Abstract I-11

ARE WE REALLY CONCERNED?
CLIMATE AND LAND USE CHANGES IN FLOOD PRONE AREAS

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ABSTRACT

Lowland, flood prone areas can be found all over the world, along the coasts, in river floodplains and as inland depressions. Generally they are by their nature sensitive areas with a high ecological value. Due to their physical conditions and environmental value they are basically unsuitable for development. However, due to the in many cases strategic location and/or suitability for agricultural production there is often a tremendous pressure to develop these areas for various types of land use. We therefore may observe a rapid population growth, a significant increase in agricultural exploitation, urbanisation and industrialisation in lowland, flood prone areas. Due to this such areas become increasingly vulnerable for extreme weather conditions that will have their effect on the requirements for drainage and flood management. The various relevant issues are summarised in this paper. Attention is paid to the impacts of developments in land use, land subsidence and climate change. Although the changes due to these processes may be of different speed and magnitude, they all result in an increase in vulnerability and requirement of an increase in measures to be taken with respect to drainage and flood management.

We are concerned about the natural disasters that hit us.
However, a significant part of these disasters are only so disastrous while we started to live on volcanoes, on active faults, along subsiding coasts and in floodplains of rivers.

Salomon Kroonenberg, 2006

INTRODUCTION

Lowland, flood prone areas can be found all over the world, along the coasts, in river floodplains and as inland depressions. Generally they are by their nature sensitive areas with a high ecological value. Due to their physical conditions and environmental value they are basically unsuitable for development. However, due to the in many cases strategic location and/or suitability for agricultural production there is often a tremendous pressure to develop these areas for various types of land use. We therefore may observe a rapid population growth, significant increase in agricultural exploitation, urbanisation and industrialisation in lowland, flood prone areas. Due to this such areas become increasingly vulnerable for extreme weather conditions that will have their effect on the requirements for drainage and flood management. The various relevant issues are summarised in this paper. Attention is paid to the impacts of developments in land use, land subsidence and climate change. Although the changes due to these processes may be of different speed and magnitude, they all result in an increase in vulnerability and requirement of an increase in measures to be taken with respect to drainage and flood management (Schultz, 2006a, 2006b and 2009).

With respect to these processes at the global scale, three groups of countries can be distinguished, being: *developed countries, emerging countries and least developed countries*[1] (Van Hofwegen and Svendsen, 2000 and Schultz, 2001). Especially in the least developed and emerging countries, population growth and urbanisation are on-going processes. Most of the urbanisation is taking place in flood prone areas.

The various relevant issues are summarised in this paper. Attention is paid to the impacts of developments in land use, land subsidence and climate change.

WORLDS' POPULATION AND POPULATION GROWTH

Figure 1 shows population and population growth in the three groups of countries. The developed countries house almost one billion people and there is almost no population growth at the current time. Some countries - like Germany and Japan - even show a decline in population. The least developed countries are home to nearly 800 million people. In these countries, there is a rapid population growth resulting in an estimated duplication by 2050. The emerging countries house almost 5 billion people (74% of worlds' population). They still show a significant population growth, resulting in an estimated 30% increase by 2050. These countries also show a relatively rapid growth in the standard of living.

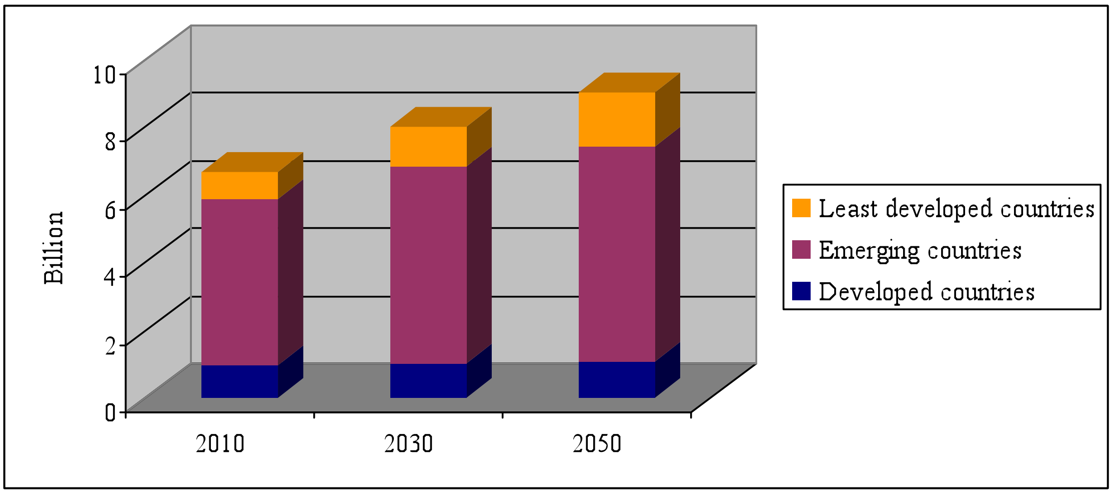
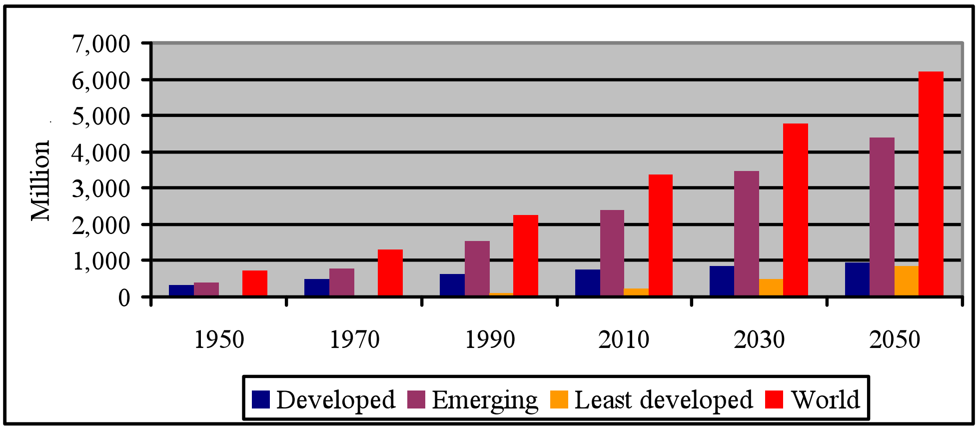


Figure 1. Population and population growth in the three types of countries (United Nations Department of Economic and Social Affairs. 2009 and Schultz, 2001 and 2010)

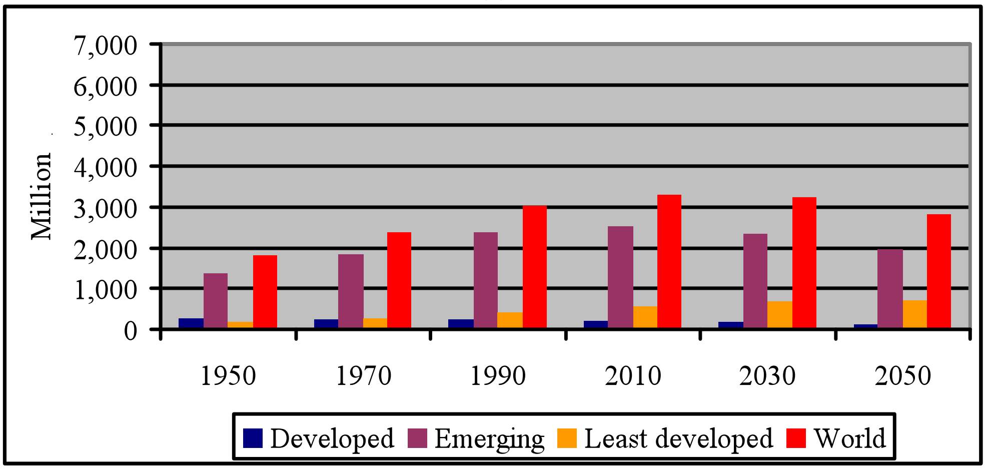
As shown in Figure 2, urbanisation is on-going throughout the world. In the developed countries, most of the urbanisation has already taken place, but still a certain increase in the urban population may be expected. In the emerging countries an increase in the urban population may be expected from 50% nowadays to 70% by 2050, which concerns respectively 2.4 and 4.4 billion people, more or less a duplication in 40 years and, when our development policies will not fundamentally change, most of them in flood prone areas. In the least

[1] *Developed countries.* Most of the countries in Western and Central Europe, North America and some countries in Central and South America, the larger countries in Oceania and some countries in Asia;
Emerging countries. Most of the Eastern European countries (including Russia), most of the countries in Central and South America, most of the countries in Asia (including China, India and Indonesia), and several countries in Africa;
Least developed countries. Most of the countries in Africa, several countries in Asia, 1 country in Central America and most of the smaller countries in Oceania.

developed countries, duplication of the population may be expected over the next 40 years. The increase in the urban population in the same period is expected to be from 0.23 to 0.86 billion people.



(a)



(b)

Figure 2. Development of urban (a) and rural (b) population in the three different types of countries and at the global scale

FLOODS AND FLOODING

World wide the terms of flood and flooding may have a different meaning. Therefore the definitions as used in this paper are:

- *flood.* A temporary condition of surface water (river, lake, sea), in which the water level and/or discharge exceed a certain value, thereby escaping from their normal confines. However, this does not necessarily result in flooding (Munich-Re, 1997);
- *flooding.* Overflowing or failing of the normal confines of a river, stream, lake, canal, sea or accumulation of water as a result of heavy precipitation by lacking or exceedance of the discharge capacity of drains, both affecting areas which are normally not submerged (Douben and Ratnayake, 2006)

Flooding is not necessary devastating, but can also been very beneficial if people are used to live with flood and can make use of it, for example for agriculture or fisheries. An interesting example of this can be found in the Mekong Delta, Vietnam, where they have developed a classification of floods as shown in Figure 3 (Trinh Hoang Ngan and Bui Duc Long, 2009).

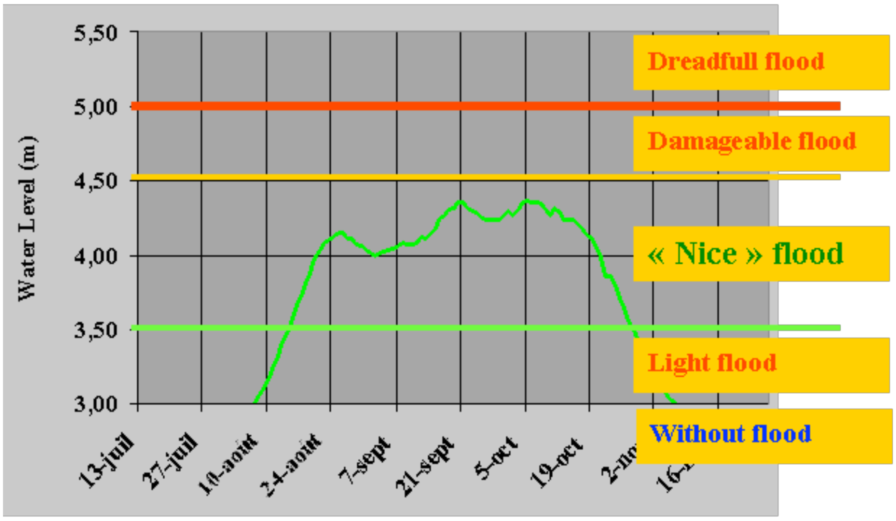


Figure 3. Classification of floods at Tan Chau Station in the Mekong Delta, Vietnam (Trinh Hoang Ngan and Bui Duc Long, 2009)

CHARACTERISTICS OF FLOOD PRONE AREAS

Worlds' population is increasingly living in flood prone areas. There are no indications that this tendency will change. Because of the generally fertile conditions and possibility for a rational lay out of the farmers fields and farms. After reclamation we may observe an improvement in agriculture, increase in value of crops, buildings, water management facilities and infrastructure. In quite some cases in a second phase urbanisation is developing in reclaimed lowlands. Due to this the value of urban property, buildings and infrastructure has significantly increased and will further increase in future.

The urbanisation process in flood prone areas will have far-reaching consequences for impacts on the hydrological regimes, water management and flood protection.

Although developments in flood prone areas of developed countries may be characterised by stabilisation, or small growth of the population, there is a significant growth in the value of public and private property. In several of these countries significant flooding is still occurring from time to time, resulting in relatively high damage, but generally only a limited number of casualties (Douben and Radnayake, 2005).

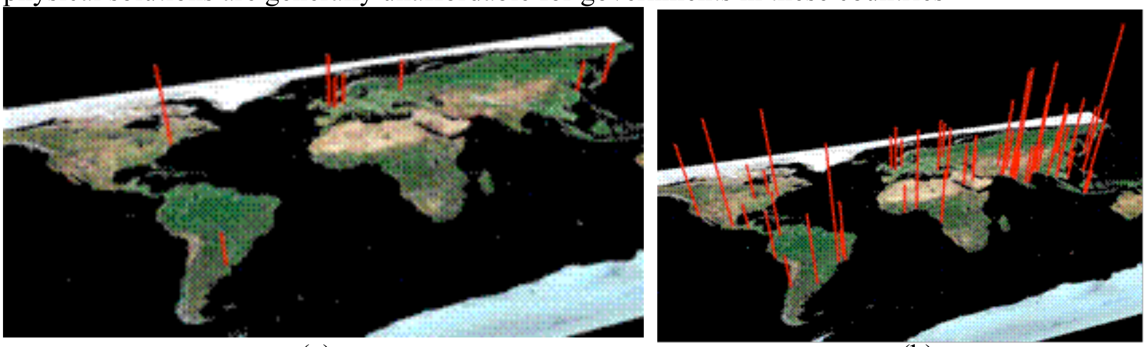
Developments in the emerging countries may be characterised by:

- rapid growth of urban areas resulting in removal of storage areas in the direct surrounding and increase in discharge;
- need for optimisation of flood protection measures related to the increase in value of protected properties and population growth;
- need for modernisation of urban drainage and flood protection systems;
- need to introduce a certain level of cost recovery from the stakeholders for drainage and flood protection.

Developments in the least developed countries may be characterised by similar processes as in the emerging countries, although at a slower speed.

Cities in flood prone areas

Especially in flood prone areas in South and East Asia we may observe a very rapid growth of cities. Most of this growth taking place in the flood prone areas (Schultz, 2001). During past decades cities like: Bangkok, Dhaka, Hanoi, Ho Chi Minh City, Jakarta, Manila, Osaka, Shanghai, Taipei and Wuhan have shown more or less an explosion in population growth and have transformed from less than one - two million inhabitants to in some cases more than 10 million inhabitants. Examples are shown in Figure 4, showing the cities with more than 5 million people in 1950 and in 2015, as well as by the growth of the city of Jakarta as shown in Figure 5. Increase in value of property has been in general even more rapid than the growth of population. As far as flood protection is concerned the level of protection is generally far below the economic optimum, especially in the emerging and least developed countries, but to a certain extent as well in the developed countries. In such cases there is a serious risk of loss of a large number of human lives and serious damage when an extreme event would occur. Costs of physical solutions are generally unaffordable for governments in these countries



(a) (b)

Figure 4. Cities with more than 5 million inhabitants in 1950 and 2015

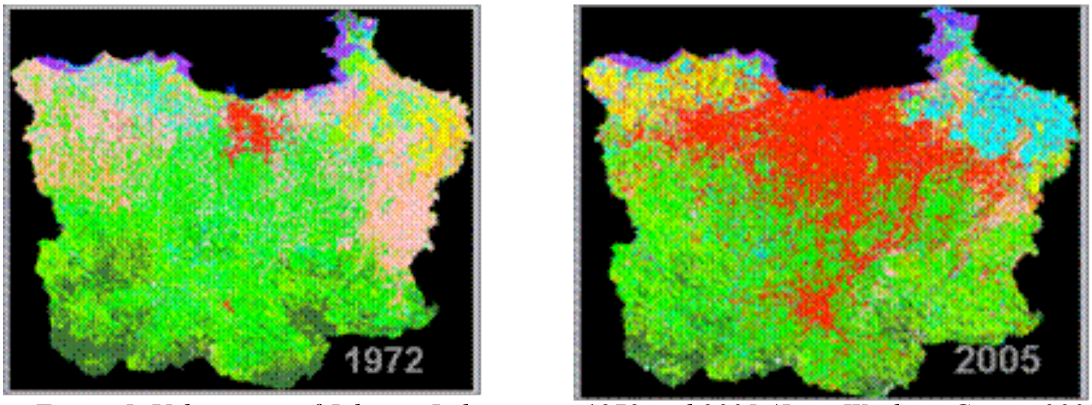


Figure 5. Urban area of Jakarta, Indonesia in 1972 and 2005 (Joint Working Group, 2009)

Figure 6 shows the statue of a wolf along the dike of Yangtze River upstream of Wuhan, as well as the dike at the same location. At this place the dike has breached several times in the past. The wolf is a symbol to prevent new breaches in future. About forty years ago Wuhan had about 2 million people. Nowadays there are more than 15 million people. So if the same devastating flood would occur again the damage and casualties will be significantly higher.

Figure 7 shows two sections of the ring dike around the western part of Dhaka in Bangladesh. The dike is a strong dike. However, the level of safety has a chance of failure of 2% per year. There live more than 10 million people in that part of Dhaka. When the dike would breach there is water around everywhere and they can go nowhere.

INTERACTIONS OF LAND USE, WATER MANAGEMENT AND FLOOD PROTECTION

If we look at the interactions of land use, water management and flood protection we may observe many problems in the emerging and least developed countries and to a certain extent in the developed countries as well, like: inadequate water management and flood protection, insufficient pollution control, increased damage and casualties due to flooding, operation, maintenance and management problems, negative environmental impacts, and long-term problems due to subsidence and impacts of climate change.

Figure 6. Wolf on the river side of the dike along Yangtze River upstream of Wuhan, China as a symbolic protection

Figure 7. Views of the Ring Dike around the Western part of Dhaka, Bangladesh

In order to recommend how these problems best can be solved under the different conditions it is first of all useful to analyse who are really the players in this field and what may be their roles. With respect to this in Figure 8 is shown which parties are responsible and which parties are contributing in water management. A similar Figure can be made for flood protection.

In addition it is important what measures are in principle available for flood protection. Here a distinction can be made between structural and non-structural measures (Working Group on Non-structural Aspects of Flood Management, 1999 and Van Duivendijk, 2005):

- *structural measures:* dams, dikes, storm-surge barriers, etc. In fact it concerns physical provisions to reduce the risk of flooding;
- *non-structural measures:* flood forecasting, flood warning, flood mapping, evacuation plans, land use zoning, etc.

In practice an integrated package of flood management and flood protection measures for both rural and urban areas would have to be developed at river basin level (Schultz, 2006b).

With respect to the strategies or approaches for flood protection three principle strategies can be distinguished, being:

- put relevant infrastructure and valuable buildings and structures relatively high and accept flooding of less valuable parts;
- protection with submersible dikes that protect the lands against regular floods, but are overtopped during more extreme floods;
- high level of protection with dikes that only fail in extreme events.

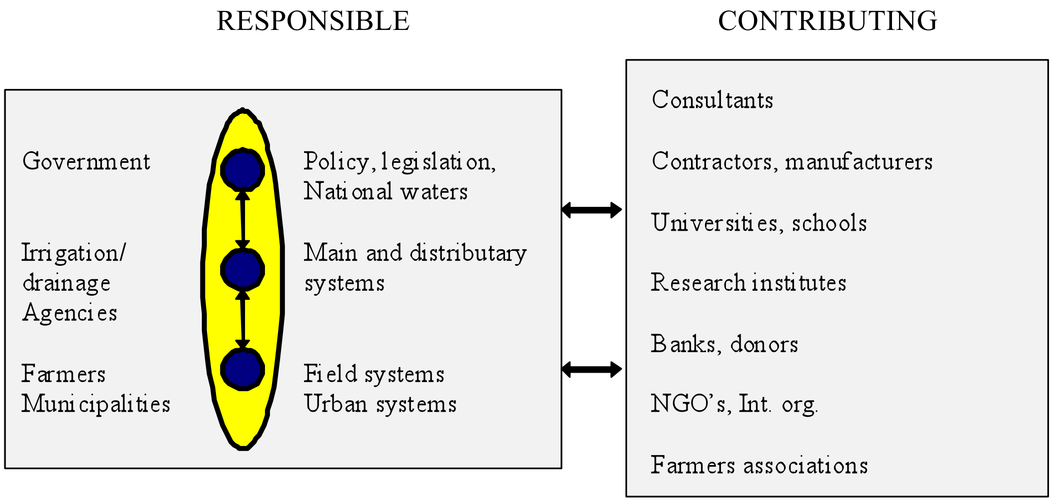


Figure 8. Actors in water management

Within the strategies as shown above three other important issues may be listed, being:

- locate urban (valuable) areas higher, than surrounding rural areas;
- within rural areas, locate farm buildings higher than the cropped area;
- within urban areas, locate houses and buildings the highest, then the streets, and finally the parks and green areas.

A special aspect that may occur in coastal or in peat areas is land subsidence. This is especially a problem in humid tropical peat soils where after reclamation subsidence may occur of up to 10 – 15 cm per year (Figure 9). Due to this in time the lands will become lower, which may have very significant consequences for water management and flood protection. With respect to water management this may imply that drainage by gravity in time will have to be replaced by drainage by pumping. In case of agriculture this may make agricultural exploitation unfeasible and may lead to abandoning of the area, leaving it in a devastating condition. In urban areas, like Jakarta and Semarang, primarily due to groundwater extraction, locally a subsidence of up to 0.10 m per year may occur.

If we summarise the impacts of climate change and man induced changes in land use for flood prone areas, than the following can be stated:

- *climate change - impact 10 – 30% per century:* rise of the mean sea level, change in river regimes and increase in peak discharges of rivers, and increase in annual rainfall and in peak rainfall;
- *impact of human activities - Impact 100 – 1,000% per century:* increase in population, increase in value of public and private property and increase in value of crops, subsidence.

The effect that the increase in value of property may have on design standards for flood protection works is indicated in Figure 10 (after Schultz, 2001 and 2008). In this theoretical figure the costs for flood protection measures are given for different design frequencies of the safety for a supposed situation in 1960. In addition the estimated damages as related to the design frequencies are given, based on the value of protected buildings, infrastructure and properties at the supposed value of 1960. An economically 'optimal' design is obtained when the total of costs and damages would be minimum. For the 1960 situation such an optimal design would in this theoretical example be in the range of a chance of occurrence of 1/1 per year to say 1/50 per year. In addition Figure 10 shows what the damage would be in 2010, when the same frequency for the design of the flood protection works would be maintained and the values in the protected area would have increased ten times during the 50 years. In many flood prone areas this is an increase, which easily has occurred in reality. So, finally in Figure 10 the total line is given for the 2010 situation, based on the assumptions as outlined before. From this line it can be observed that the design frequency for the flood protection measures would have to be raised to say at least a chance of occurrence of 1/1,000 per year. This would mean significant investments in flood protection, just to maintain the economic optimal level. Final conclusions can only be drawn when the cost figures for designs at this safety level would be determined. In this theoretical example the increase in number of people in the flood prone area has even not yet been taken into account.

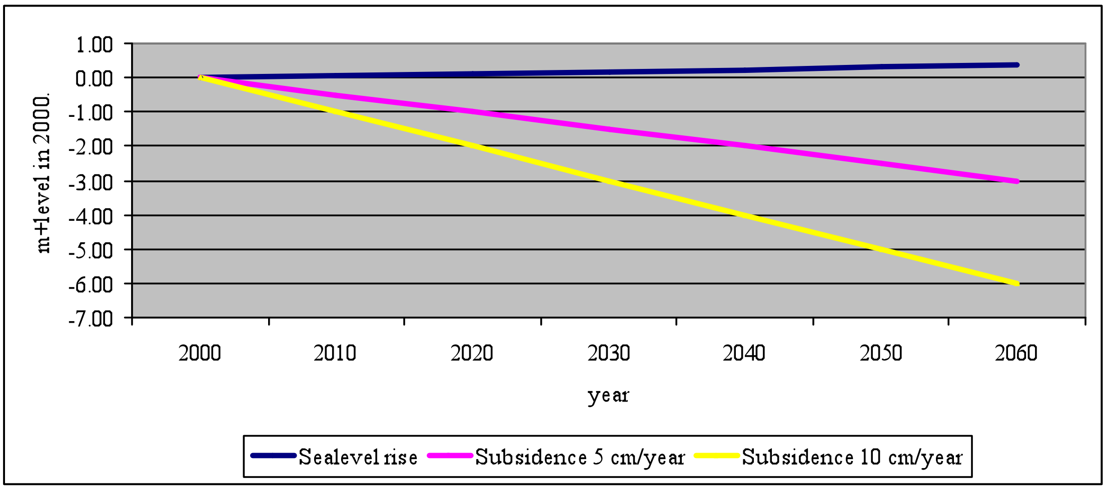


Figure 9. Possible impacts of sea level rise and land subsidence (Joint working Group, 2009)

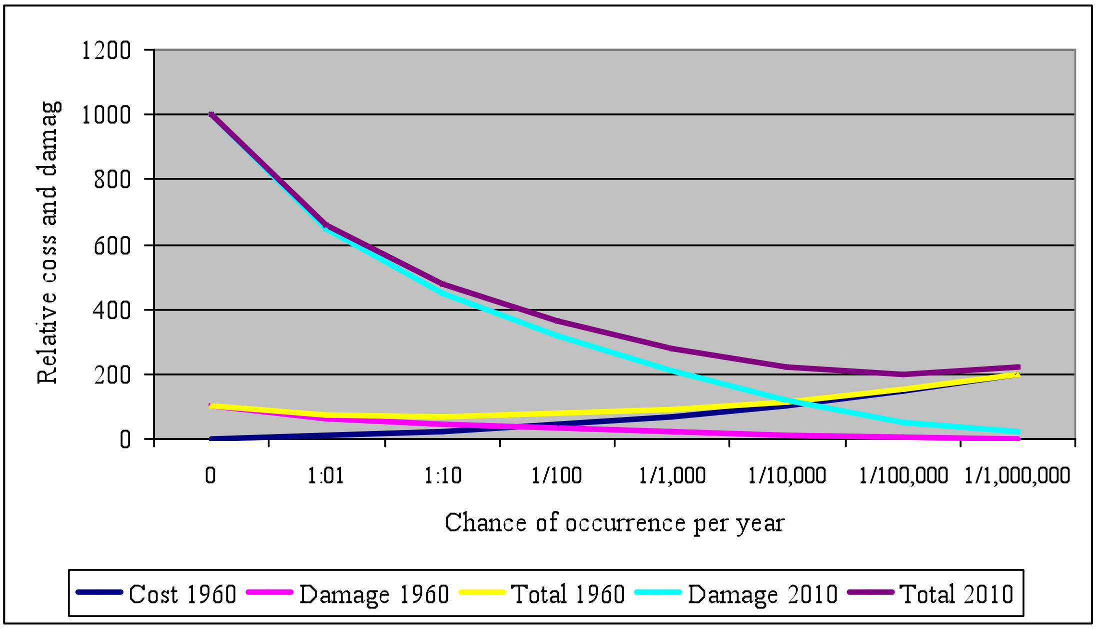


Figure 10. Interactions between design frequency, costs and damage (after Schultz, 2001)

Finally Figure 11 shows the safety standards for flood protection in the Netherlands. Although this are the highest safety standards for flood prone areas in the world we know that especially for the densely populated western part of the Netherlands they are below the level that would belong to the economic optimum. Reconsideration of the standards is on-going and we have to see what the final decision with respect to them will be.

A very different development in flood prone areas may be illustrated by the envisaged developments in the Mekong River Basin. In this basin for centuries the people have been living with floods (Figure 3). In the past some dams have been built upstream in the river in China.

However, there are nowadays serious plans for eleven more dams, mainly for hydropower and irrigation (Figure 12). When these plans will indeed be implemented there will be a significant change in the hydrology of the river due to removal of peak floods and deposition of sediments in the reservoirs. The first aspect will have the advantage of reduction of damage due to floods, but will also have negative impacts for especially recession agriculture and fisheries in Ton Le Sap lake in Cambodia and for agriculture in the Mekong Delta. The deposition of sediments in the reservoirs will significantly reduce the deposition of fertile sediments in the same locations.

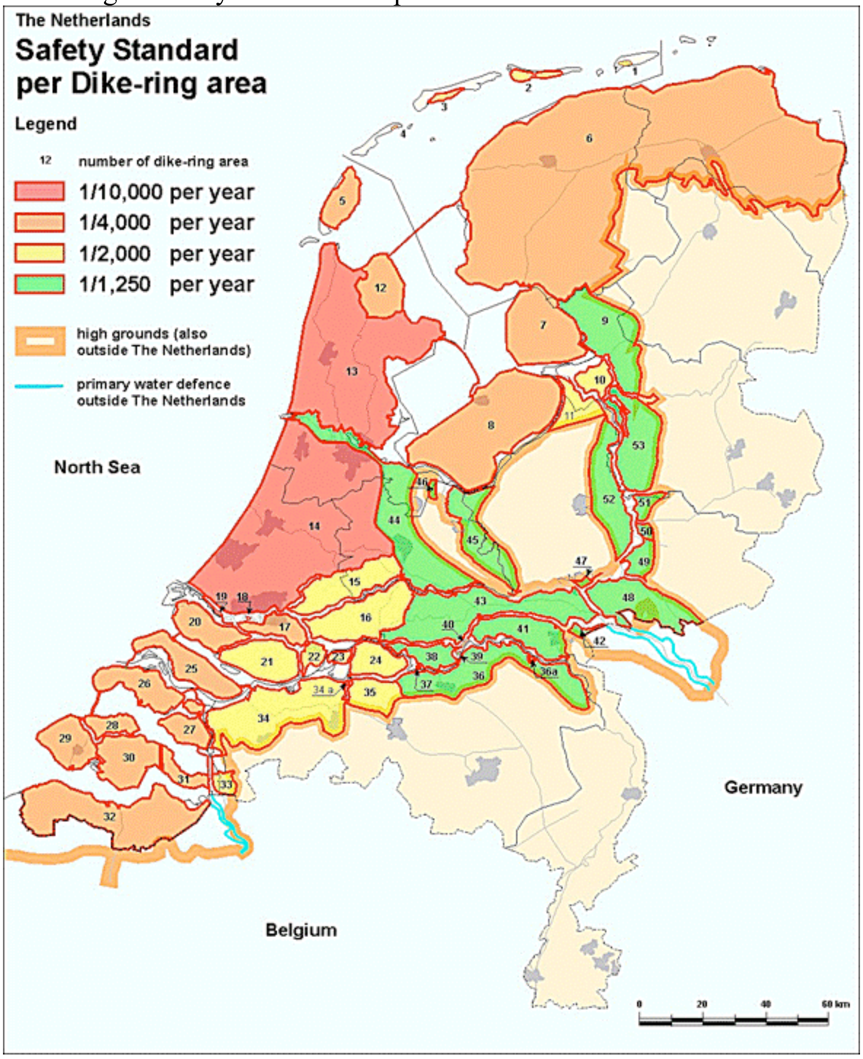


Figure 11. Design standards for dike rings in the Netherlands (Technical Advisory Committee on Water Defences (TAW), 2000)

In light of the above critical issues with respect to flood protection will be:

- countries need a development strategy, taking into account, short, medium and long term perspectives;
- need for a strong Central Government for policy development, standards, laws and supervision;
- the need for development of integrated flood management packages, especially for densely populated flood prone areas need to be carefully developed and implemented;
- the need to put responsibility and funding for operation, maintenance and management of water management and flood protection as much as possible with stakeholders;
- the need to develop improvement works in close consultation with the stakeholders. At least partly funding by them.

Figure 12. Existing and projected dams in the Mekong River

The flood protection measures themselves can best be developed based on the so-called safety chain. Such a chain will consist of five components:

- *pro-action.* Removal of structural causes of disasters to prevent that they might occur;
- *prevention.* Measures to prevent accidents and disasters and reduction of consequences if they nevertheless occur;
- *preparedness.* Measures to take care that one is sufficiently prepared to combat accidents or disasters when they would occur;
- *response.* Actual combat of accidents and disasters;
- *aftercare.* Activities with result that effects of accidents and disasters will be repaired as fast as possible and enable affected persons to get back to normal situation and relations as soon as possible.

Pro-action concerns removal of structural causes of disasters in order to prevent that they occur. One can think of removal of abandoned structures and buildings, 'illegal' developments in the floodplain or river foreland, giving room to the river by lowering the river bed, removal of dike sections and replacement of dikes inland, making by passes, etc. (Figure 13).

Prevention concerns the measures to prevent accidents and disasters, and reduction of consequences if they nevertheless occur. One could think of: flood forecasting (Figure 14) and flood warning, as well as of the structural measures that in principle can be taken. With respect to the design criteria, it is of interest that nowadays increasingly these are being based on a risk analysis in which the various failure mechanisms are being taken into account (Figure 15).

With respect to the cost – benefit relations the following developments may be listed:

- from overtopping to risk of flooding with designs based on failure mechanisms and a risk based approach and analysis per dike ring;
- detailed investigation of damage;
- determination of optimum design standard, based on economic criteria and loss of lives;
- robust designs taking into account future developments that may be expected.

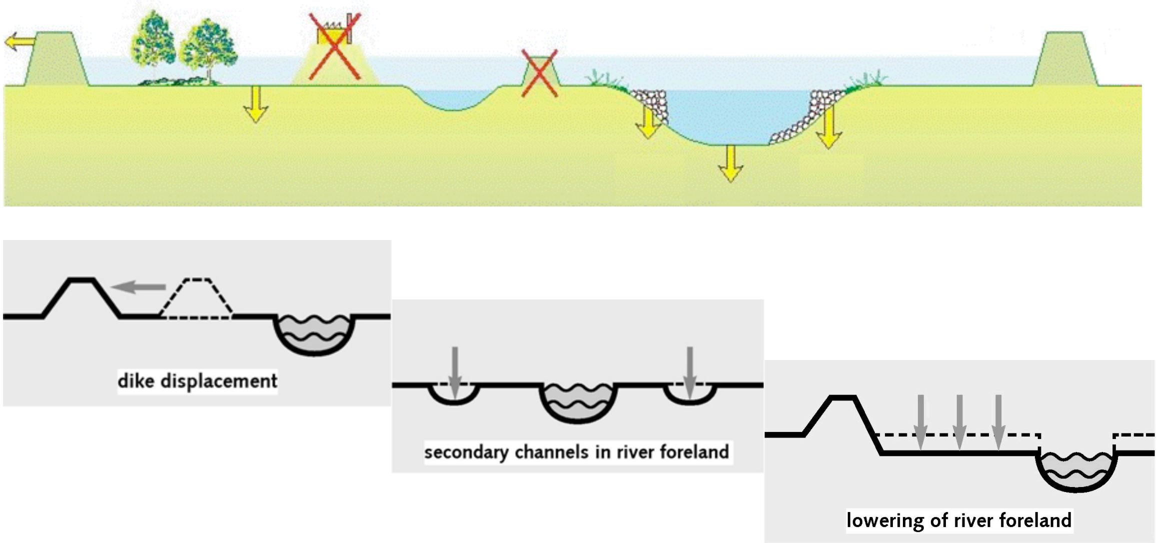


Figure 13. Measures to remove objections and to give room for the river

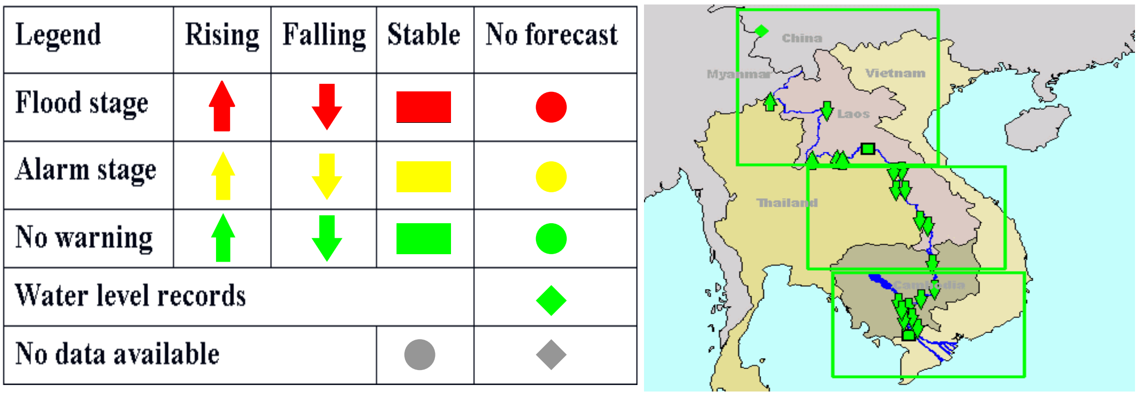


Figure 14. Basic elements of the flood forecasting site of the Mekong River Commission

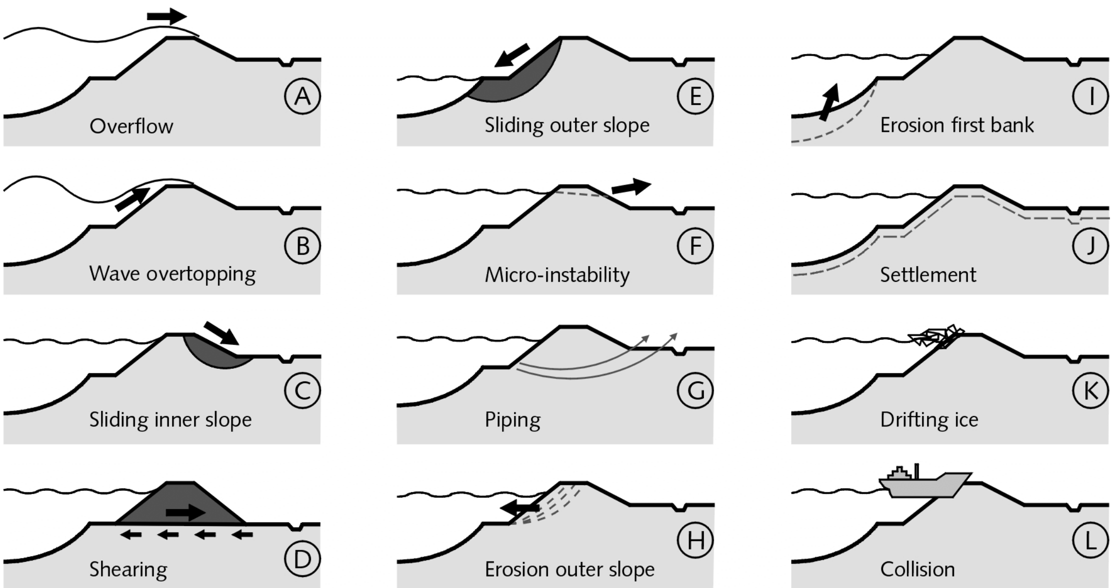


Figure 15. Failure mechanisms of dikes
(Technical Advisory Committee on Water Defences, 2000)

Preparedness may involve the following items:

- measures to be sufficiently prepared to combat disasters when they would occur;
- temporal structural measures (sandbags);
- evacuation plans, refugee mounts, communication, medical aid, food and drinking water supply.

Response may concern the actual combat of accidents and disasters, in fact controlled implementation of the preparedness measures during a calamity.

Finally after care may concern activities with result that effects of accidents and disasters will be repaired as fast as possible and enable affected persons to get back to a 'normal' situation and relations as soon as possible, cleaning, repair, reconstruction, initial aid to those that are hit, and reactivation of public services and economic activities.

CONCLUDING REMARKS

In order to cope with the rapid developments in flood prone areas, especially in the emerging and least developed countries, in the coming decades, these countries will have to significantly improve their water management and flood protection provisions. To a certain extent this also applies to the developed countries.

As long as population growth, increase in standards of living, urbanisation and industrialisation in flood prone areas goes on, increasingly water management and flood protection provisions will be required.

Climate change and land subsidence create complications, which make flood prone areas increasingly vulnerable. This may require abandoning such areas in medium, or long term future. If this would become actual in an area there is need for timely and complicated measures.

Flood management and flood protection measures are generally taken after a flooding disaster and not before. Many casualties and substantial damage would have been prevented when the same measures would have been taken before the disaster, but it looks like our societies are not able to take such decisions in time.

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