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Evolution of Urban Pluvial Flood Risks and Approaches to Urban Flood Resilience

CHENG Xiaotao, WANG Yanwei
China Institute of Water Resources and Hydropower Research (IWHR)
China

ABSTRACT

In recent years, "sea view in cities" during flood season becomes almost the normalcy. In order to explore the causes of increasing risk in urban pluvial floods and proper strategies in the context of climate change and rapid urbanization, the status quo of urban floods in China has been investigated thoroughly, and the Taihu Basin is selected to conduct scenario analysis of the flood risk in 2050. The investigation involves urban flood control and drainage management system, relative laws and regulations, planning, construction and operation, emergency management and technical standard systems, etc. Based on the geographical and chronological comparison within China and the comparison between China and other countries, the main existing problems and causes of increasing urban flood are analyzed. The trends of flood risk until 2050 in the Taihu basin show that the rapid urbanization inevitably breaks the fragile water balance among regions and between human and nature, and the climate change aggravates the imbalance. It is unlikely for the current management system and operation mechanism to meet the increasing demands of security. The approaches to urban flood resilience in rapid urbanization with Chinese characteristics are discussed in order to enhance the adaptive and bearing capacities, achieving rapid response and recovery.

1. INTRODUCTION

China has experienced unprecedented urban expansion since 1998 with urbanization rate increasing from 30% to 50 % within only 14 years. In the past 30 years, China’s urban population witnessed a net increase of more than 508 million, which is equivalent to the combined population of the 28 countries in European Union. Urbanization concentrates not only population and properties, but also risk of disasters. Among the current 654 cities in mainland China, 641 of them are under threat of floods. According to the statistics from the Office of State Flood Control and Drought Relieve Headquarters of China, numbers of the flooded cities above county level are more than 130 every year since 2008, 258 in 2010 and 234 in 2013 in

particular, and most of them suffered pluvial floods during local heavy rains. A special investigation of the Ministry of Housing and Urban-Rural Development for 351 cities during 2008-2010 shows that 62% of the cities suffered from pluvial floods, and 137 among them were flooded more than 3 times. The situation is getting worse, extreme examples include the flood in Beijing on 21July, 2012 and the 7-day inundation of Yuyao City in October 2013. The normalization of “sea view in cities” has become major problems that seriously affect the normal operation of cities and threat the urban public security and economic development.

The frequently occurred urban floods have got much concern of the government and the communities. “Notice of the General Office of the State Council on Effective Conducting Construction Work for Urban Water Drainage and Flood Control Facilities” and “Opinions of the State Council on Urban Infrastructure Construction” was issued successively in 2013, and “National New Urbanization Plan (2014 - 2020)” was published in 2014，which clearly stipulate that the capacity of urban drainage and flood control shall be improved comprehensively and a sound urban drainage and flood control system shall be built in 10 years.

In order to explore the causes of increasing risk in urban pluvial floods and proper strategies in the context of climate change and rapid urbanization, relevant departments and agencies conducted a series of investigations on the status quo of urban floods in China, involving urban flood control and drainage management system, relative laws and regulations, planning, construction and operation, emergency management and technical standard systems, etc. Based on the geographical and chronological comparison within China and the comparison between China and other countries, the main existing problems and causes of increasing urban flood are analyzed. Through a collaborative research with the UK experts, the trends of flood risk evolution in the Taihu basin until 2050 are foreseen by scenario analysis concerning climate change and urbanization. This paper illustrates the main results of the research and accordingly discusses the proper approaches to urban flood resilience in China today.

2. PRESSURE AND CHALLENGES ON URBAN FLOOD PREVENTION

With rapid urbanization, the development of urban flood control and drainage system is important for flood prevention of cities. In 2013, the urban population in China reached 731.11×10^6, accounting for 53.7% of the total, and the urbanized area expanded to 44.5×10^3 km^2, about 6 times that of 1981. Meanwhile, the urban embankments reached 28×10^3 km, protected area increased to 88×10^3 km^2, and the total length of the urban drainage pipelines extended to 43×10^3 km, about 18 times that of 1981. In order to strengthen the urban flood control, 25 cities closely related to large rivers were assigned as the national key cities for flood control early in 1987, and the number of such cities increased to 31 till 1998. Later, another 54 cities were assigned in succession as the major cities for flood control after 1998.

However, it is a huge task to build a perfect urban drainage and flood control system because the regulatory level of urban flood control and drainage systems are relatively low in general. Up to now, for the 641 cities with flood prevention tasks, only

321 of them (51%) have reached the national flood prevention standards, and among the 31 national key cities and 54 major cities for flood control, only 10 and 16 cities are up to the national standards, 32% and 30% of the total respectively. As for the urban drainage system, the incomplete statistics of the top 20 metropolis show that their rainwater pipelines take up only about 1/4 of the total pipelines, and more than 70% of which are designed at a low regulatory level, with a capacity to stand up to the rainstorm with a return period of only 0.5～1 year. In the context of rapid urban expansion, sharply increased impervious area and increasing surface runoff, urban flood control and drainage systems is now faced with exceptional pressure.

Furthermore, among the cities with flood threats, 359 of them (56%) have formulated the flood control plan; and 228 of them (36%) are in the process of planning. Six national key cities and 20 major cities for flood control, as well as 258 other cities have not completed plan formulation or modification due to the rapid changes of situation. It should be noted that, the total number of such cities was 170 in 2006, while 7 years later, instead of decreasing, the number increased to 284 cities. This is because, with the urban development and expansion, the pre-existing plans of many cities have become outdated and cannot meet the demands of higher standard of flood prevention. Based on the “Flood Control Standard” issued by the state, urban flood control standard is divided into four grades with return periods of ≥200, 200-100, 100-50 and 50-20 years, respectively according to its urban population ≥1.5 million, 1.5-0.5 million, 0.5-0.2 million and ≤0.2 million. The drainage system planning is also faced with higher pressure.

As for the flood prevention administration in urbanized areas, according to the Flood Control Law: “Urban flood control planning shall, in accordance with the river basin flood control planning and the regional flood control planning of the people's government at the next higher level, be formulated by the water conservancy administrative department, the construction administrative department and other relevant administrative departments under the people's government of a city which shall organize those administrative departments in the formulation of the planning, and be included into the overall urban planning subject to approval through the examination and approval procedures stipulated by the State Council.” At present, the administration of urban flood control and drainage systems in China has formed diversified modes as shown in table 1.

Table 1. Diversified modes of Urban flood control and drainage management systems

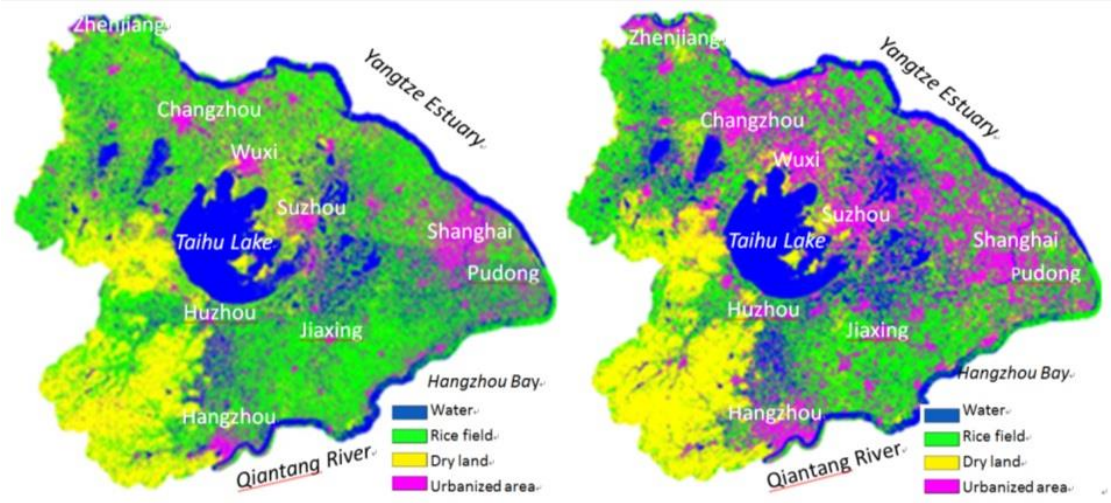
Type	Specific department for flood control	Specific department for drainage system
1	Water authorities	Water authorities
2	Water authorities	Both water & construction authorities
3	Water authorities	Construction authorities
4	Both water & construction authorities	Both water & construction authorities
5	Both water & construction authorities	Construction authorities
6	Construction authorities	Construction authorities
7	Not specified	Not specified

Comparing the statistics in 2006 and 2013, the number of cities whose flood prevention are managed by water authorities alone decreased from 379 to 370, and by construction authorities alone decrease from 114 to 103, while by both of water and construction authorities increased from 142 to 152, and unclear ones rose to 16. Such trends show that the proper administration modes of urban flood prevention are still in the process of exploration and adjustment, and in the face of rising urban flood risk, the relevant authorities should integrate their efforts and strengthen the collaboration to cope with the huge pressure and challenges in urban flood mitigation. In addition, disparity of urbanization rate in eastern (62.2%), central (48.5%) and western (44.8%) China also brings difficulties for the administration of urban flood prevention systems.

3. SCENARIO ANALYSIS ON FLOOD RISK EVOLUTION

In order to understand the flood risk evolution along with the rapid urbanization and global warming and to support the decision-making, a China/UK scientific cooperation project, Scenario Analysis Technology for Flood Risk Management in the Taihu Basin was conducted from 2007 to 2010[1]. The study has got the followed support by the National Key Technology R&D Program in the 12th Five-year Plan (2011-2015) for exploring the proper adaptation strategies to inhibit the growth of the flood risk and to support the sustainable development.

The Taihu Basin, located in the estuary area of the Yangtze River and Qiantang River, covering 36,895 km^2, is one of the most important economic regions. Driven by the policy of opening up in Pudong in the early 1990s, the process of urbanization has been boosted in the Taihu Basin, with the urbanized area increasing by 4.3 times from 2,206.8 km^2 in 1995 to 9,476.4 km^2 in 2010. Meanwhile, the cultivated area decreased by 42% from 22,468 km^2 to 12,999 km^2[2][2]. Its population reached 57.24 million in 2010, increasing by 17.71 million in only 10 years. Figure 1 shows the land use change (2001-2010) in the Taihu Basin[3]. The basin is prone to serious flood disasters caused by plum rains, typhoons and storm surge. Features of flood risk in the Taihu basin are very sensitive to both global warming and rapid urbanization[4].



a. Land use in 2000/2001 b. Land use in 2009/2010

Figure 1: Change of Land Use types from 2000 to 2010 in the Taihu Basin

A scenario analysis system has been developed, consisting of a series of models of climate change impact analysis, social economic development forecast, flood loss assessment, hydrological analysis, flood simulation, dyke reliability evaluation and GIS based system integration. The results show that the flood risk growth will be faster than the economic growth in the Taihu basin by 2050 because of the combined effects of global warming and urbanization if we continue the current flood control measures. Analysis on the scenario cases considering the impact of climate change and urbanization separately, as shown in Figure 2, indicates that, with the global warming, the sea level rise and rainfall increase will lead to the growth of flood damages in normal flood events, and increasing assets and population in urbanized areas may lead to the sharp increase of flood damage in extreme flood events. For the flood events with return period above 20-year, the influence on social and economic development may be larger than that of climate changes.

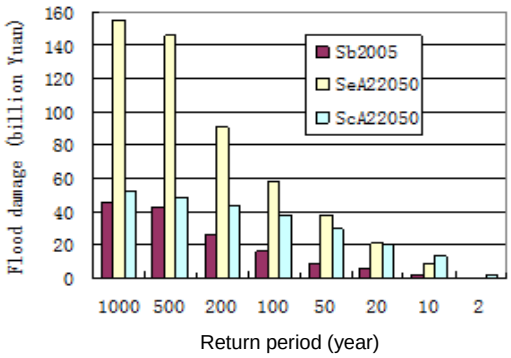


Figure 2 : Comparison of damages for the events of eight return periods in the scenario analysis
Note: Sb2005 - baseline 2005; SeA22050 - A2 scenarios in 2050 with economic change only; ScA22050 - A2 scenarios in 2050 with climate changes only.

The principle of *the higher the better* is not necessarily true when designing flood control standard. Figure 3 shows the scenario analysis results of the Expected Annual Damage (EAD) in the Taihu Basin[5], which indicates that the maximum contribution comes from the flood events with return periods between 20 to 50 years. If the standards of the drainage capacity for the urbanized areas and the flood control capacity for the vast polder areas can be limited within 50-year floods, the unwise competition by structure measures in the Taihu Basin may be avoided, and more effective non-structure measures should be taken to cope with the extreme flood events.

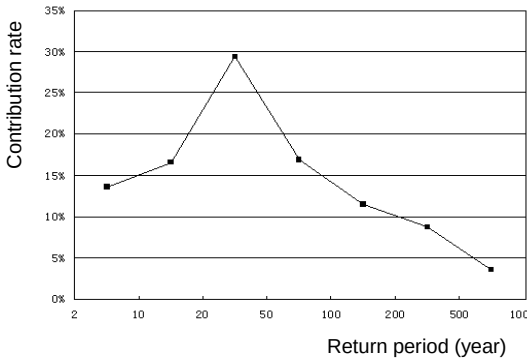


Figure 3: Contribution rates of flood events with different return period to the EAD

4. APPROACHES TO RESTRAIN THE INCREASING URBAN FLOOD RISK

It is worthwhile to note that the developing countries are facing more challenges than the advanced countries in the current world. The urbanization rate, for instance, in the advanced countries has been over 80%, and their urban population will merely increase from 900 million to 1.1 billion by 2050. However, the figure of the developing

countries for the same period will rise from 2.5 billion to 5.2 billion[6]. Such a difference means that the former is basically pursuing sustainable development at an almost equilibrium state, while the latter has to seek proper adaptive strategies for building dynamic balance on the way of rapid development. Especially, the developing countries in Asia are subject to unprecedented pressure as half of the current 26 megacities in the world with a population over 10 million are in Asia, and there will be up to 37 in Asia alone by 2025. Obviously, the flood risk increasing with rapid urbanization is far from whatever it is at current stage. The basic strategy for the developing countries is not to restore the disturbed balance but to build new balance according to the higher demands of development.

In order to effectively restrain the increasing urban flood risk, integrated approaches based on the foresight future flood risks may be helpful to build a framework of proper strategies[7,8]. Taking the Taihu Basin as an example, Figure 4 shows the basic concepts for such process to solve the difficult problems in reality. In light of the comprehensive assessment of flood risk in three aspects, namely hazard, exposure and vulnerability[9], flood risk zoning can be identified, which may provide the basis for the optimal combination of controlling, adaptive and resilience strategies. Capacity building is a key to ensure the synchronized development of flood prevention system and urbanization, which should be enhanced step by step in administration, coordination, control and operation, and emergency response, etc.[10]

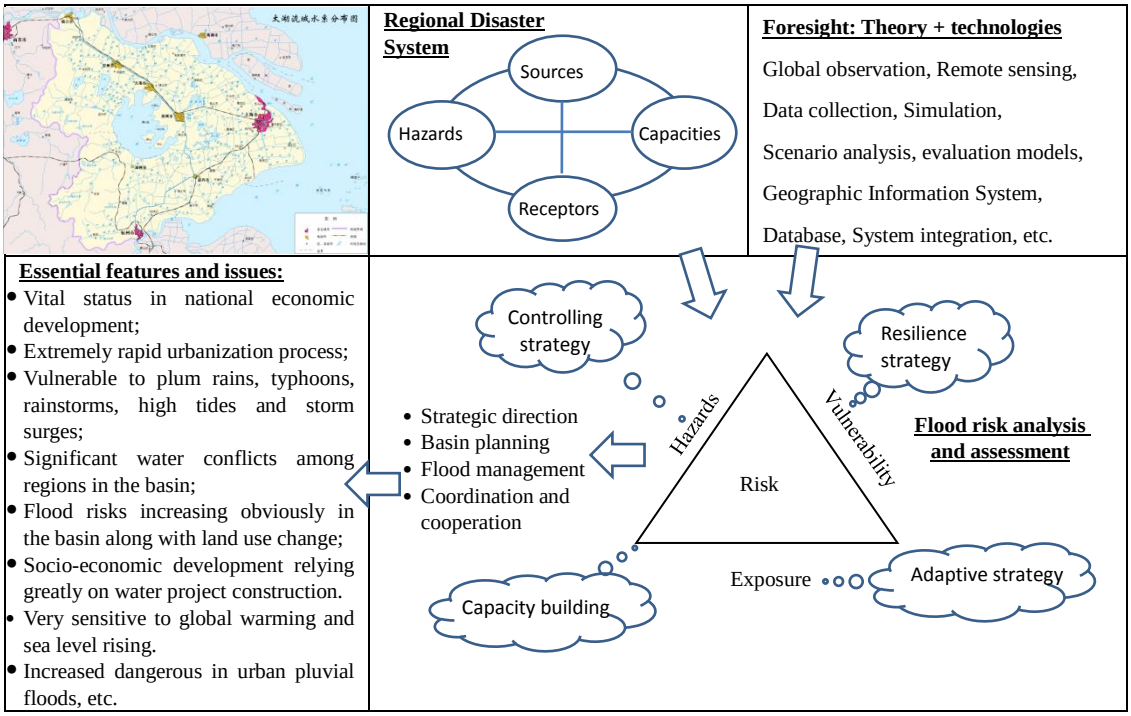


Figure 4: Basic concepts involved in foresight future flood risks in the Taihu Basin

Formulation and modification of flood control and urban drainage planning is an urgent work, which includes planning at three scales, river basin, municipality and community[11]. (1) Cities have always been the focus of protection in flood control planning at the river basin scale, involving the layout of flood control reservoirs and detention areas, as well as their scheduling operation during the flood seasons.

However, with the expansion of the cities, especially the forming of the 10 mega-city clusters, the river basin flood control plans have to be improved. Yuyao city, located at the middle reach of the Yaojiang River and inundated for seven days during the Typhoon Fitow in 2013, cannot mitigate its pluvial flood without an overall plan at basin level. (2) At the municipal scale, it is important to deal with the relationship between the drainage system and the waters (lake, river and wetland, etc.) through overall planning, which requires a better cooperation among the relevant authorities. Flood risk zoning is urgently needed to guide the layout of urban development and urban flood prevention planning. At present, the urban flood risk mapping had been developed from trialing in pilot areas to wide application in many cities, but how to use it in urban flood risk management remains to be explored. (3) At the community scale, various kinds of source control measures can be taken to reduce the peak discharge and the existing pressure on drainage system. For communities in the old and new urban districts, diversified measures should be carried out for rising flood prevention standards. Many successful modes, such as BMPs, LID, WSUD and SUDS etc., have been introduced to China, and their applicability should be explored in depth according to the local conditions.

5. CONCLUSIONS

Frequently occurred urban floods have become a serious threat to the public security and smooth and rapid development. It is of course concerned with the meteorological conditions such as the increase of local heavy rainfall in short duration and enlarged amplitude of annual precipitation, but the main cause is the imbalance between the construction of flood prevention system and the development of economy in the process of rapid urbanization. Today conflict between the current management system and its operation mechanism and the growing demands of sustainable development and safety guarantee is increasingly conspicuous, becoming an important constraint for development.

Aggravating trend of urban flood risks has not been effectively curbed. When the urban population rate exceeded 50% in 2011, the speed would slow down, but still remain at a high level. Today the urbanization waves are spreading from coastal regions to inland areas, which inevitably break the delicate water balance among regions and between human and nature. The deterioration trend of urban water problem caused by rapid urbanization will last for a longer period, which should be fully recognized in decision making.

Urban flood prevention is system engineering with longevity and complexity. It needs to properly handle not only the relationships between urban development and flood prevention system construction, urban drainage and flood control, and short-term and long-term planning, but also the relationship between structural and non-structural measures, government leadership and social participation, and unified command and inter-department interaction. Urban flood prevention involves numerous departments, which needs unified planning, comprehensive measures, and sustainable and stable investment support. Only in this way, can we enhance our flood prevention capacity effectively.

Acknowledgement

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