes and low probabilities of a critical event, the social reaction was cautious.

In 2002, in response to massive river flooding throughout central and eastern Europe, the European Union launched the Solidarity Fund, with the purpose "to show practical solidarity with Member States and candidate countries by granting exceptional financial aid if these were the victims of disasters of such unusual proportions [...] that their own capacity to face up to them reaches to their limits". This new Fund is one of mechanisms enhancing economic and social cohesion throughout the European Union (Hochrainer et al., 2009). Under the Fund, Member States and accession countries can request aid for emergency measures (e.g., restoring public infrastructure, providing services for relief and clean up, and protecting cultural heritage) if a natural disaster causes direct damages above €3 billion (at 2002 prices) or 0.6 percent of GNP.

The European Union Solidarity Fund can be regarded as a high-layer reinsurance, spreading and diversifying risks across the larger European economy. The Fund plays an important role in flood relief in much of Europe, where penetration of insurance is not high, so that costs of relief and reconstruction are largely paid either by the victims themselves (self insurance) or by their governments (Hochrainer et al., 2009). For instance, in case of the 1997 floods in Poland, insurance covered only 8% of direct losses, the government 48%, while the remaining 44% was a contribution of the private sector and net loss. In case of the 2002 floods in Austria, insurance covered 20%, the government 32%, while the remaining 48% was a contribution of the private sector and net loss. In contrast, in case of the 1998 floods in the UK, the widespread private insurance covered 39% and there was little post-disaster government assistance (Hochrainer et al., 2009).

5. Flood Forecasting and warning policy

An efficient flood preparedness system should be seen in a holistic perspective, including the suite of monitoring, forecasting, warning, dissemination, and response. In an ideal system, an accurate forecast with adequate forecast lead time is translated into a reliable warning, which is broadly and effectively disseminated to the communities at risk who, in turn, take adequate loss-reducing actions.

Flood forecasting and warning are very important components of modern flood preparedness systems, in the category of non-structural flood protection measures, which may save lives and reduce material losses and human suffering. The system embraces detection of danger of occurrence of a flood-triggering situation, quantitative flood forecasting, construction of a warning message, issuing and dissemination of warning, response action, and finally post-audit, in order to learn a lesson and improve the system for the future.

Flood warning has been present in human living memory for thousands of years - the Old Testament mentions the oldest "early warning", received by Noah from the God. For centuries, floods were believed to be a divine punishment for sins of the mankind. There have been some early, not really scientifically-based, flood forecasts, also covering longer time horizons. For instance, in 1523, a forecast of a flood to occur in February 1524 was published in Augsburg, based on a peculiarity of conjunction of planets. That forecast flood did not materialize (Brazdil et al., 2006).

In order to detect the danger of occurrence of a flood-triggering situation, a meteorological and hydrological monitoring system (possibly embracing manual, automatic, and remotely-sensed observations) should be set. Time series of observed records of rainfall (also radar-based information) and river stage are fed (usually in a real-time mode), to a mathematical model (e.g. rainfall-runoff model) and a flood forecast is obtained. In other words, forecasting allows experts to convert the information on the past-to-present (or foreseen) rainfall, present status and changes of moisture and snow cover into a flood forecast for a future time horizon. A flood forecast should deliver possibly reliable and accurate information on the future development of an event, based on which an alert and warning can be issued. A forecast expresses when, where, and how intense (flood magnitude: water stage, discharge, inundated area, duration of flooding) flood is likely to occur in the near future (minutes, hours, days, up to weeks ahead), how it will travel downstream and evolve, and what secondary effects it may cause.

For small and/or urban, catchments and for flash floods in steep and rapid mountain streams, a time lag between an intense precipitation and the destructive river flood peak may be very short (minutes to hours). Then, observation of rising river water level and intense precipitation may come too late for a flood forecasting, therefore deployment of radar and quantitative precipitation forecast is required in order to estimate the future river flow. In case of propagation of a flood wave in a large river, when high flows are already observed upstreams, a hydrodynamic flood-routing model can be used, allowing visualization (via GIS) of the forthcoming inundation in downstream cross-sections of the river. Propagation of a flood wave in a large river may take several weeks, allowing ample time for response to flood forecast. It is attempted to improve the forecast accuracy and to extend the forecast lead time. One of challenging avenues is to make use of the Atmosphere-Ocean track in medium and long-horizon (e.g., seasonal) forecasts.

Flood warning is a timely information based on a reliable forecast that high water level (or high river discharge) is expected to occur in a cross-section of interest at some defined future time point, so that emergency actions, such as strengthening dikes or evacuation, can be undertaken. A warning should be issued sufficiently early before the peril, in order to allow adequate human preparations. It should persuade people to take appropriate action in order to reduce damages and costs of the forthcoming flood.

Flood warning should contain additional information to flood forecast, including recommendations or orders for action by the population affected, such as evacuation or emergency flood proofing, specifically designed to safeguard life and property (Smith and Ward, 1998). The warnings should capture the nature of the loss-reducing actions, being tailored in terms of their contents and delivery, to achieve an optimal behavioral response from an intended group of recipients.

Speed of reaction to warning is essential, because there may be quite a short warning lead time before the occurrence of high risk, when emergency pre-flood actions (such as strengthening the defenses, evacuation) should be completed. Among the useful criteria or indicators of warning quality are such as: warning errors ratio, penetration of warning (proportion of those who need information and receive it to those who need information), degree of satisfaction, etc.

Two warning errors can be defined: (i) when a warning was issued while the risk has not materialized, or (ii) when no warning was issued while a risk, and disaster itself, occurred. The former case does not embrace situation when the risk has materialized, but the disaster has not (i.e., there was a high risk of levee breach, yet, ultimately, it did not happen). For instance, flood warning in the Netherlands in 1995 resulted in massive evacuation. A disaster did not arrive, as the levees withstood the high load of water masses, but the warning, and the evacuation, were justified, and taken positively by the population. The risk of dike failure was high. Similarly, during the summer 1997 flood on the Odra, the Polish town Słubice was evacuated due to high inundation risk. Yet, in consequence of major dike-strengthening action (and occurrence of dike breaches upstream, on the German side), Słubice was not inundated.

As noted by Nigg (1995), there is an official hesitancy to issue warnings, due to fear of error, recognition of disturbances, and myths about response, especially when warning systems are just developing and officials have little experience or when there is still a great deal of uncertainty about the occurrence of the future event. Among issues, which are of importance for the efficiency of message dissemination are: the source credibility (person-specific), dissemination channel accessibility, redundancy and system´s resistance to floods.

Developments of the system of flood forecasting and warning usually result in reduction of the number of flood fatalities. Thanks to improvements in the advance time and accuracy of a forecast, it has been possible to reduce the number of flood fatalities in many countries. Preparedness to floods varies with the wealth. In countries with a high GNP level, when an extreme flood arrives, it is not possible to avoid high material damage, but it is possible to save lives, thanks to a well-functioning forecast-warning system.

6. Integrated Flood Risk Management policy

Structural flood protection measures, e.g. levees, are dimensioned based on the probability theory, to withstand a "design flood" of a certain magnitude, i.e. an N-year flood, i.e. a flood discharge whose probability of exceedance in any one year is 1/N, where N may differ between countries and land-use classes within the range from 10 to 4000 years. In the Netherlands, the protection level of flood defenses is probably higher than in any other country (even up to 4000-year flood for major dikes). In many countries, the principal design standard for river dikes is a 100-year flood. As regards low-probability events, there is an "unreliability of reliability estimates" (Vit Klemes, personal communication), due to small-sample and uncertainty problems, even if the stationarity assumption were justified.

The longer the assumed return period of the design flood the better the level of protection (albeit at higher costs). Should one design dikes to withstand a 100-year flood or perhaps more robust levees, withstanding a 500-year flood? The latter solution would give a better (but not absolute) protection being far more costly. It is a clear trade-off situation. Societies should protect themselves against floods up to an agreed level, being a compromise between the requested safety and the accepted willingness-to-pay. Preparing to rare floods can be counter-productive, because more important public priorities may exist in other sectors, providing better cost-benefit ratio for the society.

Dikes protect well against small and medium size floods, but when a deluge is of disastrous size and dikes break, losses in a levee-protected landscape can be higher than would have been in a levee-free case, since existence of a dike is taken by the riparian population as a guarantee of absolute safety, and this false feeling of security of the riparians drives the growth of the damage potential. However, no matter how high a design flood is, there is always a possibility of occurrence of a greater flood, inducing losses. Even a perfectly maintained dike designed to withstand, for example, a 100-year flood does not guarantee absolute protection. It can be overtopped and destroyed by a more extreme flood (e.g. with return period of 1000 years).

An early warning notion in the long-term context is a statement that a high water level / discharge is likely to occur more frequently in the future (Kundzewicz, 2009), that is, in a site of concern, a present (i.e. corresponding to a control period, e.g. 1961-1990) 100-year flood may occur more frequently, e.g. becoming a 50-year flood in some defined future time horizon (e.g. 2031-2060). Finding that a 100-year flood in a past control period is unlikely to be of the same amplitude as a future 100-year flood is of importance for design and operation of large water infrastructure (e.g. dikes, dams and spillways), which are intended to serve over a long time. It clearly results from Figs. 5 and 6, that, over much of Europe, what used to be a 100-year flood under current climate conditions will occur more frequently in the future. Hence, in order to maintain the same standard of protection against a 100-year flood, a need for a costly overhauling comes about. One can expect that in those areas where 100-year floods become lower and the adequate, and properly maintained, protection systems are already in place, the existing defenses will provide higher-than-standard protection level.

Such an early warning, in large temporal scale, is (or should be) an important signal of relevance to decision makers, informing them that the requested (current) level of protection is not likely to be maintained in the future, unless adequate efforts are taken. Upgrade of flood preparedness system is needed in order to assure the necessary protection level. If studies come to reliably predict that a present design flood, e.g. corresponding to a 100-year return period in the control period, becomes more frequent in the future, changed, climate, then the consequences for the existing procedures for designing dikes, dams, spillways, by-pass channels, reservoirs, and storm sewers, traditionally based on the assumption of stationarity of river flow, would be severe. For instance, one would have to design and build bigger storage volumes, at higher costs, in order to accommodate larger flood waves in the future and to strengthen levees (activity being both time consuming and resource-intensive).

Existing infrastructure may not guarantee an adequate level of protection and may need to be re-developed, since – as phrased by Milly et al. (2008) – “stationarity is dead”. Without changing design codes, systems will be over- or under-designed and will either not serve their purpose adequately, or will be overly costly (e. g., with large safety margin). Existing design procedures would have to be revised, accounting climate change (and other changes of relevance).

There are many sources of uncertainty in future projections related to river flooding, starting from impossibility to foresee future human behavior (population change; social and economic development; effectiveness of the climate mitigation policy: controlling intensity of greenhouse effect via the future greenhouse gas emission and carbon sequestration; and adaptation to climate change impacts). Uncertainties are also introduced by several coupled transfer functions in the cause-effect suite of processes from greenhouse-gas emissions/sequestration to atmospheric concentration of greenhouse gases, and then further to climate change (including feedbacks) and to climate change impacts. Every transfer function in the above system bears large uncertainty, so that amplification of uncertainty can be observed, throughout the logical chain from greenhouse gas emissions to climate change impacts. Already the climate model uncertainty (related to numerical converting of greenhouse gas concentrations into climatic variables, such as temperature and precipitation) is large. Uncertainties of climate change projections increase with the length of the future time horizon. In the near-term (e.g. 2020s), climate model uncertainties play the dominant role, while over longer time horizons, uncertainties due to the selection of emission scenarios become increasingly significant.

Uncertainty in practical flood-related projections is also due to a spatial and temporal scale mismatch between coarse-resolution climate model, the scale of a drainage basin, and a “point” scale of a locality (e.g. flood-prone areas in a small riparian town) where adaptation is undertaken. Further, time scales of interest may differ from those for the available climate model results (typically given at monthly/daily intervals). For heavy precipitation resulting in flash flood, the dynamics of flood routing is at the scale of minutes to hours. Scale mismatch renders downscaling (disaggregation) necessary and this is another source of uncertainty. Uncertainty in findings about future climate change impacts refers particularly to extreme events. Part of uncertainty is due to deficiencies of hydrological models and available observation records for model validation. There is an overwhelming scarcity of available homogeneous long-term observation records. The inherent uncertainty in analysis of any set of flood flows stems also from the fact that direct measurements in the range of extreme flows are problematic (rating curves not available for the high flow range, gauges destroyed by the flood wave, observers evacuated), and recourse to indirect determination is necessary.

However, due to the difficulty in isolating the greenhouse signal in the observation records and the large uncertainty of future projections of precipitation and related variables, no precise, quantitative information on future flood risk can be offered by scientific research. Despite this, water managers in some countries (e.g. the Netherlands, the UK, and Germany) have begun to consider the early climate change warning explicitly in flood protection design codes. In parts of Germany (e.g. in the Federal State of Bavaria), flood design values have been increased by a safety margin, based on climate change impact scenarios. The projections for 2050 include an increase of 40-50 % in small and medium flood discharges and of around 15 % in 100-year floods. In the UK, design flood magnitudes are increased by 20% to reflect the possible effects of climate change, based on early impact assessments. Measures to cope with the increase of the design discharge for the Rhine in the Netherlands from 15 000 to 16 000 m^3/s will be implemented by 2015 and it is planned to increase the design discharge to 18 000 m^3/s in the longer term due to climate change, to maintain the existing high safety level. A safety factor (climate change factor) has been proposed, which is to be taken into account in any new plans for flood control measures in the Netherlands (EEA, 2007).

In response to destructive recent floods in the European continent and projections of growing risk in many areas, the Floods Directive (CEC, 2007) was adopted on the European Union (EU) level, embracing river floods, flash floods, urban floods, sewer floods and coastal floods. The Directive calls for assessment, mapping, and management of flood risk as mandatory activities aimed at upgrading the preparedness systems at an unprecedented multi-national scale. The Directive states that EU Member States shall, for each river basin district or the portion of an international river basin district lying within their territory, undertake:

- a preliminary flood risk assessment (a map of the river basin; description of past floods; description of flooding processes and their sensitivity to change; description of development plans; assessment of the likelihood of future floods based on hydrological data, types of floods and the projected impact of climate change and land use trends; forecast of estimated consequences of future floods);
- preparation of flood hazard maps and flood risk maps (i.e. damage maps), for areas which could be flooded with a high probability (return period of 10 years on average); with a medium probability (return period of 100 years), and with a low probability (extreme events);
- preparation and implementation of flood risk management plans, aimed at achieving the required levels of protection, by 2015.

7. Concluding remarks

It is necessary to take lessons from flood events, i.e. to build awareness and understanding of reasons of the failure of performance and identification of weak points in the flood preparedness system. It is necessary to take a holistic, systems view. A single weak point in a system, which otherwise contains excellent components, may render the overall system performance non-satisfactory. The system requires adequate integration of components, while responsibility for them may reside in different agencies. This means that an adequate (often difficult) collaboration and co-ordination between multiple institutions is often needed. In emergency situations, it may become evident that distribution of roles of agencies is unclear, and possibly redundant.

People’s experience of flood may reduce damages in the next flood. Where large floods visit a place twice in a short time period (e. g., on the Rhine in Cologne in December 1993 and January 1995), losses during the second flood occurrence are typically far lower than during the first occurrence (cf. Munich Re, 1997). Lessons from the first flood incidence are taken by a riparian living near a river, a farmer living on high ground, whose fields and meadows are on the floodplain, a professional in a water district, a legislator, spatial planning (zoning) officer, and a public administrator (at different spatial levels – country, province, town, community). Lessons from flood events, and human failures, are indeed being learnt, but the memory fades with time after the flood.

Typically, an occurrence of a destructive flood boosts willingness to strengthen the flood preparedness system and heavy expenditures follow. After an occurrence of a deluge, ambitious plans are laid out and works are launched, but the lessons are not remembered for long. After some time without floods, the willingness-to-pay drastically decreases and projects are downscaled or suspended. When a next deluge comes, it acts as a reminder and starts a new cycle. This vicious circle, known as “hydro-illogical cycle” (concept introduced in the drought context by Donald A. Wilhite in mid 1980s) is a general principle, valid across different social, political and economic systems. A return period of a destructive flood is usually much greater than the political horizon of primary interest of decision-makers and the electorate, marked by the term of office and the next elections. The above rule of hydro-illogical cycle is at odds with the precautionary principle.

Misconceptions and myths about floods and flood protection are deeply rooted in the society – the general public, politicians and decision-makers alike. People naively believe that floods occur in large time intervals, that a term “return period” or “recurrence interval” can be taken at face value (without the important restriction – on average) and that embankments offer a perfect safety.

Several ongoing land-use changes, such as urbanization, deforestation, and reduction of natural storage (floodplains, wetlands), can be regarded as adverse from the viewpoint of flood safety. They diminish the available water storage capacity and increase the runoff coefficient, leading to growth in the flow amplitude and reduction of the time-to-peak of a flood triggered by a ‘typical’ intense precipitation (e.g. design precipitation). Furthermore, human encroachment into unsafe areas has increased the potential for damage. Societies become more exposed, developing flood-prone areas (maladaptation).

Appendix 1

Important issues regarding sustainable flood prevention, protection and mitigation are:

- Flood events are a part of nature. They have existed and will continue to exist. As far as feasible, human interference into the processes of nature should be reversed, compensated and, in the fu-true, prevented.
- Flood strategy should cover the entire river basin area and promote the co-ordinate development and management of actions regarding water, land and related resources.
- Considering the evolution and trends, the approach to natural hazards re-quires a change of paradigm. One must shift from defensive action against hazards to management of the risk and living with floods, bearing in mind that flood prevention should not be limited to flood events which occur often. It should also include rare events.
- Transnational efforts should be intensified to restore rivers' natural flood zones in order to reactivate the ability of natural wetlands and floodplains to retain water and alleviate flood impacts.
- Human uses of floodplains should be adapted to the existing hazards. Appropriate instruments and measures should be developed for all flooding related problems: flooding, rising groundwater tables, sewage network disruption, erosion, mass deposition, landslides, ice flows, pollution, etc.
- Mitigation and non-structural measures tend to be potentially more efficient and long term more sustainable solutions to water-related problems and should be enhanced, in particular to reduce the vulnerability of human beings and goods exposed to flood risk.
- Structural measures (defense structures) will remain important elements and should primarily focus on the protection of human health and safety, and valuable goods and property. We will have to keep in mind that flood protection is never absolute, and may generate a false sense of security. The concept of residual risk, including potential failure or breach, should there-fore be taken into consideration.
- Flood forecasting and warning is a prerequisite for successful mitigation of flood damage. Its effectiveness depends on the level of preparedness and correct response. Therefore the responsible authorities should provide timely and reliable flood warning, flood forecasting and information.
- A specific preparedness to alert, res-cue and safety measures should be planned and implemented at all levels, including the public, by maintaining regular basic information and continuous ongoing training actions. With appropriate and timely information, preparedness, everyone who may suffer from the consequences of flood events should be able to take -if possible- his/her own precautions and thus seriously limit flood damages.
- In flood-prone areas, preventive measures should be taken to reduce possible adverse effects of floods on aquatic and terrestrial ecosystems, such as water and soil pollution. It is necessary to distinguish between different kinds of flooding and the environmental conditions that contribute to the problem. For instance, there are significant differences between on the one hand sudden flooding in upstream or headwater areas where mitigating risk involves a wide range of innovative small-scale solutions and on the other hand lowland flooding where warning periods and the duration of flood events are longer and large-scale measure have to be taken. Therefore, the effectiveness of the best practices described in part II depends on among other hydrological and environmental circumstances.
- A compensation system should sup-port the victims of flood disasters to re-store their economic basis and their living conditions in due time. Insurance solutions at the private or public level or subsidence by state, which reinforce solidarity, should be furthered.

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国際情報ネットワーク構築による世界洪水年鑑の作成

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【Abstract】

Flood risk and vulnerability tend to change over many areas, due to a range of climatic and non-climatic impacts whose relative importance is site-specific. Several ongoing land-use changes, such as urbanization, deforestation, and reduction of natural storage (floodplains, wetlands), can be regarded as adverse from the viewpoint of flood safety. In order to understand the best flood management policy practices and lessons learned, ICHARM has been launched a project focuses on the experiences of the past large scale floods mainly in recent years. The target groups and audiences of the project's outcome are policy makers and flood risk managers, particularly those who are involved in decision making to deal with large-scale floods with national and regional impacts. The outcomes of the project will be publicized in various formats by ICHARM using its strong worldwide network. In total 10 original reports to cover large-scale floods o in the recent years have been collected as follows:

Keywords: Large-scale flood, Flood Management Policy, Climate Change, Flood Risk Management, IFRM