TECHNICAL REPORT OF TC CROSS-CUTTING PROJECT ON
URBAN FLOOD RISK MANAGEMENT (UFRM)
IN THE TYPHOON COMMITTEE AREA

GUIDELINES ON URBAN FLOOD RISK MANAGEMENT (UFRM)

NOVEMBER 2013

ESCAP/WMO
Typhoon Committee

UNITED NATIONS ESCAP
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TC/TD-No. 0008

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FOREWORD

Economic growth and urbanization are inextricably linked. Economic growth often implies the conversion of rural land to urban uses, massive inflows of capital transformed and more people concentrated in urban areas. An important effect of urbanization is to increase the sensitivity of urban watersheds to the distribution of short-duration rainfall rates and flood. That creates much larger potential flood-related damage especially in the Asia and the Pacific region influenced by typhoon. A successful 'urban flood mitigation and management' requires proper understanding of the problem, long-term planning, availability of resources for taking immediate action during flood events and coordination between different public and private agencies.

In this connection, to promote the capability of urban flood mitigation and management, WGH took an initiative to consider the proposal of the Project on the Management of Floods in Urban Areas on its thirty-ninth session held in Manila, Philippines, from 4 to 9 December 2006.At TC second Integrated Workshop on Social-economic Impacts of Extreme Typhoon-related Events, which was held in Bangkok, Thailand from 10 to14 September 2007, the participants reviewed and discussed the proposal and road-map reported by China, and concurred that it is very important and necessary for TC members to enhance the cooperation and research on urban flood disaster management. The participants also recognized this project would be the first one to integrate WGM, WGH, WGDPP and TRCG into one project Considering the urban flood management relates to meteorology, hydrology and disaster prevention and preparedness and other aspects,. The title of the project was advised as current 'Urban Flood Risk Management in Typhoon Committee Area'. At TC 42nd Session which was held in Singapore from 25 to 29 January 2010, the Committee made decision to upgrade the UFRM project as cross-cutting project of TC.

The Project was proposed to be carried out with the objectives as: (1) to exchange the experiences on management and mitigation of floods and typhoon-related disaster in urban area between TC Members; (2) to share the technology of urban flood monitoring and methodology of urban flood forecasting and prediction, early warning and disaster assessment between TC Members; and (3) to promote management of urban flood and other typhoon–related disasters in TC area. The expected achievement of the project was proposed to prepare and publish the "Guidelines on Urban Flood Risk Management in the Typhoon Committee Area".

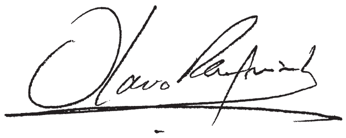
During the period from 2008 to 2012, the Committee gave its very close attention and strong support to the implementation of this project. I would like to emphasize specially with great appreciation that, all Members of pilot cities and model cities, working groups on meteorology (WGM), hydrology (WGH), disaster prevention and preparedness (WGDRR) and Training and Research Coordination Group (TRCG) as well as Task Force members made very close cooperation and very strong support, AWG Members of TC, ESCAP and WMO provided constructive guidance and advice to the project.

I have to point out that, as the first cross-cutting project, the implementation of UFRM project brought the remarkable and obvious benefit to the Committee, including the aspects of technology, cooperation and visibility. In general, the main outcomes of the project could be summarized as following six aspects: (1) provided and accumulated the experience for the Committee on how to carry on the cross-cutting project in the Committee; (2) summarized and abstracted the good practices in TC area on urban flood risk management; (3) identified the main gaps and needs in TC Members on urban flood risk management in aspects of hydrology, meteorology and disaster prevention and preparedness; (4) trained the staffs and transferred the technique for TC Members on QPE/QPF application, urban flood inundation mapping and disaster assessment; (5) drafted the UFRM Guidelines for TC Members; and (6) Enhanced the visibility of the Committee in a sense. The achievements and outcomes on

UFRM would be used not only in TC Members but also in outside of TC area. As the executive body of the Committee, TCS staffs played their efforts and roles, and also learnt a lot from coordinating this cross-cutting project.

The finalizing the cross-cutting project on UFRM, does not mean the end of research on urban flood risk management in the committee. Actually, there are many topics on the aspect of UFRM still exiting and waiting for further action. I hope the further research, cooperation and exchange on UFRM will be continued to promote and enhance the capacity of urban flood forecasting, warning and inundation mapping among TC Members.

Finally, I would like to take this opportunity to express my highest gratitude to all drafters for their dedication of expertise and time on the Guidelines drafting and editing, particularly Dr. Zhiyu LIU, Deputy Chief Engineer of Bureau of Hydrology, the Ministry of Water Resources of China, working as the leader of project and editor in chief. I surly believe the publishing the Guideline will play its import and valuable role in urban flood risk management in Typhoon Committee area.



Olavo Rasquinho
Secretary of UNESCP/WMO Typhoon Committee
October 1, 2013

PREFACE

Urbanization is a leading trend of the in Asia-Pacific region. By 2010, almost 43% of the region's population lived in urban areas. Urbanization is closely linked to the rate of economic growth, and has also resulted in the growth of Megacities.

Asia-Pacific region is under the very frequent and severe impacts of floods because of its geographical composition. Majority of the region's major cities are riverine or coastal, which have concentration of population, assets, economic & industrial development and infrastructures. Flooding in urban areas can be caused by urban water-logging, flash flood, riverine flooding, or storm surges. In this respect, rapid urban growth brings us not only the prosperities but also a series of challenges, in which the water-related issues, including the escalation of urban floods, the shortage of water supply and the aggravation of water pollution, have become essential problems in connection with sustainable development.

The increasing urban flood risk has urged all nations and international organizations to take measures to confront the threats caused by floods and to build flood resilient cities. The Urban Flood Risk Management (UFRM) project was formally launched during the 41st Session of the TC held in Chiang Mai, Thailand in 2009, as a cross-cutting one among three Working Groups of Meteorology, Hydrology and Disaster Risk Reduction (DRR). The goal of UFRM project is to exchange and share the experience on UFRM including technology of flood monitoring, forecasting, and warning; to enhance the capacity of urban flood management.

The Guidelines on UFRM for the Typhoon Committee Area were supposed to compile rules or instructions about the best way to manage urban flood risk in the Typhoon Committee Region. The target users will include technicians and decision-makers. This document seeks to: a) present a brief review of urban flood issues in the Typhoon Committee Area, and identify good practices and progress of urban flood risk management from the model cities study, b) propose a new framework of urban flood risk management, c) illustrate with technical methods and tools for urban flood risk management, with emphasis on the aspects of meteorology, hydrology and disaster risk reduction.

The draft manuscript of the UFRM Guidelines was made by Prof. LIU Zhiyu, Prof. CHENG Xiaotao, Dr. CHEN Zuhua, Dr. Wan Haotao and Ms. Zhou Li from China, Mr. Edwin ST Lai from Hong Kong of China, Mr. Masashi Kunitsugu from Japan, Dr. Yang-Su Kim, Dr. Tae Sung Cheong, Dr. Gunhui Chung from Republic of Korea, Dr. Susan P. Espineva from Philippines, and reviewed by Chen Charng Ning from Singapore.

Working Group on Hydrology
Vice Chair: Liu Zhiyu (on behalf of authors)
September 26, 2013

CHAPTER 1. INTRODUCTION

1.1 Background

The Asia Pacific region accounted for 91% of the world's total death and 49% of the world's total damage due to natural disasters in the last century. It was noted in recent years that there was significant increase in the intensity and/or frequency of many extreme events such as heat waves, tropical cyclones, prolonged dry spells, intense rainfall, tornadoes, thunderstorms, and severe dust storms in the region. The series of devastating flooding in Vietnam, Cambodia and Thailand in 2011, flashfloods/landslides in the Philippines from 2009 to 2012, etc. are manifestations that variability in the climate will pose a serious and additional threat in urban areas. Climate change is in fact emerging as the pre-eminent development issue in the region. Impacts of such disasters range from hunger and susceptibility to disease, to loss of income and human livelihoods.

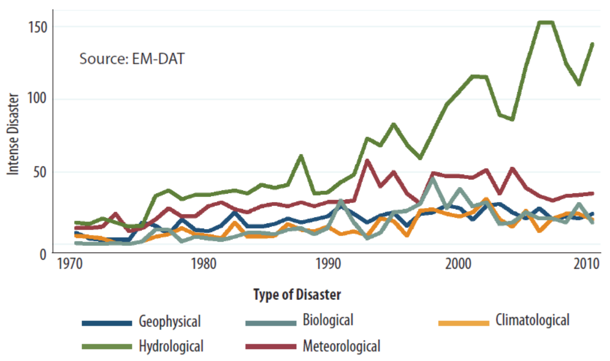


Fig. 1-1. Global frequency of intense natural disasters

Among the natural hazards classified as geophysical, hydro-meteorological, and biological by the Emergency Event Database (EM-DAT) established by the Centre for Research on the Epidemiology of Disasters (CRED), there was a 66 percent global increase of intense hydro-meteorological disasters of 1210 during 1991–2000 to 2004 during 2001–2010. The Asia and Pacific accounted for about two-thirds of the 1.6 million lives lost to intense natural disasters from 1991 to2000. Fig. 1-1 shows that global trends are largely due to the rise in intense hydro-meteorological disasters.

It was noted that the increasing impacts of hydro-meteorological-related hazards are being experienced in highly urban areas with unabated economic development.

It was noted that in 2008, the urban population of the world exceeded its rural population for the first time. Fig. 1-2 indicates the increase in urban population as the % of the global population over the last three decades. The significant rise is recorded in Latin America & the Caribbean the Middle East & North Africa, and East Asia and the Pacific.

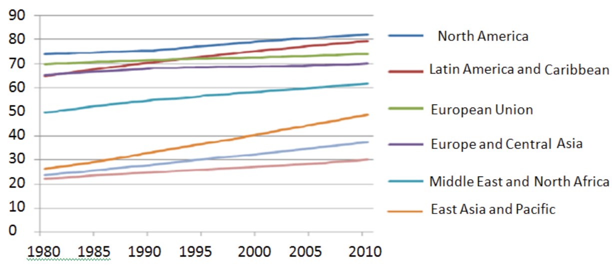
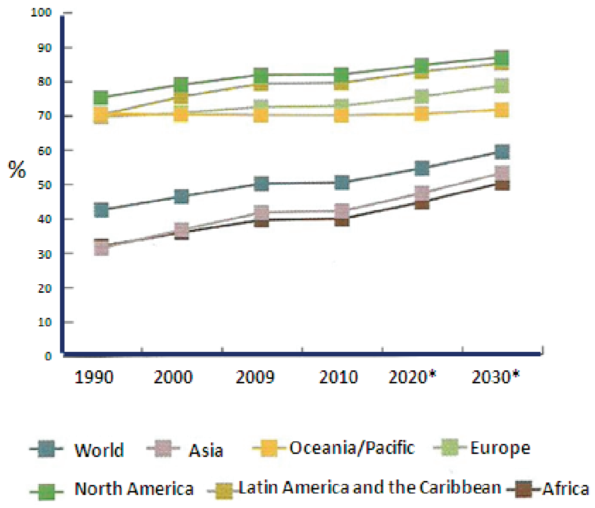


Fig. 1-2. Urban population as a % of total population, by region (Source: data from World Bank development indicators 2012)

Based on United Nations report, urbanization will grow from about 50 % of the world's population today to about 60 % by 2030 (Fig 1-3). Asia's urban population has grown from 31.5% of the total in 1990 to 42.2% in 2010. Based on the UN HABITAT report (2010), there is marked difference in urbanization patterns in the region. For instance in Asia, China and India's population alone account for 2.5 billion people equivalent to more than 37% of the world's total population (Fig. 1-4).

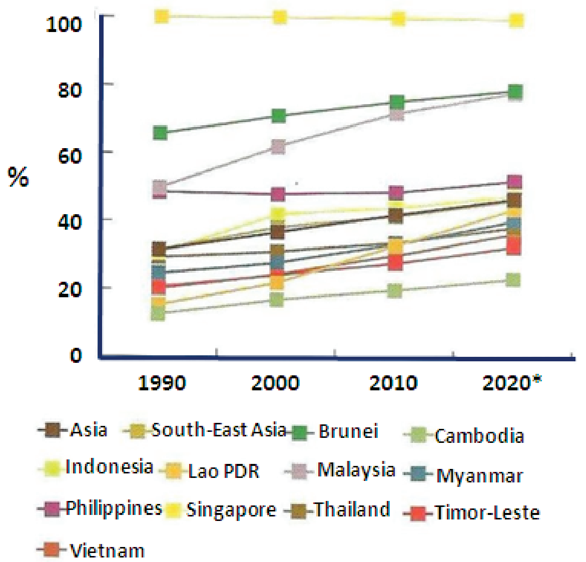
In the Asia-Pacific region, the urban population grew an average of 2.8% a year between 1990 and 2010 and is expected to increase by two-thirds over the next two decades (i.e., between 2010 and 2030), which implies that 53% of the world's urban population growth will occur in Asia, or an addition of 840 million annually, or a daily increase of 115,000 (United Nations, 2010). This setting will definitely pose considerable challenge to local and national governments.



*Projections
Source: United Nations (2010)

Fig. 1-3. Global urbanization rates, 1990 – 2030*

As compared to the global trend, Asia's overall urbanization rate is relatively low, however, cities have recorded rapid economic growth that contributed to national outputs. In Vietnam, 30% of the population lived in urban areas (2010) but contribute to 70% of the gross domestic product (GDP) while in China, 120 cities contribute as much as 75% of the country's economic production. In the Republic of Korea, Seoul produces about half of the country's wealth, while in the Philippines, the contribution of Metropolitan Manila and its surrounding areas is about 60% (World Bank, 2007).



* Projections
Note: The trend-lines for South-East Asia and Asia as a whole track each other very closely.
Source: United Nations (2010)

Fig. 1-4. Urbanization South-East Asia – Trends 1990-2020*

The urban areas in the Asia and the Pacific accounts for 80 % of the region's GDP (UNESCAP, 2011) and the cost of flooding is taking a toll on the GRDP (Gross Regional Domestic Product) of the cities in each country. It is against this backdrop that the TC saw the urgent need to come up with a framework to formulate and adapt feasible and tested management strategies to address the current issues on urban flood risk management.

1.2 Climate Variability and Change

The IPCC (Inter-government Panel of Climate Change) Fourth Assessment Report states that climate change will have adverse impact on people's health, safety and livelihoods, with the "poorest people in the poorest countries expected to suffer first and foremost". In particular, climate models indicate temperature will increase in the Asia Pacific region on the order of 0.5-2°C by 2030 and 1-7°C by 2070. Climate models indicate rising rainfall concentration throughout much of the region, including greater rainfall during the summer monsoon. Furthermore, winter rainfall is likely to decline in South and Southeast Asia, suggesting increased aridity from the winter monsoon. The region will be affected by an increase in global sea level of approximately 3-16 cm by 2030 and 7-50 cm by 2070 in conjunction with regional sea level variability. Other scientific studies have also indicated the potential for more intense tropical cyclones and changes in important modes of climate variability such as the El Niño-Southern Oscillation.

The latest study on daily precipitation time series obtained from a global dataset of 8326 land-based observing stations shows that statistically significant increasing trends can be detected at the global scale, and there is a statistically significant association with globally averaged near-surface temperature, with the median intensity of extreme precipitation changing in proportion with changes in global mean temperature at a rate of between 5.9% and 7.7% K−1 (Westra et al. ,2013).

According to the IPCC special report on managing the risks of extreme events and disasters to advance climate change adaptation in 2012 (IPCC, 2012) , it is likely that the frequency of heavy precipitation or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe. This is particularly the case in the high latitudes and tropical regions, and in winter in the northern mid-latitudes. For example, based on a range of emissions scenarios (B1, A1B, A2), a 1-in-20 year annual maximum daily precipitation amount is likely to become a 1-in-5 to 1-in-15 year event by the end of the 21st century in many regions. Heavy rainfalls associated with tropical cyclones are likely to increase with continued warming. There is medium confidence that, in some regions, increases in heavy precipitation will occur despite projected decreases in total precipitation in those regions.

In a separate study and adopting the IPCC high emission scenario, the ADB (Asian Development Bank)-JICA(Japan International Cooperation Agency)-WB (World Bank) study (2010) estimated that for a 1-in-30-year flood, the cost of flood damage in Bangkok is approximately 2% of the GRDP (THB 49 billion or $1.5 billion) and 6% of GRDP of Metro Manila (PHP 30 billion or $0.65 billion).

Urban settlements in the Typhoon Committee Area (TCA) are now experiencing the impacts of climate change and will continue to be threatened due to their size, location and elevation. The threat of sea level rise due to climate change will inundate the urban areas in deltas and coastal plains. The Southeast Asia has high concentration of population and economic activity in coastal areas. For instance, 29.4% of the total urban area in Southeast Asia (SEA) is 10 meters or below in elevation from the coast to about 100 km. This area provides abode for 12.3% of the total population and 36% of the total urban population (CIESIN, 2006). A major challenge will be the relocation of informal settlers from the plains to safer but maybe less attractive due to limited opportunities for urban settlers.

1.3 Background of the UFRM Project

The Pacific is one of the main spawning grounds of tropical cyclones, typhoons or hurricanes, rotary wind systems with speeds in excess of 64 knots (1 knot=0.5144 m/s). The North Western Pacific Ocean is the most active basin that accounts for one-third of all tropical cyclone activities in the world. Tropical storms developing in this region frequently affect China, Japan, the Philippines, as well as many other countries in East or Southeast Asia, such as Vietnam, South Korea and Indonesia, plus numerous Oceania islands.

The Typhoon Committee (TC) is composed of 14 Members with very diverse culture, economic setting and urban development.

The TC Members experience the brunt of the tropical cyclones occurring in the North Western Pacific basin where about 30% of the tropical cyclones in the world developed. This unique set-up and the trans-boundary nature of weather disturbances affecting the region make the Typhoon Committee the most successful program of the UNESCAP and WMO.

The TCA is urbanizing rapidly with the increasing trend of population and economic growth. Fast urban development has also brought many potential troubles, and urban flooding is one of the most serious. Many aspects of urban areas are vulnerable to flood disasters and climate change. How to minimize losses caused by urban floods and harmonize relationship between floods and socio-economic development has been a significant problem that governments and international organizations work on. In recent years, risk management ideas have been introduced into flood management in the TCA. During the forty-first session of the Typhoon Committee held in Chiang Mai, Thailand in 2009, the project on Urban Flood Risk Management (UFRM) led by China was formally launched as a cross-cutting one among Working Groups on Meteorology, Hydrology and Disaster Risk Reduction of the committee. The goal of the project is to exchange and share the experience on urban flood management among the TC members including technology of urban flood monitoring, forecasting, and warning; to enhance the capacity of urban flood management in the TC Members. The expected outcome of the project is to prepare guidelines on flood management for urban planning and development in the TCA.

The kick-off activities of the project were to study on the emerging urban flood issues and current status of urban flood management in the TC region and survey to selected model cities of China, Japan and Republic of Korea for collecting the good practices on urban flood risk management (Fig. 1-5). Among the model cities, the Shanghai Typhoon Institute and Shanghai Climate Center introduced the Shanghai Multi-Hazard Early Warning System (Appendix A).

Fig.1-5 Location of UFRM model cities

Fig.1-6 Location of UFRM pilot cities

The pilot cities include 5 cities in 5 countries of the TCA, namely: Guangzhou, China; Kuala Lumpur, Malaysia; Metro Manila, Philippines; Hat Yai, Thailand and Hanoi, Vietnam (Fig. 1-6). Each pilot city consider flooding as the most recurrent and destructive natural disaster.

For instance, in September 2009, the interaction of the Southwest monsoon with Typhoon Ketsana generated 455 millimeters of rainfall in less than 24 hours that inundated more than 80% of the Manila Metropolitan area with flood heights reaching nearly 7 meters and affected 280,000 – 300,000 people (ADB, 2010). The toll on casualties of 464 in Metro Manila was heavy for a flood that lasted only for about 10 hours. Typhoon Ketsana also registered substantial flood damages in Vietnam, Cambodia and Lao PDR. To improve its UFRM, the Philippines need to assess and integrate all existing and on-going initiatives (after Ketsana) for an effective implementation of UFRM. Among its urgent needs is the application of telemetering data in rainfall forecasting and training on QPE (Quantitative Precipitation Estimation)/QPF (Quantitative Precipitation Forecast) as well as inundation mapping.

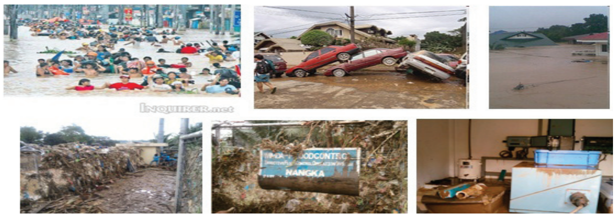


Fig.1-7 Impacts of flooding in Metro Manila

After the big flood of 2010, Hai Yai needs to recover its Telemetry System in Utaphao River basin with more safety and reliable technology that include training on QPE/QPF and inundation mapping training.

Fig.1-8 Impacts of flooding in Hat Yai, Thailand

Difficulties and challenges for Hanoi inundation forecasting result from the absence of real-time monitoring system of meteorological and hydrological parameters. Radar for Hanoi area is not yet sufficient for rainfall detection and for now-casting and quantity input to hydrologic and hydraulic models. High resolution base maps for inundation mapping are not yet available while numerical rainfall forecasting model with high resolution up to 1km is an urgent requirement for real time inundation forecasting in

Hanoi. To address its urban flood problems, the government is implementing a project: Building technology in urban flood & inundation forecasting to be applied for operational early warning system in Hanoi, Vietnam. The project components include: flood risk assessment, using a combination of 1D and 2D modeling; operational flood forecasting system, using current rainfall data and a dynamic 1D model to simulate the short-term flow patterns and flood risks; and the generation of flood risk maps to validate the operational flood forecast system as part of the implementation.

Fig.1-10 Impacts of flooding in Hanoi, Vietnam

In May 2007, Guangzhou, China experienced an average of more than 100 mm of rainfall resulting in 118 water-logging in the city. More than 30 underground garages and a large number of cars were flooded, some places' water depth reached a height of 3 meters. Economic losses were estimated at more than 1 billion RMB Ruan. In its efforts to address urban flooding, Guangzhou City increased its waterlogged level stations in 2012 from 10 to 20 stations. It also planned to carry out coupling model research of radar rainfall measurement and water dynamic, developing the warning system based on GIS. Initial results have already been achieved in Foshan City. Currently, Guangzhou has built more than 300 rainfall stations, more than 4000 video monitoring stations and 16 level stations.

Fig. 1-8 Impacts of flooding in Guangzhou, China

Although the pilot cities have started some initiatives on UFRM, they need to consider the following to really improve their flood risk management activities:

- To establish the comprehensive urban flood management strategy;
- To highlight the land use planning;
- To enhance meteo-hydrological monitoring, forecasting and warning to provide timely, accurate and all-sided information support to the urban flood management;
- To apply flood hazard/risk map widely as an important technique of urban flood preparedness;
- To emphasize on the function of retarding basins and discharge ponds in the urban flood management;
- To build up various dissemination ways of flood warning information to individual residents.

Existing policies on flood management evolved from reactive responses to flood disasters are generally based on knowledge of past weather events. However, in the last couple of years, the prevalence of extreme weather events resulted to unprecedented magnitude of flooding. The attribution to climate change and variability has set the trend to shift flood protection to integrated risk management approach due to the considerable cost of damage particularly in urban areas where people and infrastructures are concentrated.

The Guidelines is expected to reflect the requirement and features of TC region and focus on the technical guidance on UFRM for TC Members so that it could be readily differentiated from existing generic guidelines or handbooks on urban flood management. It highlight the best practices of model cities on urban flood risk management that are currently in place in Shanghai City in China, Yokohama City in Japan and Ansung City in South Korea. These best practices will be adopted or replicated in the five (5) pilot cities: Metro Manila in Philippines, Hat Yai City in Thailand, Hanoi City in Vietnam, Guangzhou in China and Kuala Lumpur in Malaysia.

1.4 Organization of the Report - UFRM Guidelines

The increasing uncertainty in the weather patterns due to climate change would require tested programs and strategies that can be applied in the planning, design and management of interventions of flood mitigation measures as well as policy adoptions in megacities and/or emerging urban centers in the TCA. The guidelines will also present the advanced scientific knowledge on early warning system, decision support system to increase flood resilience of urban systems.

The UFRM Guidelines present a number of concepts that have already been tested, adapted and proven to be useful in the model cities. Focus is made mostly on non-structural measures, particularly on forecasting, monitoring and delivery of effective early warning system considering the urbanization component, as follows:

- features of urban floods, and efforts to reduce flood risk in urban areas;
- Comprehensive capacity building in urban flood risk management;
- Meteorological Monitoring, Forecasting and warning procedures for UFRM;
- Information sharing and delivery;
- Flood inundation mapping;
- Flood forecasting (RR-RO models, statistical models, automated flood warning system (AFWS), flash flood warning;
- GIS based urban flood risk management system (integrated info analysis, simulation for disaster risk management, GIS spatial analysis and visualization, planning games);
- Flood management measures (structural measures, non-structural measures, urban flood management measures);
- Alternatives for flood risk management measures (ALARP principle, ROBUST strategy);
- Implementation of flood risk management measures (institutions, financing, maintenance);
- Flood risks change along with urbanization;
- Characteristics to be considered in urban flood risk analysis (medium and small cities, large cities);
- Procedures of urban flood damage analysis (features of urban flood damages, limitations of urban flood damage analysis, method of urban flood damage analysis);
- Decision Support System for UFRM - GeoLinking System (GLS);
- Training and research I support of UFRM;
- Gaps in TCA;
- General training resources for capacity building;
- Training strategies under TC (existing resources under Training and Research Coordination Group (TRCG), initiatives in support of UFRM).

CHAPTER 2. FRAMEWORK OF URBAN FLOOD RISK MANAGEMENT

People living in the typhoon prone countries in the Asia-Pacific region have to live with floods in the long history and have accumulated rich experiences fighting against them. However, the features of the catastrophic floods have changed dramatically in recent decades, due to the large scale development in river basins, rapid urbanization and the global warming (WMO & GWP, 2008). We have to face more complicated situations and more unpredictable factors in flood control and disaster mitigation. It is impossible to cope with the increasing urban flood damages and adverse impacts only by experiences and traditional measures. That is why we should establish a new framework of urban flood management, including concepts of flood risks, integrated structural and non-structural measures, as well as comprehensive capacity building.

2.1 Varying Features of Urban Floods

Rapid urban growth brings us not only the prosperities but also a series of challenges, in which the water-related issues, including the escalation of water hazards, the shortage of water supply and the aggravation of water pollution, have become essential problems in connection with sustainable development. Floods are common phenomena in water cycle over the world. Different type and scale of cities located in mountain, hill or plain areas, and along rivers, lakes and coastal zone, face different kinds of floods or their combination, such as fluvial flood, pluvial flood, flash flood, high tide and storm surge, as well as snowmelt flood and ice flood, etc., which are affected by both natural and human factors as shown in Table 2-1.

Table 2-1 Factors contributing to flooding (WMO & GWP, 2008)

Meteorological Factors	Hydrological Factors	Human Factors Aggravating Natural Flood Hazards
• Rainfall • Cyclonic storms • Small-scale storms • Temperature • Snowfall and snowmelt	• Soil moisture level • Groundwater level prior to storm • Natural surface infiltration rate • Presence of impervious cover • Channel cross-sectional shape and roughness • Presence or absence of over bank flow, channel network • Synchronization of run-offs from various parts of watershed • High tide impeding drainage	• Land-use changes (e.g. surface sealing due to urbanization, deforestation) increase run-off and may be sedimentation • Occupation of the flood plain obstructing flows • Inefficiency or non-maintenance of infrastructure • Too efficient drainage of upstream areas increases flood peaks • Climate change affects magnitude and frequency of precipitations and floods • Urban microclimate may enforce precipitation events

Urban floods are a growing issue of concern for both developed and developing nations (TWB & GFDRR, 2012), particularly for the residents of the rapidly expanding towns and cities in developing countries today. The harmfulness of floods may be aggravated along with urbanization. Normally, the modes of producing and living in the Asia-Pacific region are adapted to the flood seasons. As floods coming too early, too late, too large or too small, it becomes a kind of water hazard. When the cities in the catchment areas develop to a certain scale, the features of flood disasters in the urbanized areas may be varied obviously. The differences between the urban type and rural type of flood disasters are shown in Table 2-2(Cheng Xiaotao, 2005).

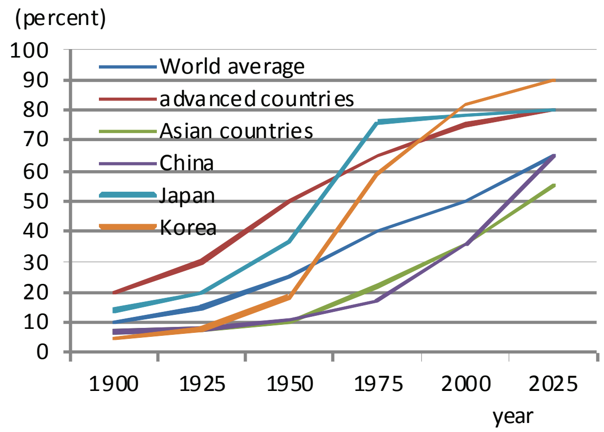
Table 2-2 Comparison of flood disaster features between modern urban type and traditional rural type

Classification	Traditional Rural Type	Modern Urban Type
Causes	Mainly by natural factors	Man-made factors increased, even become the dominant ones
Types	Fluvial flooding, storm surge, rainstorm, levee-breach flood, waterlogging	Increase of man-made floods, such as, dam-breach flood, accidents of burst of the water supply conduits
Affected area	Mainly limited in the inundated area, larger but clear	The inundated area may be decreased, but the affected area become uncertain, maybe much larger than the flooded areas
Affected Probability	Floods with different return periods may form different flooding areas	Odds of big flood still exist, the flooding possibility in suburban district may be increased, pluvial flooding occur more frequently
Affected objects	Floodplain, farmlands, villages, towns and cities	Upper reservoir area, newly urbanized area, underground spaces such as subway and basements
Time	During the flood season with certain periodicity	Maybe advanced or deferred artificially; the failure or interruption of water supply system may occur at any time
Duration	Related to area, duration of the rainfall and geographic features	Maybe prolonged or shortened artificially
Damage species	Mainly in crops, farmhouses, farm tools, and casualties of life	Assets of industry and commerce, public facilities, family properties, urban infrastructures of lifeline system, indirect losses increased
Influences	Causing famine, plague, larger casualties, poverty, transport interruption, severely affected area may be recovered in several years	with duplex effects to enlarge or to reduce the disaster, the total damage increased, the affected area much more exceed the flooded area, some losses may be unable to recuperate, but can be recovered rapidly
Flood control measures	Flood control system and regulated in lower level, flood proofing	Flood control and drainage system and regulated in higher level, flood proofing, storm flood storage in city
Disaster mitigation	Evacuation, victims have to bear the damages themselves	Disaster forecasting and warning system, social safeguard system consummated gradually

Since the land use conditions have been changed greatly by human activities, the rainfall-runoff correlations in many river basins have been transformed. Not only the impermeable surface increased in urbanized areas, but also decline of forestation coefficient, the aggravation of soil erosions, and the rapid disappearance of wetlands in catchment areas，which are all the consequences caused mainly by human activities, have created new influences on flood control situations during urbanization process. However, the conservancy and restoration of environments are restricted due to the survival pressure and the lack of necessary investments especially in the developing countries.

2.2 Increasing Flood Risk on the Process of

Comparatively speaking, urbanization levels for most Asian countries are far lower than those countries in Europe and America, referred to Fig. 1-2. Even in East and Southeast Asia, the urbanization process is not synchronized. For examples, Japan entered high-speed development in 1950s, and South Korea speeded up in 1970s, and then the coastal region of China in 1990s, with more experiences in coping with the growing risk of urban floods. Today, the urban population rate in many developing countries in Asia, including China, are in between 30% to 60%, which is the most dramatic urbanization stage as



shown in Fig. 2-1.

Fig. 2-1 Urban population growth rate

During the rapid process of urbanization, there are not only more and more people and assets gathering in cities and towns, but also more risks being accumulated. Potential flood damages and the relevant impacts are major risks in the urbanized areas of the typhoon prone countries. A series of changes happen in each phase involved in flood risk analysis as shown in Fig. 2-2 and Table 2-3 (Cheng Xiaotao, 2006). For different cities in different stages of development, such changes can be further identified in some extent.

Table 2-3 Changes happening along with urbanization

Aspects	Some Changes for Example
Weather condition	Intense tropical cyclones occur more frequently with global climate changing
Rainfall distribution	Heavy rains occur more frequently in mega cities due to the “heat island effect”
Flood routing	Peak discharges increase due to deforestation, enhanced drainage capacity in upstream areas, and enlarged runoff coefficient in urbanized areas.
Flooding process	Inundated areas and duration, distribution of water depth and flow velocity may be better or worse due to land-use changes, ground subsidence, and the development of flood control system and other infrastructures.
Flood damage	May be reduced within the flood control capacities, but increase sharply once beyond. The direct losses increase in quantity and type, and indirect losses could be even more than direct losses because of the worse vulnerability.
Disaster impacts	More significant influence on government prestige, social stability, economic development, environment protection, and ecosystem restoration and so on.

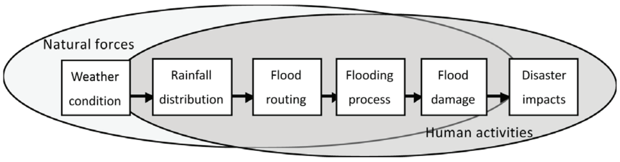


Fig. 2-2 Main aspects involved in flood risk analysis

Although Asian people know the features of flood hazards in aspects of hydrology, hydraulics and sediment transportation, and nowadays of pollutant transportation & diffusion within flooding flow, and we know well about the flood damages such as direct losses and indirect losses, but the concept of "flood risk" is a new one with various understandings. Today, we realized that it is necessary to accept the concept of risk because we have to consider how to cope with the possibility of flood losses (a kind of definition of flood risk) under the varying circumstances particularly during the rapid process of urbanization, and we have to consider how to convert the adverse impacts into beneficial ones through the establishment of advanced flood management system combining structural and non-structural measures (See Fig. 2-3). In fact, during the rapid process of urbanization, flood risks often involve the flood related interests that exist objectively in between man and nature and among related regions. The significance of flood risk analysis and assessment is to find a more reasonable way and to grasp a moderate degree in flood management for harmonious and sustainable development.

2.3 Effective Strategies to cope with Flood Risk in Urban Areas

The framework of flood risk management strategies can be established on the base of a commonly-accepted risk triangle concept (Crichton, D. 1999), by which the flood risk is defined as a function of the flood hazard, of exposure to the flood hazard, and of the vulnerability of receptors to the flood hazard. Accordingly, the effective strategies for coping with flood risk in urban areas can be classified into three aspects: flood control and defense, preparedness and adaptation and increasing resilience, and to do these well we have to enhance our capacity building comprehensively (See Fig. 2-4).

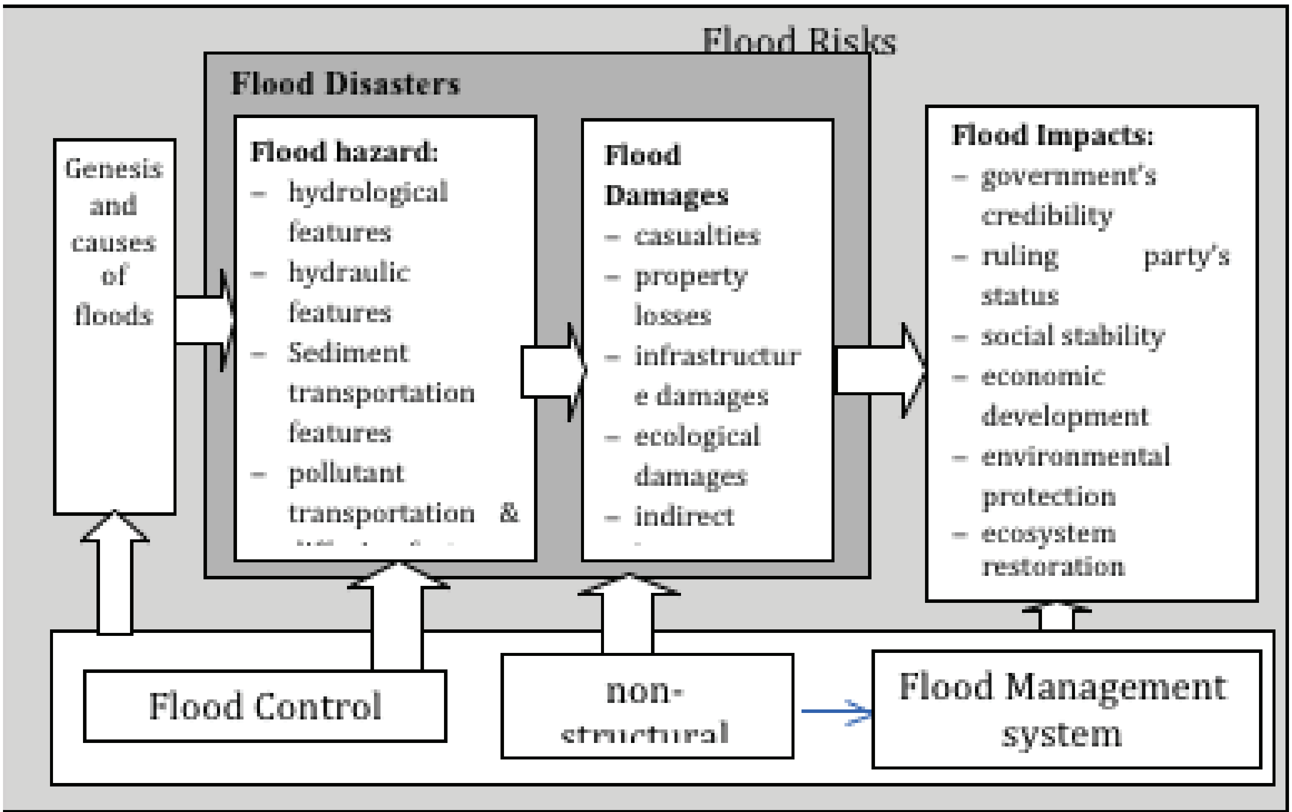


Fig. 2-3 The scope involved in flood risk and flood management system

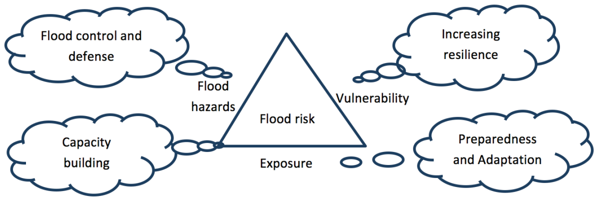


Fig. 2-4 Coping strategies for urban flood risk management

Flood hazard involves the features of flooding events: the inundated areas, the distribution of water depth, velocity and duration of flooding at certain return periods. The corresponding flood control and defense strategy to deal with flood hazards is based on the comprehensive structural measures to cut down and delay flood peaks, to limit the inundated areas and reduce the destructive effects of flooding. The urban areas are always the focus protected by the flood control system at catchment scale, especially during the flood defense. While at the city scale, structural measures are used to control the flow of water both outside and within urban settlements, including what are traditionally viewed as structural hard-engineered solutions, such as drainage channels, as well as more natural and sustainable complementary or alternative measures, such as wetlands and natural buffers (Abhas K Jha et al, 2011).

Exposure to flood hazard describes the external characteristics of receptors: the distribution of residents, type and amount of assets and infrastructures, as well as ecosystems involving in the flooded areas. The relevant strategy for preparedness and adaptation is taken to protect receptors exposed in flooding from damage or to reduce flood losses to acceptable limit relaying on both structural and non-structural measures. The former in this case is designed at community and building scales, such as local flood wall, rainwater storage and infiltration, drainage pump, as well as elevated building and flood proofing in buildings or of infrastructures. The latter is prepared for emergency response, such as flood forecast and early warning, evacuation, rescue and land use management, and so on (Ivan Andjelkovic, 2001).
Vulnerability of receptors to flooding describes the inner properties of receptors: the degree to which a system (in this case, people or assets) is susceptible to or unable to cope with the adverse effects of flood hazard. Vulnerability to flooding is particularly increased where inappropriate, or inadequately maintained infrastructure, low-quality shelters, and lower resilience of the urban poor intertwine (World Bank, 2008). The corresponding strategy for increasing resilience is taken to enhance the flood risk-bearing and quick recovery capacities of the system mainly relaying on non-structural measure, such as flood awareness campaigns, flood insurance, risk financing, compensation and tax relief, flood recovery and reconstruction, and so on.
In order to restrain the flood risk increasing with the urbanization, a key task is how to enhance capacity building in implementing the above mentioned strategies. Comprehensive capacities in promoting urban flood risk management include hard capacities in reducing risk by structural measures and in emergency response, and soft capacities in risk foresight, adapting, sharing and enduring aspects by administrative, economic and technical means, and further the social management and law enforcement capacities to avoid man-made risk, as shown in Fig. 2-5 (Cheng Xiaotao, 2009).

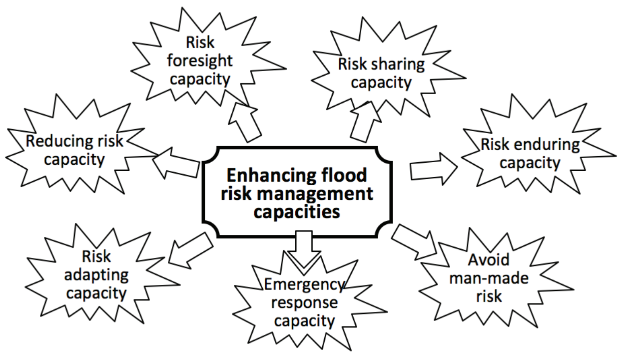


Fig. 2-5 Enhancing risk management capacity building in UFRM

2.4 Integrated Urban Flood Risk Management

Integrated urban flood risk management is a multi-disciplinary and multi-sectoral intervention that falls under the responsibility of diverse government and non-government bodies. Flood risk management measures need to be comprehensive, locally specific, integrated, and balanced across all involved sectors (Abhas K

Jha et al, 2011).

The flood risk is manageable because floods present not only a hazard which involves both natural and social attributes of flood disaster, but also opportunities and benefits for natural resource and the environment, and there are complicated relations of mutual conversion between benefits and damages. Flood management is to strive for the most favorable possibility through effective improving and operating all related flood prevention and mitigation systems under a series of uncertainties (See Fig. 2-6). Consequently, flood management does not strive to eliminate flood risks but to mitigate them. This may be achieved either by reducing flood risks to an acceptable level or by retaining, sharing or transferring flood risks through respective measures. These measures should form part of an integrated risk management process (WMO & GWP, 2008). It is the essentials of flood risk management to modulate the flood risks-related interests among communities and between man and nature by means of integrated measures of legislation, administration, economics, techniques, education, and engineering, which plays more important role in the process of rapid urbanization.

In order to ensure the effectiveness in promoting the integrated urban flood risk management, the following factors (involved in political, social, economic, ecological, natural, engineering system, science and technology, etc.) are considered:

- Objects: for different types of cities, there are differences in geographical environment (climates, surface and underground, and mountains, hills, estuary and coastal zone, rivers, lakes and wetland), hazard- formative factors (flood types and the possible magnitude and scope of influence, maximum
- depth distribution, duration, etc. with different return period), a hazard-affected body, (receptor, vulnerability) and disaster prevention capacities.
- Scales: time scales (from hours, days, months to years) and spatial scales (river basin, city,

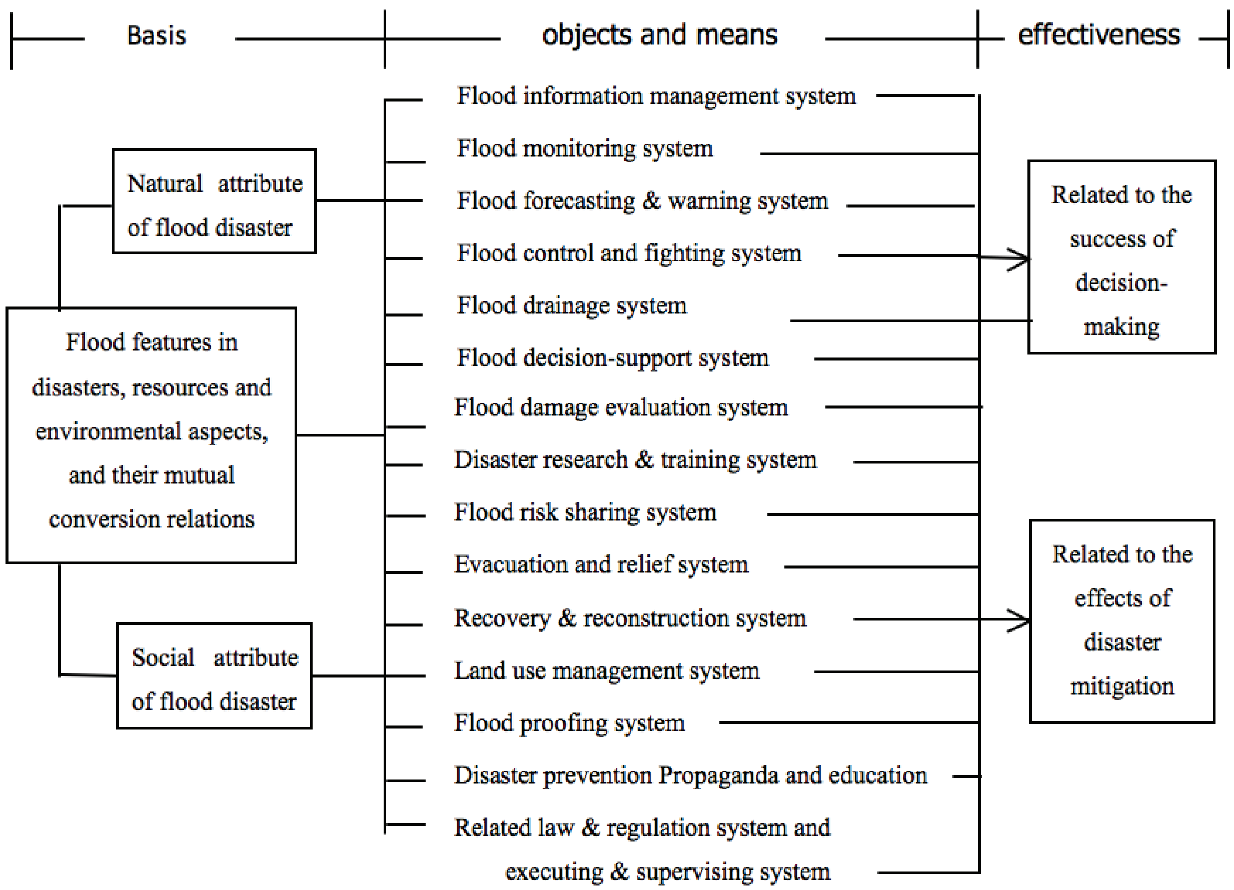


Fig. 2-6 Manageability of the flood risks, feasible means and effectiveness

district, community, etc.).

- Levels: governments at all levels, the publics and NGO (rights and interests, management system, joint management mechanism, etc.)
- Government departments: authorities of water, weather, civil, urban planning and construction, public utilities, public finance, power supply, housing administration, public health and gardens, etc. (responsibility, planning, operation, and stakes among them)
- Stage: even for a certain region in different stages of social and economic development, there are obvious changes in water management demands, economic power, technical capacities, managerial level, operation mechanism and human resources, etc.
- Zoning: Different sub-regions in a river basin or city play different roles in flood management system with different flood risks. The proper land use pattern, the way and standard of flood protection should be determined separately.
- Values and cognitions: pursuing what kind of goals and choosing what kind of approaches, depends on the decision maker's values and cognitions in a large measure, such as avoiding risk or bearing the risk.
- Stakes: regional conflicts of flood related interests objectively exist between upper and lower reaches, left and right banks, main stream and tributaries, as well as urban and rural areas, which should be considered for the harmonious implementation of UFRM.
- Science and technology: available means in planning, design, construction, maintenance, operation of flood control system, as well as decision support in emergency response, are largely depends upon the level of science and technology.
- Regional development activities: Human development activities in a river basin, even beyond the municipal limits, have significant impacts on urban flood management. For instance, deforestation and mining in upper mountain areas may increase soil erosion and peak discharge, and decrease the flood-carrying capacity of the river channel; road and railway construction may affect the intensity and distribution of flooding area.

Local governments in Asia face the common challenge of securing their locality's social, political and economic future against disaster (USAID & ADPC, 2010). It is a gradual process to shift from flood control to flood management, implying the adjustment and improvement of conceptual frameworks, administration systems and operating mechanisms. We should select a flood management approach based on the risk of flooding in relation to the local conditions.

CHAPTER 3. METEOROLOGICAL MONITORING AND RAINFALL FORECASTING

3.1 Forecasting, Monitoring, Analyzing and Warning Procedures for UFRM

In this section, weather information including weather warnings/advisories issued for disaster risk reduction (DRR) is reviewed from the view point of forecasting procedures to be taken by meteorological authorities. Weather information for urban flood areas to appropriately support DRR activities (e.g. evacuation instruction) should be provided with sufficient lead time and higher resolution in space and time. Therefore, weather information for the urban areas should be issued objectively based on the automatic quantitative analysis and prediction. Forecasters working on weather Decision Support System (DSS) should be able to select suitable values among various kinds of objective analysis and prediction products, and to monitor real-time weather situation continuously. Utilizing observed and analyzed data, forecasters could modify or confirm their previous forecast scenario to adjust to the real weather situation in the area. To make it convenient for forecasters to forecast, monitor and issue warnings, DSS should automatically produce weather information including warnings/advisories, alerting forecasters to the fact that forecasting values, such as rainfall amount, exceeds the criteria of warnings/advisories for the targeted area. Provided the DSS alerts forecasters to issuing warnings/advisories, forecasters should check the validity of warnings/advisories produced by the system and then decide to issue information.

To facilitate DRR activities in emergency situations such as torrential rainfall and storm surges, sufficient lead time from issuance of warnings to occurrence of disasters should be ensured. For a smooth operation to issue warnings, "weather forecasting scenario (scenario)" should be developed. Scenario includes a time sequential forecast, and should explain past, current and future weather situation theoretically. Validity of the scenarios is checked with key-points of weather phenomena in forecasting and warning/advisory procedures. According to the scenario, forecasters should select the most suitable forecast values from various products such as numerical weather prediction (NWP) outputs and Quantitative Precipitation Forecast (QPF), and modify the values based on monitored and analyzed weather situation. To do those procedures appropriately, forecasters are required to improve their skills and expertise to develop scenarios. Conceptual approaches from forecasting to warnings/advisories are:

To develop scenarios and to select/modify the most suitable forecast value with the various products to be input to DSS;

- To recognize increasing potential of hazardous phenomena such as torrential rainfall and storm surge by monitoring current weather situation;
- To issue warnings/advisories.

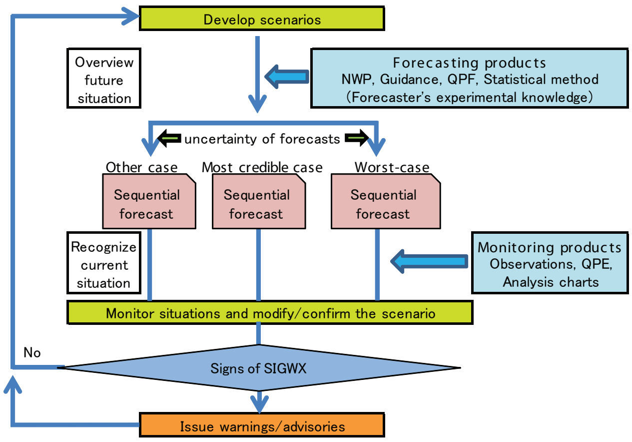


Fig. 3-1 Workflow of forecasting, monitoring, analyzing and warning procedures

Workflow of the forecasting, monitoring, analyzing and warning procedures on DSS is shown in Fig. 3-1. First of all, forecasters develop scenarios for a targeted area utilizing various types of available forecasting products, including NWP outputs, guidance as the application of NWP outputs, statistical methods based on forecaster's experimental knowledge and QPF, paying full attention to real atmospheric characteristics. Thus, those scenarios should reflect the most suitable weather phenomena for the targeted area, and should not be the simple and direct substitution of forecasting products.

For the effective and flexible forecasting procedures, multiple expected scenarios should be prepared and stored in DSS.

Consistency of the real weather situation with those scenarios should be monitored to ensure their validity. For appropriate and smooth determination to issue warnings/advisories with DSS, key-points to monitor the signs of significant weather (SIGWX) potential in the area should be preliminarily set. But monitoring of severe weather not expected in the scenario should also be carefully considered.

Observation and analysis data such as radar, surface observations and Quantitative Precipitation Estimation (QPE) are utilized for monitoring weather situation qualitatively or quantitatively, according to their accuracies and time/spatial resolution. As the weather situation varies, forecast values previously input to DSS should be replaced or modified based on the monitored observation and analysis data. For early response to hazardous weathers leading to disasters in urban areas, accuracy, time/special resolution and dissemination with enough lead time are critical for monitoring data.

warnings/advisories.

3.2 Products for Forecasting, Monitoring, Analyzing and Warning Procedures

In this section, various kinds of products utilized for the forecasting, monitoring, analyzing and warning procedures for UFRM are shown. Information on the products including the techniques introduced in the Good Practices and their data acquisition is described in Appendix B.

3.2.1 Meteorological Parameters for the Use of Forecasting Procedures

In forecasting procedures, products below are used for developing possible scenarios and making sequential forecasts for targeted areas according to each of the scenarios:

(1) NWP outputs such as rainfall amount, wind speed/direction, and storm surge in targeted areas can indicate possible areas of hazardous

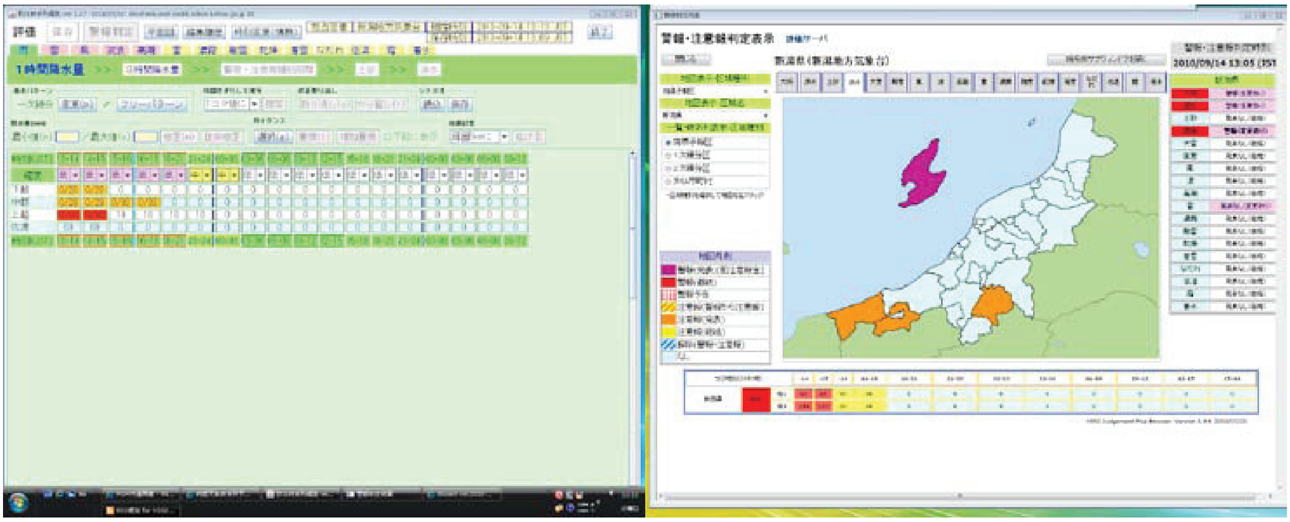


Fig. 3-2 Example of DSS for warning procedures. Editing monitor of the QPE/QPF time sequence and resulting warnings/ advisories alert (left). Proposed warnings/advisories for targeting areas by DSS (right)

In the warning procedures, DSS should facilitate monitoring of severe weather by providing useful information on warning/advisory determination and should automatically propose warning/ advisory of the targeted area as soon as forecast values exceed criteria for warnings/advisories (See Fig. 3-2). By modifying the forecast values, forecasters can reflect the real time situation to

weather. They are utilized to be input to DSS as a first guess of sequential forecasts, and are also available for the inputs to hydrological models. Some indices indicating atmospheric stability (Convective Available Potential Energy (CAPE), Showalter Stability Index (SSI), etc.) and weather forecast guidance are calculated with the NWP outputs. Weather maps drawn with NWP outputs are effective to understand and forecast atmospheric structures such as synoptic and meso-scale systems (tropical cyclone, upper trough/ridge, low level warm moist flow (potential temperature), vertical wind shear, shear line, meso-scale low pressure system caused by the heating of the ground surface, etc.). High resolution NWP models are especially used for short range forecast of localized severe weather such as heavy rainfall (Fig. 3-3). The NWP outputs also provide information on the meteorological fields indicating possibility and backgrounds of hazardous weather. The NWP forecast rainfall is utilized as the source to merge into the Quantitative Precipitation Forecast (QPF). Other forecast elements such as temperature and moisture are utilized to give the information on orographic effects to the QPF's extrapolation method.

(2) Typhoon track forecast is important for monitoring weather situation to be affected by tropical cyclones. Track of tropical cyclone significantly affects scenarios. For example, rainfall amount caused by orographic effects and the height of storm surge generally vary according to the movement (course and speed) of tropical cyclone and the location of the site, that is, whether the point is located on the right or left side of the center of tropical cyclone. Probability maps of strong wind distribution caused by tropical cyclones can provide useful information on the uncertainty of high winds and storm surge.

(3) Ensemble prediction system (EPS) will offer a variety of options for forecast scenarios. For example, accumulated rainfall amounts in the targeted area by the EPS's each track forecast will indicate the worst and the most credible case for sequential forecast. Consensus method applied to EPS will improve the accuracy of NWP results, such as tropical cyclone track forecast, especially for the long range forecast. Probabilistic products can be made using each member of EPS. Spreads of tropical cyclone tracks obtained from EPS can be the source to determine the probability circle of tropical cyclones.

(4) Weather forecast guidance, which is produced utilizing statistical method such as multiple regression, Kalman Filter and Neural Network applied to the NWP outputs, will improve the accuracy of NWP outputs such as precipitation by reducing their systematic errors. Weather forecast guidance will provide information on the maximum, probability and categorical values besides the elements directly calculated by NWP models, such as maximum precipitation forecast for a time period, heavy rain/thunderstorm probability forecast, and weather category forecast. Outputs of weather forecast guidance are the most reliable sources of time sequential forecast in DSS for the long forecast time (6 hours – several days).

(5) QPF is calculated up to 6 – 12 hours with high time/spatial resolution GPV format which is suitable for UFRM. The forecast precipitation of the extrapolation of the rainfall distribution derived from QPE and of the high resolution NWP model are blended considering their accuracies, because the accuracy of the extrapolation methods is relatively high in the short forecast range (say, up to 3 hours) but decreases rapidly as forecast time increases, while that of NWP is at first lower than that of the extrapolation but is relatively constant with the longer forecast time. The accuracy for the 3 or 4 hours QPF decreases to a critical level for the directly use in the issuance of warnings/advisories, therefore, modification process of the QPF's outputs on DSS by forecasters are usually required. Samples operated by the meteorological agencies are shown in Fig. 3-4, 3-5, 3-6, and 3-7. Satellite-based rainfall forecasts for tropical cyclones are derived utilizing observations of several microwave sensors. Ensemble and probability satellite-based precipitation products become available recently.

(6) A Storm surge model is calculated driven by the wind and pressure fields of NWP outputs, or of the simple parametric tropical cyclone structure model. Storm surge guidance assuming some cases of the tropical cyclone track with high resolution NWP models will provide various scenarios for the targeted area precisely.

3.2.2 Meteorological Parameters for the Use of Monitoring, Analyzing and Warning Procedures

The following products are used for monitoring procedures. Some products are also input to time sequential forecast (analysis) in DSS for the issuance of warnings/advisories:

(1) Surface observations at manned stations generally provide various elements such as surface pressure, temperature, humidity, wind direction, wind speed, precipitation, snow depth, snowfall amount, hours of sunlight, solar radiation, cloud, visibility and atmospheric phenomena. Most of the elements can be observed automatically in recent years. Though space and time resolutions of observation at manned stations are relatively sparse, above elements are fundamental for analysis of synoptic scale weather phenomena mainly recognized as the background causing severe weather in the targeted area.

(2) Automated weather stations (AWS) are installed to collect meteorological data automatically. Though it is difficult to catch the most intense storm areas, density of AWS network, e.g. 10-20km spatial resolution, enables to detect meso-scale weather phenomena leading to localized severe weather, such as shear lines and cold outflows from convective clouds, and a part of convective rain areas (Fig.3-3). It affects the accuracy of QPE through the calculation of the calibration factors or coefficients of Z-R (reflectivity – rainfall) relationship of radar equation. Integration of the raingauges operated by other organizations effectively and efficiently improves the accuracy of QPE.

(3) Upper-air observation by radiosonde and wind profiler can be used to overview the atmospheric structure causing heavy rain regarding atmospheric stability or low level warm moist flow, including some indices such as CAPE, SSI, Lifting Condensation Level at the observation points. Cross section charts to grasp synoptic atmospheric structures are drawn using upper observation network. Upper observation data are essential inputs to NWP models. GPS (Global Positioning System) precipitable water vapor can indicates the possibility of heavy rain. Aircraft observation, e.g. WMO Aircraft Meteorological Data Relay (AMDAR) and reconnaissance observation are used for monitoring of atmospheric situations and inputs to NWP models.

(4) Geostationary and polar orbital satellite observations are used to monitor and analyze synoptic/meso scale weather phenomena such as low pressure/frontal systems, tropical cyclones and CB clusters. Cloud patterns causing heavy rain such as Meso-scale Convective Complex (MCC) including extensive CB clusters are continuously and carefully monitored. Satellite images with short observation time intervals (10 minutes) and high spatial resolution have possibility to detect the generation of convective clouds leading to heavy rain. Satellite products such as Satellite-Derived Atmospheric Motion Vector (AMV) and equivalent black body temperature (TBB) by geostationary satellite (Clear Sky Radiation), microwave imager, microwave/ IR sounder, microwave scattorometer wind products and GPS occultation data are used for the NWP model analysis.

(5) Radar observation (echo intensity, echo top and Doppler wind) is important to monitor abrupt disasters such as flush flood, because its observation time interval is shorter than that of QPE (Fig. 3-3). Observed echo intensities are mainly used qualitatively. Observation time interval is generally a few minutes according to the number of scanning elevations for a volume scan to make CAPPI (Constant Altitude Plan Position Indicator). Echo intensification, generation, patterns (line, CB cluster, etc.), movement and continuation and the height of echo top are monitored. Upper level echo appearance and some indices induced by the volume scan such as Vertical Integrated Liquid Water content (VIL) are effective for the early identification of severe convective precipitations. Precipitation nowcasting up to 1-2 hours using extrapolation of echo intensity is useful for early heavy rain warning. Radar data (intensity and Doppler wind) are also utilized for the analysis of NWP models.

(6) QPE is the most reliable method to derive quantitative rainfall distributions in GPV format,

for the issuance of warnings/advisories as a direct input to DSS. It is made by integrating surface observations and remote sensing observations such as radar and satellite considering the pros and cons of both observations. Remote sensing observations cover large detective ranges with higher spatial resolution compared to the raingauge networks. As remote sensing observations measure the amount of rain overhead, they are usually different from precipitation observed on the ground. On the other hand, raingauge generally measures actual amounts of precipitation though it observes precipitation at points. To produce radar-derived QPE, two procedures are mainly used among Members. One adopts calibration factors calculated comparing precipitation observed by raingauges and radars, considering radar beam height and neighboring radars. The other uses Z-R relationship with coefficients varying dynamically comparing precipitation observed by raingauges and a radar. In the process of issuing warnings/advisories, anomalous values of QPE shall be rejected considering the characteristics of the products in the area, e.g. radar intensity affected by ground clutters and bright bands. Utilizing satellite-based precipitation observations in place of ground-based observations are useful for the regions where radars and raingauges are not sufficiently installed and in the sea. Satellite precipitation data are derived by Precipitation Radar (PR) with quality, microwave sensors and the Visible and Infrared Scanner (VIRS), though their time/spatial resolution and dissemination time should be considered in the case of the immediate use such as flash floods. Samples of PR/VIRS and microwave sensors are shown in Fig. 3-8.

(7) Synoptic weather maps including wave distribution map are used for overview of atmospheric structure. Recently, weather maps using surface and upper observation data are drawn automatically by NWP's analysis at first and modified by forecasters on man-machine systems. Localized weather maps using AWS data are effective to analyze meso-scale weather phenomena which cause severe weather.

(8) NWP model assimilation methods are used to grasp the current atmospheric structure including the input to calculate some indices of hazardous weather as the application of NWP forecasts. Wind distributions derived from the analysis are utilized for storm surge model and wind distribution maps.

(9) Hydrological indices such as Soil Water Index and Runoff Index are useful time sequential data for forecasters to issue warnings/advisories. Because precipitation data (QPE/QPF) alone do not provide enough information on the sediment-related and flood disasters. Those indices calculated with hydrological models such as tank models with the inputs of time/spatial high resolution QPE/QPF (e.g. 10 minutes/1 km) are closely linked to the amount of soil moisture and water flow which indicate disasters in the specified targeting area.

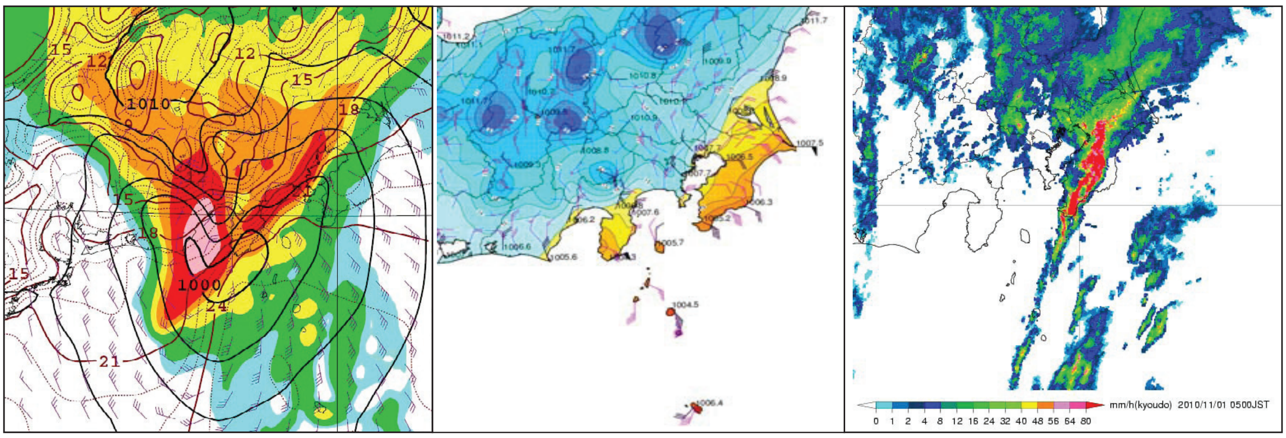


Fig. 3-3 Sample of NWP (left), AWS (middle) and radar intensity (right)

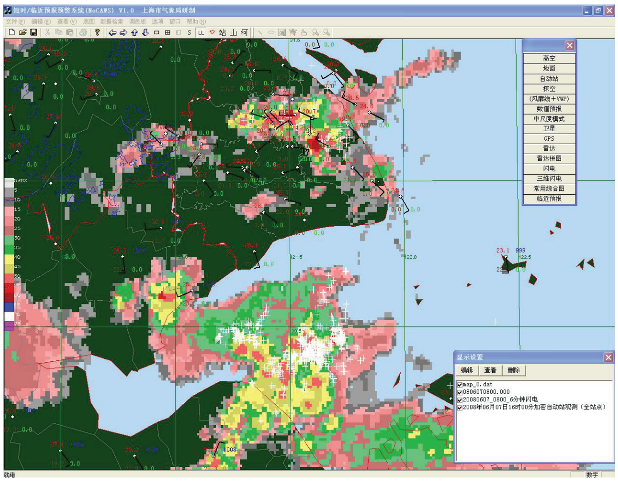


Fig. 3-4 Sample of nowcasting system by CMA

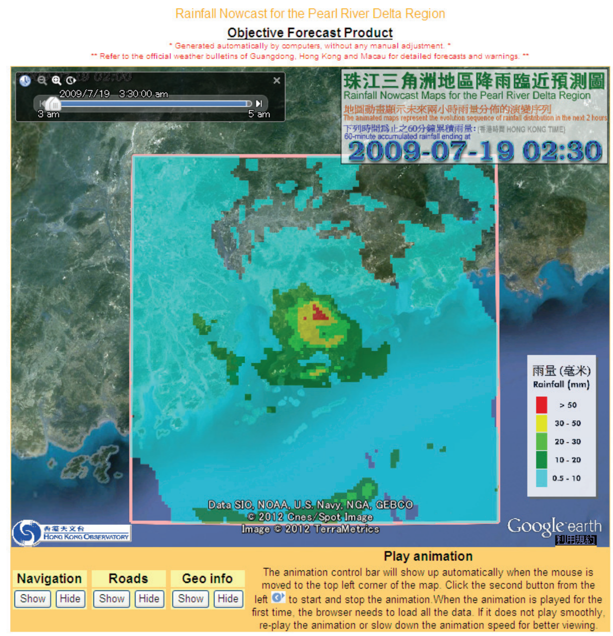


Fig. 3-5 Sample of SWIRLS by HKO

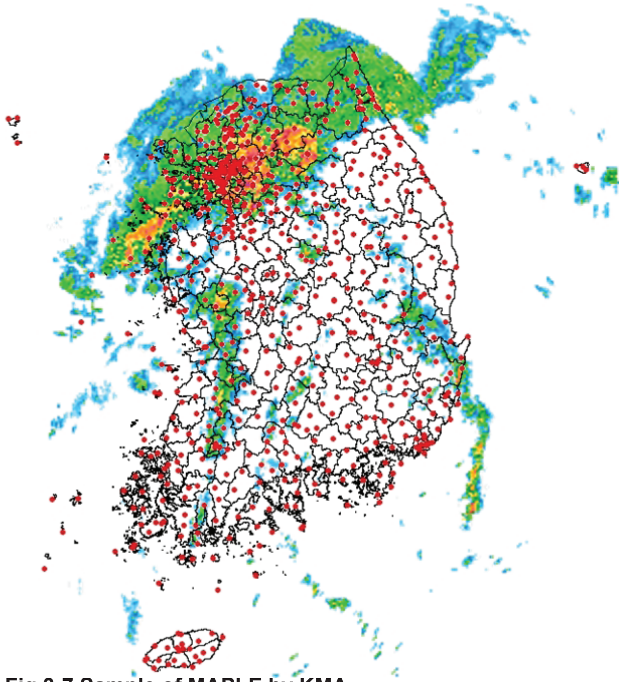
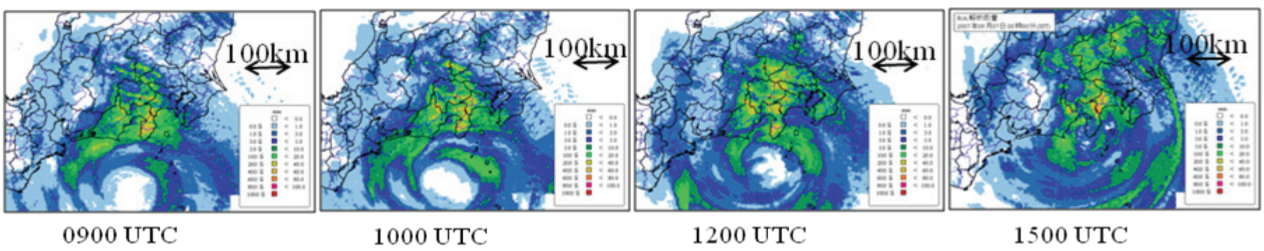


Fig.3-7 Sample of MAPLE by KMA



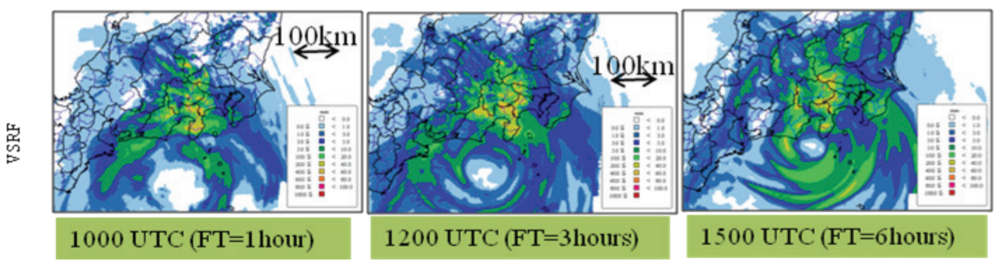
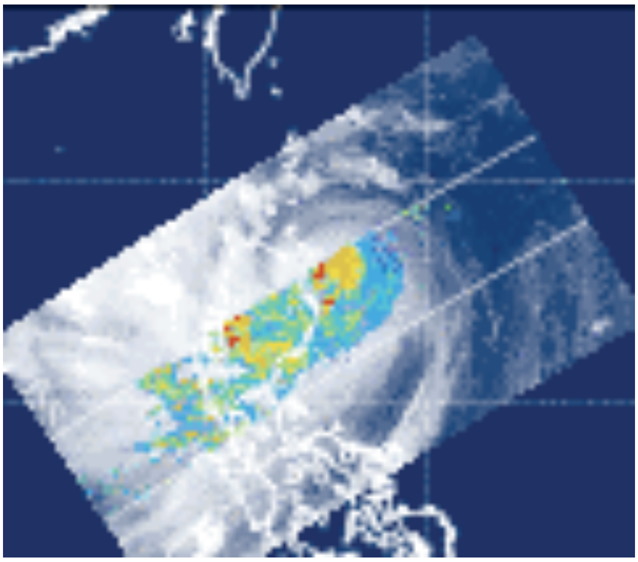


Fig. 3-6 Sample of QPE (top) and very-short-range-forecasting of precipitation (bottom) by JMA)



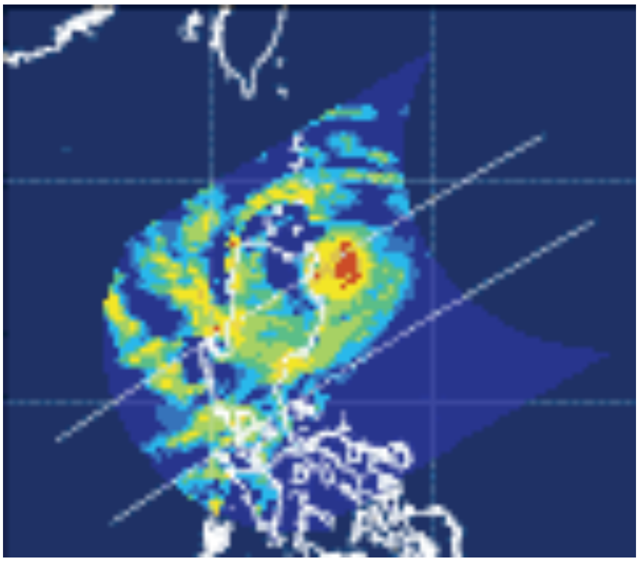


Fig. 3-8 Sample of TRMM PR/VIRS imagery (left) and microwave sensor (TMI) precipitation (right) by JAXA EORC (Earth Observation Research Center)

3.3 Information Sharing and Delivery

Meteorological information such as warnings and advisories is usually disseminated in plain messages to the general public through media and directly to disaster prevention authorities including local governments for their disaster prevention/ mitigation measures. Local governments disseminate instructions/recommendations to the residents through various means such as sirens and public electronic screens. In addition, Extensible Markup Language (XML) format and graphic form recently start being use for the information delivery for standardized processes and easy understanding. Common Alert Protocol (CAP) is one of XML-based data formats. Though announcement to the public by media such as TV and radio is important, information disseminated via the Internet and mobile phones recently prevails.

Sharing information, such as observational and analyzed data (rainfall, water level etc.) on a real-time basis, and issuing warnings/advisories through consultation based on such information, by DSS or other means, among relevant authorities are important. GPV data such as outputs of QPE/ QPF from meteorological authorities can be input to hydrological models for flood forecast in DSS operated by hydrological authorities. Water level observations are conversely provided by the hydrological authorities to meteorological authorities' DSS. Based on such information exchange, collaborative meteo-hydrological flood warnings/advisories consistent with the evacuation stages can be issued (See Fig. 3-9). Cooperation with DRR authorities (e.g. setting criteria of warnings/advisories, inclusion of warnings/advisories as criteria in evacuation planning, and lectures on warnings/advisories for staff of local governments) is also important to ensure effectiveness of warnings/advisories for DRR activities.

Examples of information sharing and delivery among authorities and public introduced in the Good Practices are shown in Appendix A.

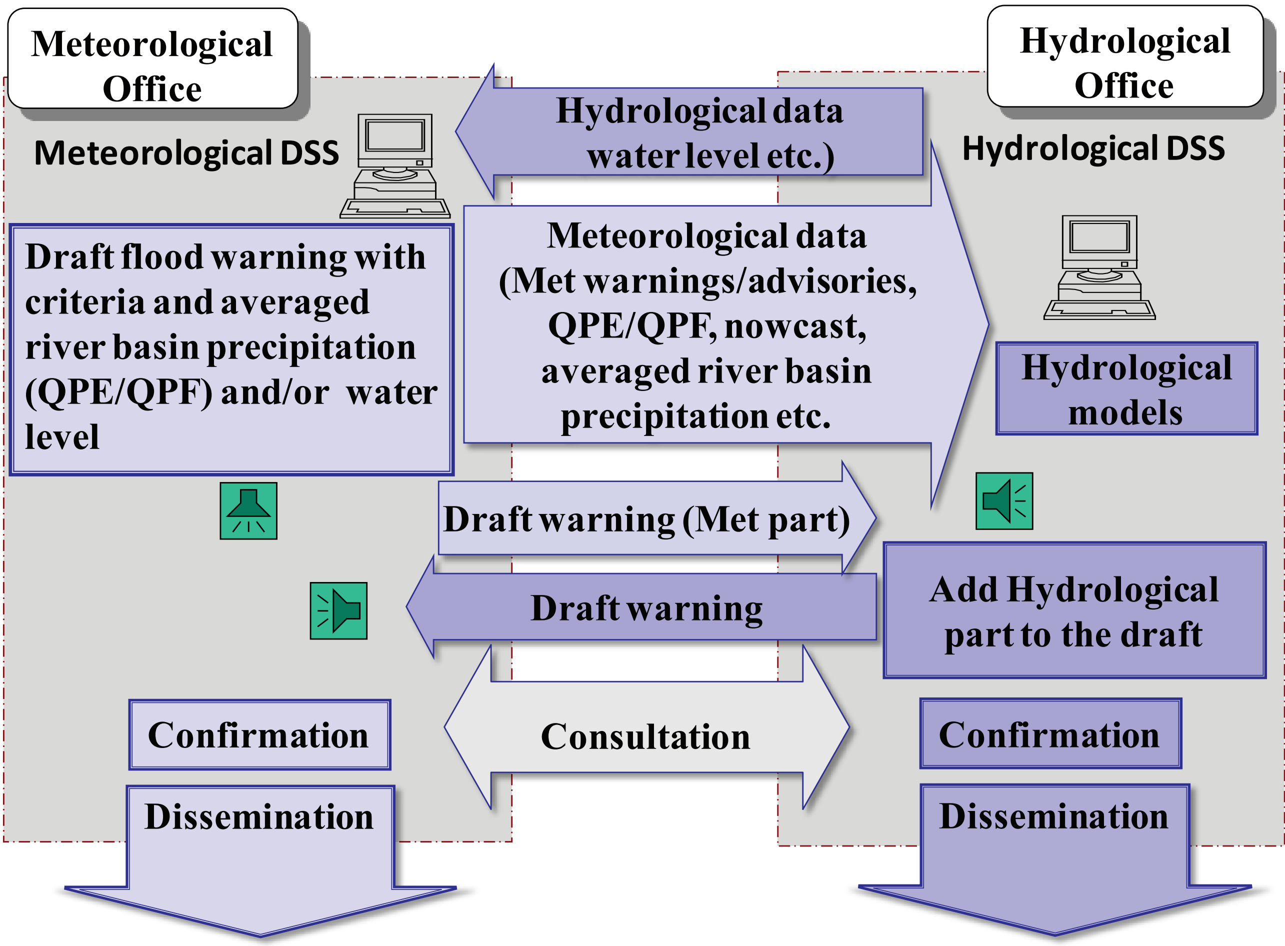


Fig.3-9 Example of warning issuance based on collaboration of meteorological and hydrological authorities through their DSSs

CHAPTER 4. URBAN FLOOD MONITORING, FORECASTING AND WARNING

4.1 Hydrological Monitoring

4.1.1 Measurement of water level

The water level is the free surface height from the arbitrary datum and water depth is the height from the river bed. For flood management, water depth is more important, however, the water level is usually measured because the river bed could be moved. The water level is measured based on the mean sea level and river bed. If the water level is measured from the mean sea level, the water level is called as elevation (EL.) which should be written together with the water level. Since river bed would be changed very easily by scouring or sedimentation, the reference point should be selected and called as zero point. The zero point is the lowest point in the river bed and it is very important for measuring the water level. If the river bed is moved by sedimentation or scouring, the effect should be considered in the measured water level.

The sensors of water level gauges are staff, float, bubble, pressure, acoustic, ultrasonic, radar type, etc. The staff gauge is manual but another is automatic type which could measure the water level automatically. Recently, most of the measuring devices are the automatic. In case of the Republic of Korea, most the water level gauge is a float gauge with stilling well whose installation expense is high, but the function is stable. The installation price of other electric water level gauge is cheap relatively, therefore the appropriate water level gauge should be selected with respect to the importance, objective, and site condition of water measuring station.

The time step of water level measuring could be selected among 60, 30, 10 minutes. Recently, 10 minute is the most popular measuring step, however, the step could be changed from the measuring machine.

(1) Staff gauge: Staff gauge are either vertical or inclined. The vertical staff gauge is used in stilling wells as an inside reference gauge, or in the river as an outside gauge. An staff gauge is usually a graduated heavy timber securely attached to permanent foundation piers. Copper barrel hoop staples and ceramic or bronze numerals are generally used for graduations (See Fig. 4-1).

Fig. 4-1 Staff gauge

(2) Float gauge: The float gauge measures the water level by the floating device which is moving with respect to the rising and descending the water level. The floating device is made of cupper or plastic and the shape is a plat cone-shaped and hollowed (See Fig. 4-2).

Fig. 4-2 Float gauge (with stilling well)

(3) Pressure gauge: The pressure changed by the water level is measured by the submerged sensor. Resonant frequency of quartz vibrator is changed based on the water pressure. Or semiconductor is also used to measure water level. The devices

should be calibrated using water temperature and concentration of water (See Fig. 3).

Fig. 4-3 Pressure gauge

(4) Radar gauge: The radar transmitters are used for continuous, non-contact level measurement. The radar pulses emitted by the antenna are reflected by the product surface and received back by the antenna. The time gap between the emission and the return of the pulse is named the fly time. The fly time is proportional to the product surface distance and processing by the electronic components of the radar transmitter allows the level measurement (See Fig. 4-4).

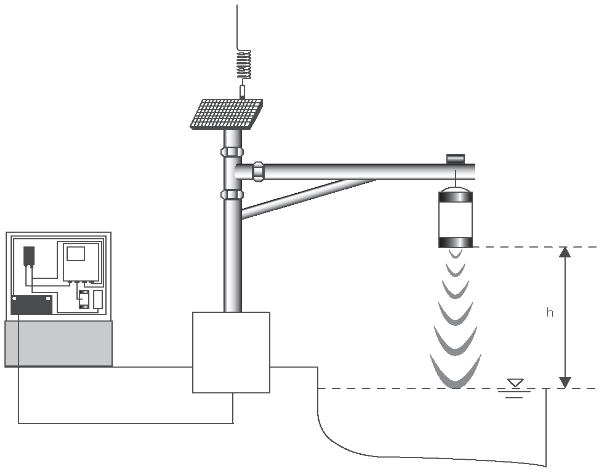


Fig. 4-4 Radar gauge and schematic features

4.1.2 Measurement of discharge

River discharge, which is expressed as volume pre unit time, is the rate at which water flows through a cross-section.
Discharge is the summation of the products of the subsection areas of the stream cross section and their respective average velocities.

$$Q = \sum(AV)$$

The formula represents the computation, where Q is total discharge; A is an individual subsection area; V is the corresponding mean velocity of the flow normal to the section.

Discharge at a given time can be measured by several different methods, and the choice of methods depends on the conditions encountered at a particular site. Normally, the discharge shall be related to a corresponding water stage at a gauging station. Flood discharge is measured by float method, dilution method, moving boat method, ultrasonic method etc. Selection of the appropriate method depends on the time available, the width and depth of the water, the bed conditions, the rate of change of stage, the existence of ice cover, and the required accuracy. Each method is explained in the following sections.

(1) Float method: This method should be used when either it is impossible to use a current meter

for estimating flow velocity because of unsuitable velocities or depths, or the presence of material in suspension, or when a discharge measurement must be made in a very short time. Surface floats or rod floats may be used. A surface float has a depth of immersion less than one-quarter the depth of the water. Surface floats should not be used when they are likely to be affected by wind. A rod float has a depth of immersion exceeding one-quarter the depth of the water. Rod floats must not touch the channel bed. Floating trees or ice cakes may serve as natural floats during periods when it is unsafe to be on the river.

(2) Dilution method: Measurement of discharge by this method depends on determining of the degree of dilution by the flowing water of an added tracer solution. The method is recommended only for those sites where conventional methods cannot be employed because of shallow depths, extremely high velocities, or excessive turbulence and debris. The two principal tracer methods used for discharge measurements are the constant-rate-injection method and the sudden-injection method. The general requirements for both methods are the same. A solution of a stable tracer is injected into the stream at either a constant rate or all at once. The primary criterion for the selection of sites for measurement of discharge by dilution is adequate mixing of the injected solution with the stream water in a short length of channel. Mixing is enhanced by high boundary roughness and features that cause the channel flow to be highly turbulent, such as at waterfalls, bends, or abrupt constrictions. Larger depth-to-width ratios result in shorter distances for the required mixing.

(3) Moving boat method: In this method, a boat is fitted with a specially designed component current meter assembly that indicates an instantaneous value of velocity (See Fig. 4-5). Recently, the ADCP (Acoustic Doppler Current Profiler) is mounted onto a boat. A measurement is made by traversing the stream along a preselected path that is normal to the flow. During the traverse, which is made without stopping, an echo sounder records the geometry of the cross-section, and the continuously operating current meter measures the combined stream and boat velocities. These data, collected at some 30 to 40 observation points (verticals) across the path, are converted to discharge. The velocity recorded at each of the observation points in the cross-section is a vector quantity that represents the relative velocity of flow past the meter assembly. This assembly consists of a vane attached to a stainless steel shaft, which, at its upper end, incorporates a dial and pointer for reading the angle between the direction of the vane and the true course of the boat. This is performed by sighting on carefully located markers on the banks. About six traverses, in alternate directions, are usually taken and the measurements are averaged to give the discharge. The discharge is calculated in a similar manner to the conventional velocity-area method by summing the products of the segment areas and average velocities.

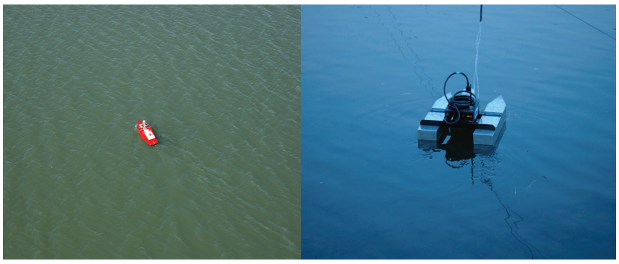


Fig. 4-5 Remote control boat and ADCP

(4) Ultrasonic Velocity Meter (UVM) method: The principle of the ultrasonic method is to measure the velocity of flow at a certain depth by simultaneously transmitting sound pulses through the water from transducers located on either side of the river. The transducers, which are designed both to transmit and receive sound pulses, are located on opposite banks, so that the angle between the pulse path and the direction of flow is between 30° and 60° (See Fig. 4-6). The difference between the time of travel of the pulses crossing the river in an upstream direction and those travelling downstream is directly related to the average velocity of the water at the depth of the transducers. This velocity can be related to the average velocity of flow of the whole cross-section. The incorporation of an area computation into the electronic processor allows the system to output discharge.

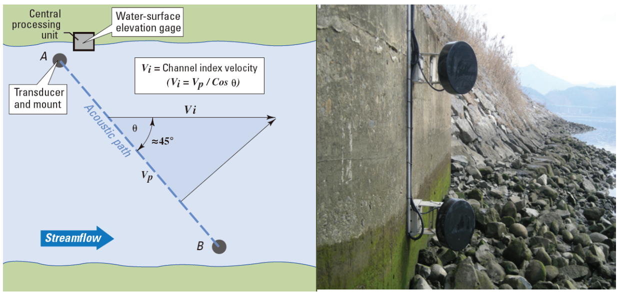


Fig. 4-6 The concept diagram of UVM method and sensor

(5) Acoustic Doppler Velocity Meter (ADVM) method: The Doppler Effect is the phenomenon we experience when passed by a car or train that is sounding its horn. As the car or train passes, the sound of the horn seems to drop in frequency. The ADVM uses the Doppler Effect to determine water velocity by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADVM by sediment or other particulates being transported in the water. The change in frequency, or Doppler Shift, that is measured by the Acoustic Doppler Velocity Meter is translated into water velocity (See Fig. 4-7).

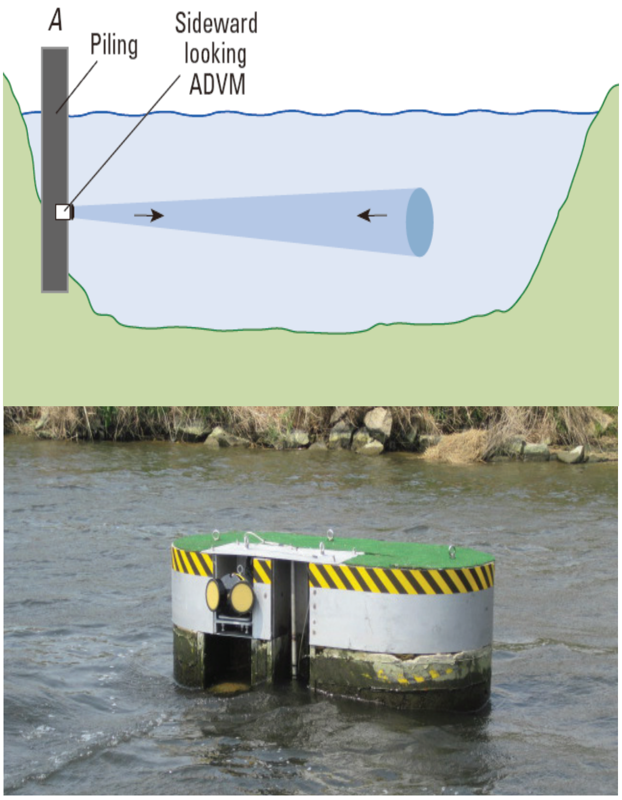


Fig. 4-7 The concept diagram of ADVM method and sensor

(6) Indirect methods: During flood periods, it may be impossible to measure discharge directly because of the excessive rate of change of discharge, excessive velocities, debris, depths, or widths or because flooded conditions make roads impassable or measuring structures inaccessible. When such conditions occur, the peak discharge may be determined after the flood has subsided by computations that combine well established hydraulic principles with field observations of channel conditions and flood profiles. All the methods involve the simultaneous solution of continuity of mass and energy equations. Such computations may be made for reaches of river channel, through roadway culverts and bridge openings, and over dams and highway embankments. Although the hydraulic formulae differ for each type of waterway, all the methods involve the following factors:

(a) Geometry and physical characteristics of the channel and boundary conditions of the reach used;
(b) Water-surface elevations at time of peak stage to define the cross-sectional areas and the head difference between two significant points; and
(c) Hydraulic factors, such as roughness coefficients based on physical characteristics.

4.2 Flood Inundation Mapping

Compare to other continents, natural conditions of the Asia Pacific region, such as their topography and climate, are severe and have been becoming more vulnerable to urban flood. Since large parts of population and its assets are concentrated in flood prone area, it is important to keep the flood hazard information for the case of the extreme flood even though the area is not under high risk due to a levee. In recent years, torrential rainfall frequently caused flood disasters, and a few of them caused tremendous social and economic damage to the inundated urban areas.

In order to mitigate those flood disasters, it is important to promote structural measures by constructing flood control facilities such as levees.

It is important, however, to prepare non-structural measures by improving public awareness towards disaster prevention, since there is always a possibility that a levee can breach if a flood exceeds its design capacity.
Urban areas are at risk of flash floods and heavy runoff. Flood inundation mapping is to predict flows in areas that will be flooded and issuing warnings to institutions and communities involved in regions (See Fig. 4-8). Mapping is a non-structural measure to reduce casualties and property loss caused from flooding. The mapping is a complementary strategy to structural measures such as dams, embankments and levees. Due to population growth and land use changes and especially climate change, the flash flood and heavy rainfall in a shorten time are increasing and the existing infrastructures are not able to secure the safety against flood.

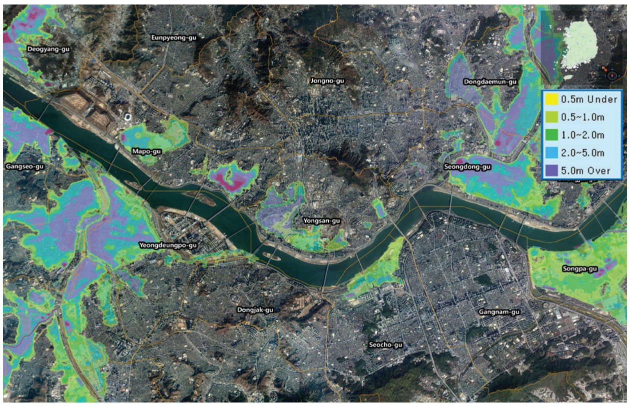


Fig. 4-8 Flood inundation map of Seoul of the Republic of Korea

Flood inundation maps can indicate each phases according the level of flood risk as flooding indicating inundation ranges and severity and it shows shelters and roads for evacuating. An inundation map provides information on the spatial extent and estimated depth of flood waters. Understanding the pattern of flood risk and vulnerable regions helps people anticipate where flooding will develop. In addition, a flood inundation map provides information for local governments and authorities to establish disaster prevention policies and strategies. Also, a map is used as a fundamental data to assess disasters effects in development projects and establish disaster prevention policies by decision-makers.

The most important purpose of use of flood inundation maps is to make people, especially residents in flood-prone areas, to understand which areas are more vulnerable as flooding and how to evacuate timely and properly. At the same times, local governments and authorities should issue the evacuation recommendation using the map.

In general, a flood inundation map refers to a map that is prepared primarily to prevent human damages by providing residents with inundation-related information, such as levee breaches and flood occurrences, and evacuation information in an easy to understand way.

A flood inundation map presents the extent of flooding expected spatially over a given area. This will indicate where roadways, streets, buildings, airport, etc., are likely to be impacted floodwaters. The map is developed with river observations and forecast, and it provides decision-makers additional information needed to better mitigate the impacts of flooding and enforce resilience.

A flood hazard map is a map that graphically provides information on inundation (predicted inundation areas, inundation depth, etc.), as well as on evacuation (location of evacuation refuges, evacuation routes, dangerous spots on evacuation routes, etc.) in an easy-to-understand format. The goal is to quickly evacuate local residents in a safe and proper manner in the event of floods. The map is produced and publicized through a joint effort by those in charge of disaster prevention and those in charge of rivers and hydrology in the respective local municipalities.

4.3 Flood Forecasting

Flood forecasting operations are centered on the timeliness and accuracy of the forecast. The model to be used by forecasting organizations must be reliable, simple and capable of providing sufficient warning time and a desired degree of accuracy.

The comprehensive model involving very detailed functions which may provide increased warning time and greater of accuracy may have very elaborate input data requirements. All input data for a specific model may not be available on a real time basis. Therefore, from a practical point of view, a flood forecasting model should satisfy the follows:

a) Provide reliable forecasts with sufficient warning time;
b) Have a reasonable degree of accuracy;
c) Meet data requirements within available data and financial means, both for calibration and operational use;
d) Feature easy-to-understand functions;
e) Be simple enough to be operated by operational staff with moderate training.

On the basis of the analytical approach used to develop a forecasting model, flood forecasting methods can be classified as follows;

a) Methods based on a statistical approach;
b) Methods based on a mechanism of flood formation and propagation.

The statistical methods have been widely used in the past. These include simple gauge-to-gauge relationship, gauge-to-gauge relationships with some additional parameters and rainfall-peak stage relationships. These relationships can be easily developed and are most commonly used as a starting point while establishing a flood forecasting system.

Increasingly, forecast procedures are based on more complete physical descriptions of fundamental hydrological and hydraulic processes. In many instances, when forecast flows and stages are needed along rivers, hydrologists use rainfall- runoff models coupled with river-routing models.

4.3.1 Rainfall-runoff models

Deforestations, urbanization, and other land-use activities have significantly altered the seasonal and annual distribution of stream flow within a watershed, especially in urban areas. Urban runoff is defined as a stream flow or the sum of surface runoff and subsurface runoff from urban area. Rainfall can be absorbed by the soil on the land surface, intercepted by vegetation, directly impounded in many different surface features from small depressions to large lakes and oceans, or infiltrated through the surface and subsurface soils into the groundwater. Soil characteristics in a watershed such as soil layer thickness, permeability, infiltration rate and the degree of moisture in the soil before the rain event have a direct effect on the rainfall-runoff process. Since urban areas have been already paved, the peak discharge of surface runoff is increasing and the respected time of peak discharge is shorten. That is, surface runoff occurs relatively rapidly in the urban watershed, thus, detention storage and/or infiltration basin have been constructed in a basin to reduce the urbanization effects as zero. The way to apply rainfall-runoff relationship in a different scale of basin could be varied and described below (See Fig. 4-9).

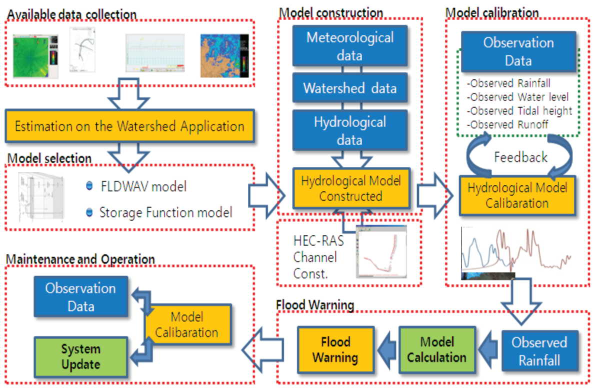


Fig. 4-9 Flow chart for the forecasting system (example)

1. Available data collection: Data collect and analysis on the watershed application;
2. Model selection: Select a model based on the Metro-manila area;
3. Model construction: Hydrological and hydraulic model construct using meteorological, watershed and channel characteristic, hydrological and HEC-RAS channel data;
4. Model calibration: Model calibration from the observed data;
5. Flood warning: Warning based on flood-forecasting model;
6. Maintenance and operation.

4.3.2 Statistical model

Regression is an extension of correlation concept that provides formulae for driving a variable of interest and regression equations have many applications in hydrology. Their general form is as follows:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + ...$$

where X refers to currently observed variables; Y is a future value of the variable to be forecasted. Regression coefficients b_n estimated from observed Y and X values. The X variables may include upstream stage or discharge, rainfall, catchment conditions etc.
In the Republic of Korea, the statistical forecasting model using precipitation and upstream discharge or water level as independent variables is used for flood forecasting of the tributaries.

$$Q(t+T) = a_1Q(t) + b_1R(t) + b_2R(t \square 1) + c$$

where, Q Q is discharge at a forecasted point; R isBasin averaged precipitation; a_1, b_1, b_2, c are regression coefficients.

The regression coefficients are calculated using historical data. The discharge $Q(t+T)$ $Q(t+T)$ in the forecasting time T is calculated in the current time t t.

4.3.3 Automated flood warning system (AFWS)

The objective of an AFWS is to increase the amount of warning time given to people who may affected by rising waters in flood-prone areas. The automated flood warning system consists of sensors which collect precipitation information interpreted by a computer for storage and analysis. Then the information can be conveyed to people in shorten time through electric devices which can receive informative signals and transfer them to signs or an alarm type siren. The possible transmission measure for flood early warning is microwave, telephone, telemeter, satellites, UHF radio communication networks to transmit real-time data.

Successful operations depend on good planning – knowing what areas are the most vulnerable; what sensor locations will best serve the vulnerable areas and what type and frequency of measurements are required. Moreover, in order to minimize flood damages, residents' awareness toward possible disaster risks and appropriate evacuation at the occurrence of floods are critical. Local governments should familiarize their residents with the process and means of communication. Therefore, the means of communication should be considered depending

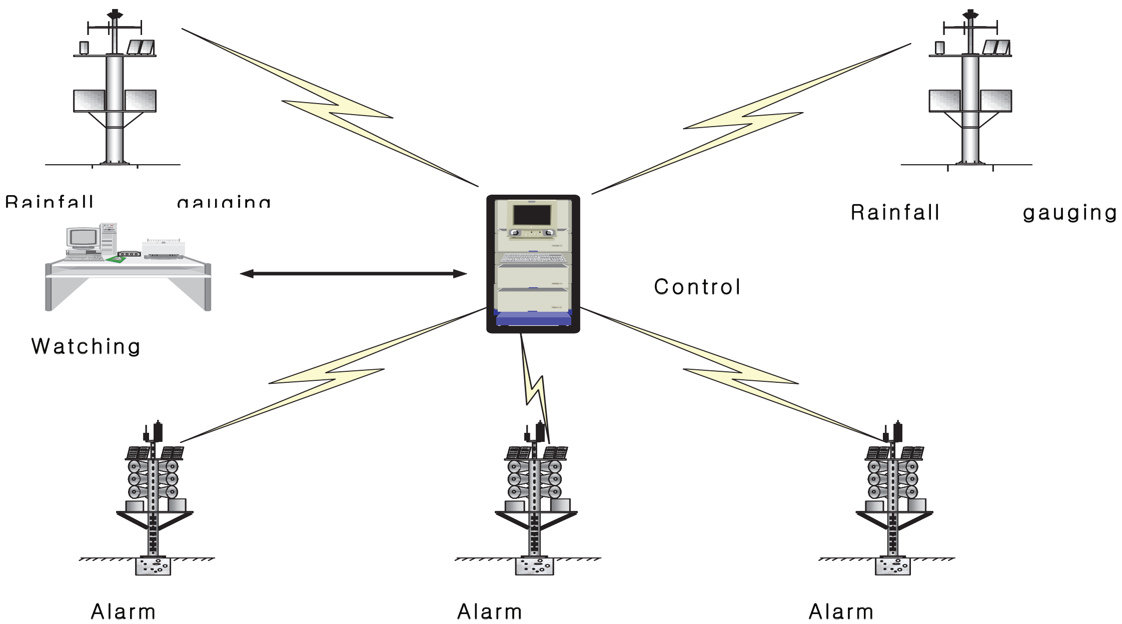


Fig. 4-10 Automated flood warning system

on information types and local characteristic. In addition, it is important to clearly specify how to provide information to flood-vulnerable people.

Table 4-1 The warning criterion of AFWS (the Republic of Korea).

Type	Methods	Warning Criterion
Warning	Alarm siren : 1 time Announcing : 3 times	· Hourly rainfall in a rainfall station is more than 20 mm · 5 hour averaged rainfall in all rainfall stations is more than 30 mm
Evacuation warning	Undulation alarm siren : 15 seconds Announcing : 5 times	· Hourly rainfall in a rainfall station is more than 30 mm · 5 hour averaged rainfall in all rainfall stations is more than 40 mm · Water level is higher than a criterion.

4.3.4 Flash flood warning

The definition of flash flood provided by the United State National Weather Service is “a flood caused by heavy or excessive rainfall in a short period of times, generally less than six hours”. The transformation from rural areas to urban land use due to population growth and industrialization has accelerated the occurrence frequency of flash flood. As a significant decrease in pervious land in urban catchments, the flood peak may transfer rapidly to surface waters within the short lead times in highly populated regions. In densely populated areas, they are more destructive because of their unpredictable characteristics of storm surge carrying out large concentrations of sediment and debris, given little or no time for communities living in its path to prepare for it and causing major destruction to infrastructure, human and whatever else stands in their way.

Urbanization likely produce higher peak flow rates that exceed capacity of small culverts under roads designed for unurbanized situation. While rapid industrial development and population increase are likely to encourage unprecedented economic prosperity in many cities, flash flood managements in urban regions turns out to be a crucial challenge. To respond to flash flood hazards, an effective system is needed for accurate, reliable and timely forecasts and warnings. The two key elements contributing to flash flooding are rainfall intensity and duration. Also, topography, soil conditions and types of ground cover are several factors resulting in flash flood.

One of the main reasons to cause flash flood in urban area is the inappropriate drainage system. In developing countries, inadequate maintenance of the drainage channels such as disposing debris and solid waste may degrade this situation. Warm season flash floods are the result form intense rainfalls in a short period of times due to slow moving thunderstorms. Flash floods warning and forecasting is a challenges for hydrologist because it is not always caused simply by meteorological phenomena. Flash floods are the result from both of meteorological and hydrological conditions. Although heavy rainfall is usually a main factor, a given amount and duration of rainfall may or may not result in a flash flood depending on the hydrologic characteristics of the watershed.

CHAPTER 5. DISASTER RISK MANAGEMENT FOR URBAN FLOODS

5.1 GIS Based Urban Flood Risk Management System

5.1.1 Integrated information analysis

Now, as disaster aspects show complex and compound disasters, integrated disaster information analysis is very important. Creating a urban flood risk management system needs to collect and integrate basic materials of the river region where the urban areas and city are located. Specifically this will include flood control planning, water planning, flood-control planning for the river region, water modulation planning, geographical materials including landform, rivers, jurisdiction boundary, and elevation, hydrological information, historical flooding information (affected range and water level), draining engineering for flood control purpose (river section, gauging stations distribution, location of embankment, water slucegate, and pumping station, remote sense images, socio-economic information as follows:

- **Planning and Preparatory plan**: Urban flood control planning, drainage planning, flood-control preparatory plan, emergency response plan, water modulation plan.
- **GIS information**: (i) Landform: urban landform map on a big scale at lease 1:10000; (ii) Rivers: main stream and tributaries in the city and go-by rivers that could affect urban water level; (iii) Road: Stem and general roads in the city area Jurisdiction boundary: Boundaries at different levels of city, district, and street.
- **Hydrological materials**: (i) Gauge stations: location of hydrological stations and rainfall stations; (ii) Rainfall information: Rainfall process, design rainfall process; (iii) Hydrological information: Water level and discharge of key stations, existing drainage capacity of rivers/waterways running through urban areas and the water level; (iv) Historic and typical flooding: General situation, flooded range, water level, loss, human damage and death.
- **Drainage engineering for flood-control purpose**: (i) River section: Location of key river sections and gauged section data; (ii) Embankment: Base elevation, top elevation, width; (iii) Pumping station: Drainage capacity, use policy, switch-on status; (iv) Sluice gate: Maximum drainage volume, use policy, switch-on status; (v) Drainage area division: Run-off quotient, drainage modulus, area; (vi) Reservoir: Capacity, water-drainage capability, and information about the water catchments.
- **Remote sense images**: Air-aviation/space remote sense images of 2.5m, 1.0 m, 0.6m, or even closer distance and higher resolution.
- **Urban socio-economic information** Community Committee is the bottom unit conducting statistics for socio-economic data survey, and subjects include population, household, industry, fixed assets, amenities and public infrastructure.

These information are not provided by one institute or one government organization but by various institutes and government organizations who provide information collected from monitoring, measuring and estimating from integrated analyzing or/and modeling for their own objectives. For the urban flood disaster management, these all information can be used for analyzing or integrating to create new knowledge for warning and decision make supporting. The main issue is how can collect the information to share and analysis. It is not easy to combine systems themselves because systems have different input-output data formats but to link among databases of various institutes and government organizations. For combining and integrating the information in an analytical system to create new knowledge, standard data format is useful to access and integrate the information conveniently. Using the geographical definition, it is possible to make combine and integrate the information in an analytical system. Also national level network system is essential to share and integrate the information in real time in anywhere.

To reduce disaster risk due to climate and environmental changes, National Emergency Management Agency (NEMA), Korea has been developing National Disaster Management System (NDMS) as a comprehensive nationwide information system to support disaster management processes in terms of prevention, preparation, response and recovery. NDMS services information as follows:

- Real time monitoring information such as river stage, flow, wind speed, rainfall, dam water level, CCTV images and satellite images;
- Statistical information analyzed by period and disaster type;
- Resources information such as emergent recovery equipments, relief goods, refugee facilities;
- Localized risk information such as forest fire risk map, landslide risk map, flood risk map and wind related disaster risk map;
- Real-time disaster information such as flood, typhoon, heavy rain, landslide, earthquake, forest fire;
- Other information such as media, communication and special weather report.

National Disaster Management Institute (NDMI), Korea developed GIS based disaster information analysis system to assess disaster risk. For example, the rainfall data with three hours leading time forecasted by MAPLE were used for flash flood warning especially in the mountain area which area has severe flood risk because water depth in stream suddenly increase and many people enjoy leisure in the mountain valley. The rainfall data also were used for input data of this integrated system to simulate rainfall-runoff and estimate water surface elevation and flow and velocity data were used for calibration and validation of it. Some information such as GIS and images was integrated with simulated and estimated results to create new knowledge and support decision making. Inundation area represented by this system can overlap on the GIS information such as population, land use, vacancy of hospital, school and utilities to support effective decision making for urban flood risk management and can estimate damages from disaster for efficient emergency recovering.

Effective disaster management, integrated network system to link the CCTVs especially established in riverside and flood risk area and integrate analysis is needed. Detecting technology to capture trig point of disaster automatically, for example automatically detecting water depth over limit line in the river is also important because numerous real-time images from various regions are presented in same time and longtime monitoring through CCTV is not easy. For operation of integrate network system, the role of each governmental organization at city, province and nation is defined as (i) national disaster agency monitor all images of CCTVs in a country to detect disaster situation for supporting decision making, (ii) province manage all CCTVs in the province to monitor and send the video images to the organizations and institutes to share information, and (iii) city collect video data from CCTV installed at disaster risk area, stage gauges, major bridges and control CCTV for rotation, angle and camera zooming for monitoring area condition.

5.1.2 Simulation for disaster risk management

For flood managing cities located on major rivers, river region hydrological and hydraulic coupling model is used to simulate flooding and inundating. The hydrological model works to predict rainfall-runoff discharges in upper streams, floods in key hydrological stations, inflow discharges into key reservoirs, and flow outlets from key tributaries linked to major rivers. An one dimensional hydraulic model calculates the only stem waterway flood evolution process and which results are integrated with hydrological prediction results to simulate the conflux process. A two dimensional flood simulation model can simulate the flooding process in water retention area and connect with the one dimensional river model to analyze and simulate the effect of water storage in reservoir or water retention area on the lower reaches urban water ways. A two dimensional hydraulic model can be used for early-warning and prediction of urban storm water logging and possible risk/impact when levees of urban water ways breaks. The hydraulic model should be able to reflect the impact caused by various buildings and structures such as road, railway, drainage ditch, bump stations, and high-density building blocks. Underground pipeline network, drainage network and boundary division, relation between water retention area and water storage water ways should be considered as much as possible. For areas with good information of underground drainage pipeline network, the model can simulate situations with accurate pipeline network information, while proceed with general estimate based on drainage capacity of the underground drainage pipelines. Considering water logging situation in urban area which continues to worsen, main roads can be treated as flood passage way in simulation calculation. For simulation of waterlogging in overfly areas, micro-landform and pump stations should be considered; for underground space water logging and drowning, the underground space area and elevation should be considered.

In calculating and analyzing, standards for 10-year, 20-year, 50-year, 100-year, and the most severe rainfall should be identified based on collected hydrological and meteorological information. Uneven temporal and spatial distribution of rainfall should be considered as well to calculate and simulate storm water logging before levees break, and proceed with prediction, early-warning and emergency management according to the simulation results. GIS-based simulation enables dynamic display of flood emulation results, analyze situation of flood-impacted areas, as well as frontier line at different times, flooding time of different locations and highest water level. Coastal cities face risks brought by astronomic tide and storm surge the major threat. When the two threats meet, the coastal cities are usually devastated by severe flooding. For cities located at river estuaries, special attentions should be given to the extreme adversity when river flooding and storm surge happen concurrently. It is necessary to analyze sea tiding laws and then utilize flood simulation model to analyze the flooding risk in case of concurrence of river flooding and storm surge, as well as the possible impact when flood overspills or breaks levees.

5.1.3 GIS spatial analysis and visualization

City is usually characterized in terms of socio-economic conditions, wide influence, increased impervious area, bigger runoff. For urban flooding risk prevention and emergency management, spatial information is widely involved in meteorological, rainfall, hydrological information analysis and treatment, flood development trend prediction, emergency plan making based on risk analysis, and urban flood control and drainage plan making and updating. The GIS technology provides an effective approach for flood risk analysis and division as it enables the weight assigning for natural, geographical and social factors related to flood risk management and their laying up spatially. In general, the GIS spatial analysis and visualized simulation provides real time data and optimize model parameters for hydrological forecasting, flood evolution, and disaster assessment models. For these reasons, GIS plays more important roles in Urban Flood Risk Management (UFRM) as it can provide spatial character analysis and proceed high resolution data. Outstanding features of GIS in UFRM include urban water catchment and receding prediction, existing drainage facilities (pipelines and pump) information management, water drainage facilities planning, design and construction management, 4D storm temporal-spatial analysis, socio-economic data spatial distribution by community/block, storm distribution and visualized presentation of water-logged community, and storage, maintenance and management of high-resolution, layered, multi-sourced, and frequently updated data.

A computer aided mapping tool for recording, collating, analyzing and displaying spatial information. Generally, the figures show GIS layers indicating land ownership and flood depths that was used to inform the designs for an integrated urban plan over the next some years and simultaneously reduce flood risk, contamination and provide environmental enhancements. In order to assess disaster and share the disaster regarding information, Geo-Linking approaches shown in Fig. 5-1 is powerful. The information is stored in database of Geo-Linking system including GIS. All information is converted to GIS information and overlapped to the various GIS information such as utilities, populations, land use, damage photos etc. The Geo-Linking system enables user to choose region or province of interest, the enhance view of which is shown to allow user to select any particular data displayed in the map such as photos, media, report and portal information can be presented in this system.

In order to assess typhoon related disaster and share the typhoon related disaster information, Typhoon Committee Working Group on Disaster Risk Reduction (WGDRR) was established WEB GIS Based Typhoon Disaster Information System (WGTCDIS) by using Geo-Linking approaches. The typhoon information menu in the WGTCDIS has all the information of the typhoons such as trajectory, rainfall, wind, damages etc. since 1951, which are stored in database of Geo-Linking system including GIS information. Similar typhoon can be checked out by the computer program running in background mode. The predicted track and the estimation of loss can be simulated and then compared with observation data and all historical typhoon trajectory and damages. To understand current typhoon's characteristics by comparing with historical typhoon, the information of the historical typhoons can be checked by either click a name of typhoon or insert specific period from one date to another date. The localized damages are estimated by localized KDFs of typhoon-related damages in the local regions and these results are converted to GIS map and overlapped to the various GIS information such as utilities, populations, land use, etc. Also WGTCDIS enables user to choose region or province of interest, the enhance view of which is shown to allow user to select any particular data displayed in the map. Another way of display the disaster information is to select a particular typhoon and then, related disaster data and information are shown in the WGTCDIS.

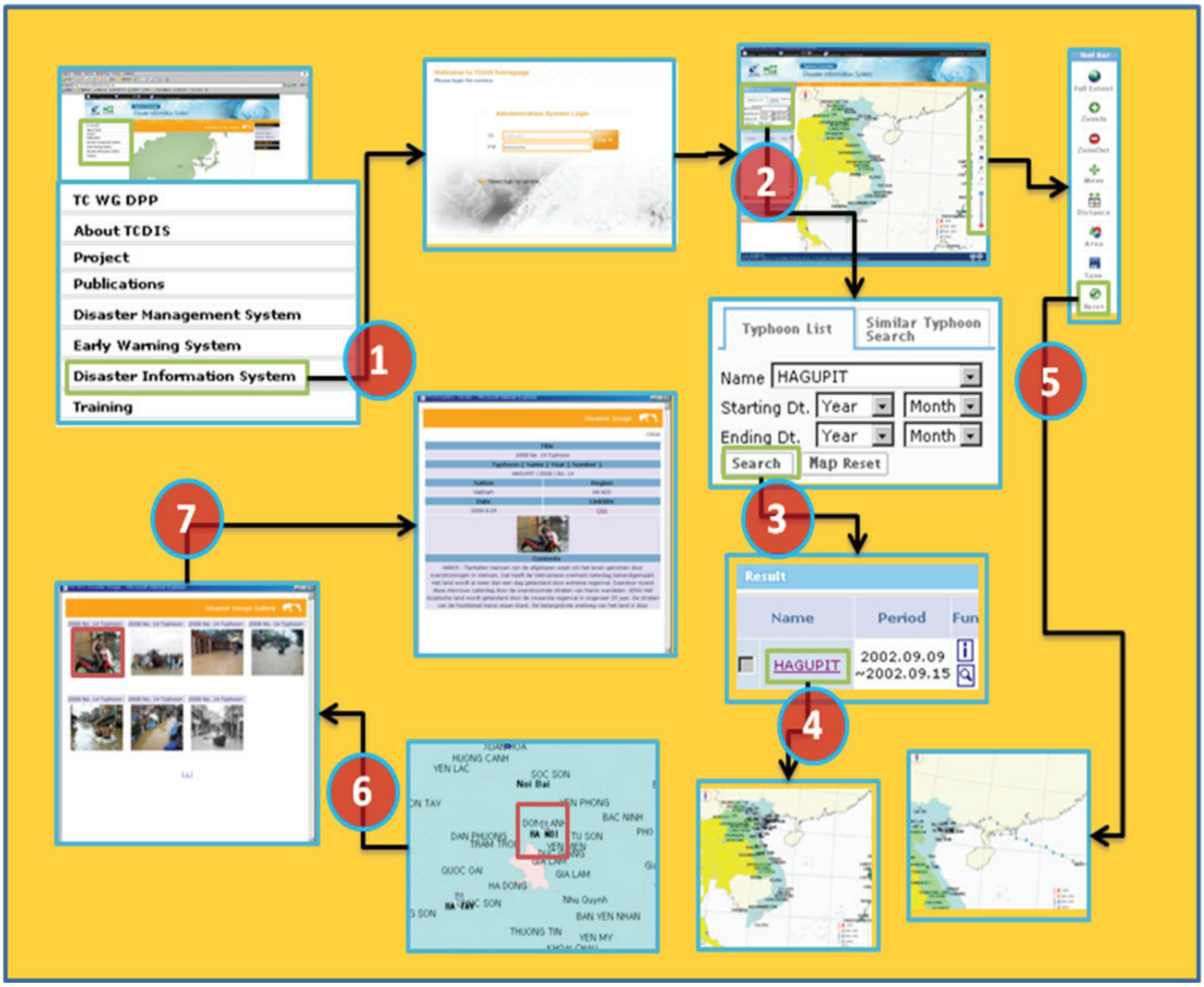


Fig. 5-1 Example of Geo-Linking services to display the typhoon related disaster information

5.1.4 Planning games

Decisions regarding flood risk management are complex and require wide participation from technical specialists and non-specialists alike. While it is impossible to entirely eliminate the risk from flooding, the right metrics, realistic simulation games, good risk data and data visualization tools aid to better understand the existing and future risks. Decision Support Tools (DST) can be used to predict the outcome of decisions, communicate risk and interface between stakeholders. Individual DSTs can be combined in a structured Decision Support System (DSS) provides a comprehensive system to aid communication with other stakeholders and to assist with individual or group decision-making. The right metrics, realistic simulation games, good risk data and data visualization tools help. But underlying such tools there has to be a fundamental understanding, which is often lacking, of the physical processes involved in flooding and the expected outcome of the flood management measures which are undertaken. Apart from economic benefits, policy makers must also consider many aspects such as the vulnerabilities of inhabitants, the impact of measures, equity considerations, environmental degradation, biodiversity, sources of funding, social capital, capacity and the potential to obtain financing from third parties.

5.2 Flood Management Measures

Flood management measures are typically described as either structural or non-structural and can be complementary in function. Structural measures are used to control the flow of water from both outside and within urban settlements. Non-structural measures manage risk by building the capacity of people to cope with flooding through better planning and management. Tools are available to assess the impact of these measures. An integrated approach to urban flood risk management recognizes that risk can never be entirely eliminated and that resilience to flood risk can include enhancing the capacity of people and communities to adapt to and cope with flooding. It focuses on finding the right balance between structural and non-structural flood management measures. Fig. 5-2 illustrates four capacities for reduced vulnerability and increased resilience.

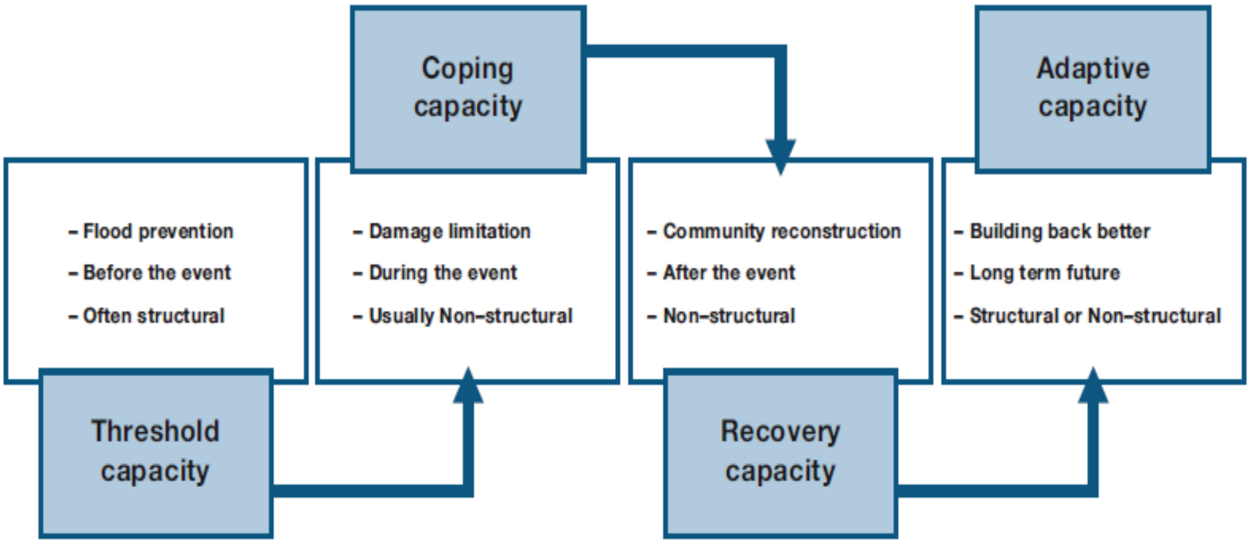


Fig. 5-2 The four capacities towards increased resilience, source: cities and flooding

5.2.1 Structural measures

Structural measures range from hard engineered structures to ecosystem management approaches that cover water management at the catchment and urban level. Hard engineered flood management structures include: (i) flood conveyance designed to route floodwaters away from areas of risk via natural or artificial channels; (ii) flood storage that reduce the peak of flood flows; (iii) urban drainage systems that increase infiltration; (iv) ground water management to prevent land subsidence; (v) flood resilient building design; and (vi) flood defenses. Ecosystem management approaches include utilizing wetlands and creating environmental buffers. Structural measures can be highly effective when used appropriately, as the well-documented success of Korea river management system developed by the four major river restoration projects.

Dependence on traditionally used structural flood management measures, such as flood defenses, can be inadequate and can be overtopped by events outside their design capacity. In Japan in 2011, although concrete sea walls, breakwaters and other structures had been constructed along more than 40% of Japan's coastline, the tsunami overtopped these walls. The unprecedented crisis in the Fukushima nuclear plant highlights the risk of dependence on seawalls in particular, and other structural measures in general. Many structural measures also transfer flood risk by reducing flood risk in one location only to increase it in another. Structural solutions can also have a high upfront cost; they can sometimes induce complacency by their presence.

5.2.2 Non-structural measures

There always remains a residual flood risk in using structural measures that necessitates incorporation of non-structural measures into any strategy. The non-structural measures often do not require huge investment upfront and can be more effective at lower costs. Non-structural measures can be classified under four main categories:

- Increased preparedness via awareness campaigns such as the ISDR campaign on "Making Cities Resilient". A campaign on awareness of flood risk reduction measures In Vietnam was successful in encouraging home-owners to invest in flood and typhoon resistant buildings. Korea identified 537 sites most susceptible to inundation, collapse, and isolation by typhoons and floods, and labeled them as "Disaster Prone Areas". These areas are classified and managed by type, grade, managing entity, size, etc. Under this plan, $141 billion has been invested to improve 488 disaster prone areas from 1998 to 2011.
- Flood avoidance via flood resilient land use planning and regulation of new development is a central measure in addition to resettlement. In Chengdu, China, slum residents along the river bank were resettled successfully with community engagement and the riverside developed as a public park and green buffer zone with water purification facilities.
- Emergency planning and management, including early warning and evacuation; early warning systems can be the first step in protecting people in the absence of more expensive structural measures as well as to manage residual risk from structural measures. When river levels were identified as dangerously high in community in Korea, the community leader went through the flood-prone community with a loud speaker asking people to evacuate. With just three hours before notice, the population of can able to leave. When floodwaters arrived, physical damage occurred, but not loss of life. The WEB GIS Based Typhoon Disaster Information System (WGTCDIS) developed by NDMI incorporates an approach to enable its users to share disaster information and disaster risk assessment results. Nearest Neighbor Method (NNM) is used to estimate long-term typhoon trajectories for the early warning of typhoon disasters and the Kernel density function (KDF) is used to estimate the damages considering the localized damages of the region of interest for the urban flood disaster risk management. The localized KDFs of damages can be established by using historical data. Assuming that the regional conditions such as terrain has not

changed much, the estimation can be made based on the trend in the past. The damages can be inferred from the historical data for each region. In this system, the most similar typhoon of past can be statistically found, the damage of the typhoon can be rough estimation of projected damages.

- Speeding up recovery and using recovery to increase resilience by `building back better' through better planning and building standards and risk financing. In Korea, to cope with the disasters due to the heavy rains and the 15th typhoon RUSA in 2002, the "Special Disaster Area" declaration was started. The declaration is for the areas where an ordinary support may not be enough for the appropriate recovery and response activities. Through the comprehensive supportive ways, that is, including the administrative and financial supports, the government intends to encourage the citizen's self-supporting intention, recover the damaged infrastructures more rapidly, and stabilize the livelihood of the sufferers at the damaged area.
- Decision Support System (DSS) for UFRM is based on computer network, GIS, flood monitoring and early-warning model, prediction and modulation model, flood disaster assessment model and database management technology. The details will be discussed in Chapter 7.
- Nonstructural measures can be challenging to implement. They rely on:
- Good understanding of urban flood hazard and on adequate forecasting systems, for example, an emergency evacuation plan cannot function without some advance warning;
- Community engagement and agreement of stakeholders and their institutions is critical for implementation;
- Lack of culture of compliance with land use regulations;
- Value of long-term investments such as maintaining resources, awareness and preparedness over decades without a flood event, bearing in mind that the memory of disaster tends to weaken over time;
- Most non-structural measures are designed to minimize but not prevent damage, and therefore most people would instinctively prefer a structural measure.

5.2.3 Urban flood management measures

Many urban flood management measures offer co-benefits with other urban environmental objectives.

- Multi-purpose retarding basins that store flood water for outflow control when necessary, offer effective utilization of limited land available in densely populated cities/ urban areas for other purposes. In Tsurumi River Basin, a retarding basin is used for sport and leisure facilities or car parking at other times.
- Rainwater harvesting can also be seen as an innovative measure to prevent urban flooding. It forms part of a sustainable drainage system and can simultaneously be used for non-drinking purposes, resulting in water conservation.
- Groundwater management can prevent land subsidence which mitigates flood risk in low-lying areas but also protects buildings and infrastructure from subsidence-induced failure, as for example has been attempted in Bangkok.
- Wetlands, bio-shields, environmental buffer zones and other “urban greening” measures produce environmental and health benefits in urban areas, while reducing flood impacts. These include reducing the urban heat island effect and the level of CO_2 emissions, and thus creating a healthier urban environment, as for example has been attempted in Korea.
- Investment in better urban management, such as for solid waste, also reduces urban flood risk and green growth can have health and environmental benefits, and can be used to create employment and relieve poverty.

5.3 Alternatives for Flood Risk Management Measures

Government decisions about management of urban flood risk need to be balanced against competing and often more pressing claims on scarce resources as well as other priorities in terms of land use and economic development. Tools and techniques exist which can predict the outcome of decisions, communicate risk and create linkages between stakeholders and allow policy makers and their technical specialists to decide between alternatives, and to assess their costs.

Cost-Benefit Analysis (CBA) evaluates costs and benefits in monetary terms. It is the industry standard analysis tool for flood risk management measures. The purpose of CBA is to assess, over its lifetime, the monetary value of all of the costs involved in the development, construction and maintenance, and the monetary value of all of the benefits to be gained from a flood risk solution, in order to determine whether its benefits outweigh its costs. This is the main form of assessment used by decision makers to determine whether a project is worth proceeding with, and if so, when it should be started. Cost-benefit analysis can make the decision-making process more transparent and accountable. However, structural measures proved not to be cost beneficial.

A limitation of CBA is that traditionally it has been unconcerned with the distribution of costs and benefits: for example, it neither considers who pays for the risk reduction measures, nor who benefits from them. Also, by taking as its basis the economic costs and benefits, it artificially weights the preferences of the wealthy over those of the less well off. Urban flood defenses will be provided more to the rich because the assets of the rich are greater and therefore the damage prevention potential within wealthy neighborhoods is much greater than that in poorer ones.

Multi-Criteria Analysis (MCA) assigns weights and ranks to aspects that cannot be quantified MCA is a complementary approach to CBA that incorporate less formal consideration of social and environmental issues into project evaluation. MCA is used to balance the needs of multiple stakeholders and to allow consideration of costs and benefits that do not ordinarily have an market value, such as biodiversity, well-being or community spirit. MCA aims to establish the goals and objectives of all of the stakeholders that may be affected by both the urban flood risk and the associated risk reduction measure. Consensual weighting is then determined for various elements, through discussion with stakeholders.

To reduce subjective weightings in an MCA, it is vitally important to gain representation from a sample of all stakeholders and to brief them thoroughly on the purpose and details of the proposed schemes. The multi-actor participation explicit in MCA, and the need for buy-in to the weighting analysis and results, means that transparency and public involvement from an early stage are essential.

5.3.1 ALARP principle

Governments have limited resources and will often choose not to implement schemes which may be cost beneficial because of the lack of available funds to do so or because there are other priorities which take precedence. It will also apply in developing countries where resources may be much more limited, or may depend on international donors with their own agendas to satisfy. Therefore it becomes necessary to determine an acceptable level of flood risk and to decide between alternatives, while taking into account wider policy, equity, and social issues and uncertainties. In deciding on an acceptable level of risk for populations to bear, the principle of ‘As Low As Reasonably Practical (ALARP)’ can be adopted. With this approach, the acceptance of risk can be expressed as a three tier system which requires definition of:

- An upper band of unacceptable risk;
- A lower band of broadly acceptable risk;
- An intermediate band of tolerability which is tolerable if risk reduction is impractical or the Cost-Benefit (CB) ratio is close to one.

5.3.2 Robust strategy

Errors in forecasting of an event, for example stage or time of arrival, may lead to under-preparation (at the cost of otherwise avoidable damage) or over-preparation (resulting in unnecessary anxiety). The balance between failure to warn adequately in advance and the corrosive effects of too many false alarms must be carefully managed. Flood risk managers must therefore consider measures that are robust to uncertainty and to different flooding scenarios.

Evaluation of the costs and benefits of each measure, or combination of measures, must be integral to a wider strategy which sets future targets for investment in measures and prioritizes spending on the most urgent and effective of these activities. Robustness, that is finding alternatives that perform well under all scenarios, then becomes a preferred strategy rather than finding the optimal solution, bearing in mind that the ALARP concept may ensure that robust solutions do not result in risks in the intolerable band. An optimal solution might perform well in most scenarios but be disastrous under some assumptions.

In managing urban flood risk today, and in planning for the future, a balance must be struck between common sense approaches that minimize impacts through better urban management and the maintenance of existing flood mitigation infrastructure, and far-sighted approaches which anticipate and defend against future flood hazard by building new flood mitigation infrastructure or by radically reshaping the urban environment. The balance will be different for each city or town at risk. This will lead to the preference for flexible and so-called `no-regrets' approaches that will include measures which will be cost effective regardless of changes in future urban flood risk. Examples of such approaches are forecasting and early warning systems which these are not sensitive to future flood risk and are relatively low in cost to set up; informal settlement upgrading or clearance by rivers also has many benefits over and above the flood management role; restoring wetlands that may also have amenity value; installation of wider foundations for flood defenses so that they can be raised later without strengthening the base builds in flexibility; the purchase of temporary flood defense barriers can also be seen as a flexible alternative as they can be deployed when and where necessary as flood risks change; and improved solid waste management systems have many benefits for environmental health regardless of flood risk. Such no regret measures yield benefits over and above their costs, independent of future changes in urban flood risk.

5.4 Implementation of Flood Risk Management Measures

5.4.1 Institutions

In implementing an integrated approach, the role of well-functioning institutions, the participation of stakeholders, and the engagement of affected communities are vital. Identifying which institutions are most effective in the delivery of these measures is fundamental to success. Institutional mapping is a tool that can be used to identify the awareness and perception of these key institutions, both formal and informal, as well as that of key individuals, inside and outside of a community, a city, a province or a country. It will also help to identify the relationships and importance of these different actors to one another or to individuals.

Multi-jurisdictional cooperation: Integrated urban flood risk management takes place at a range of scales, including the community, local/municipal, river basin and water catchment, region and nation as a whole. This is due to the fact that the source of flooding may be at some distance from the city or town. Often the best option may be to tackle flooding before it reaches the urban setting. Structural measures such as flood defenses and conveyance systems can form a long-term response to flood risk. However, these require large investments which will not always be available in one jurisdiction. Further flood defenses in one location could increase risk elsewhere.

Multi-stakeholder cooperation: Integrated flood risk management requires coordination between national governments, city governments, public sector companies, including utilities, along with civil society, non-government organizations (NGOs), educational institutions and the private sector. Engagement of the community at all stages through risk assessment through implementation to will ensure that the undertaken measures are equitable and effective, and meet the needs and priorities of the entire affected population. It may also generate extra knowledge and resources, as will the utilization of measures that are community-designed and implemented. Very often residents are unwilling to move from already-developed locations in floodplain areas, which are vulnerable and contravene the land use regulations drafted by decision makers and planners. This situation can involve poorer residents, living on riverbanks close to economic opportunities, or wealthier people who have houses on seafronts. Generating the necessary attitudinal and behavioral change requires time and investment in wide communication and multi-stakeholder consultation through a participatory process.

The Associated Program on Flood Management (APFM) is making an effort to provide guidance tools for flood managers and various other specialists working in flood management. Integrated Flood Management (IFM) requires various specialists to work together under a joint flood management strategy or policy. While the overall aims and objectives of such policy are usually explicitly provided, the consequences for the application of various principles are far less understood. In Bangkok, the engagement of the community strengthened urban flood risk management activities and led to the development of greater local capacity to cope with flooding. Time constraints are an issue that needs to be considered by decision makers in relation to the involvement of communities and other stakeholders in flood risk management. The time that people, especially poorer people, have to participate in flood risk management measures, in public consultations and other activities, is often limited. Moreover, mobilization of the community to engage in voluntary service is also a challenge. The role of the private sector in the implementation and delivery of urban infrastructure has been increasingly recognized. In flood risk reduction, public-private partnerships can provide to the private sector a better understanding of their interdependence with locally critical infrastructure, and improve coordination with the local stakeholders before, during, and after a disaster. In Metro Manila, multi-stakeholder collaboration for better Flood Risk Management leveraged public private partnerships successfully.

5.4.2 Financing

The sources of finance for integrated flood risk management are broad and can benefit from a partnership approach which includes contributions from multiple stakeholders as well as international donors. Flood and other disaster risk reduction activities are long-term processes that increase the sustainability of development interventions, and donors therefore need to incorporate this perspective into their plans and programs. The fact that flood risk management measures may not offer quick returns to donors and governments can limit available funding opportunities. The notion of “Not in my Term of Office” may lead to politicians and government officials placing flood risk management lower on the agenda than other, more tangible or immediate programs, and deferring or delaying action.

Flood risk management spending does not always have to be explicit: it can be form part of broader municipal budgeting for development spending, climate change adaptation spending, integrated water projects, slum upgrading, or education. In Palo, Philippines, to reduce the impacts of flooding, the municipality initiated a review of their local planning and development tools to incorporate DRR. After the assessment, the most appropriate measures were identified and responsibilities were allocated amongst relevant administrative bodies and incorporated into the municipality’s Annual Investment Plan. Microfinance arrangements have the potential to empower individuals and communities to implement flood risk management solutions for themselves. A community-owned disaster fund can be set up which can accept funds from multiple sources including micro investments from the community. Allocation of grants and micro credits towards flood or other disaster mitigation can be determined by the community organization controlling the fund.

5.4.3 Maintenance

Implementing processes for adequate long-term Operations & Maintenance (O & M) is a critical aspect of implementation. Flood mitigation infrastructure requires regular repair and maintenance on a risk-assessed basis, so that the most critical elements are inspected and maintained and repaired at the most frequent intervals. The cost of operation and maintenance is a critical aspect in the long term, so there will be a preference for designs that minimize maintenance. Unfortunately, despite appropriate design, high maintenance requirements are often introduced at the procurement and construction stages through the constraints of the bidding process, poor contractual enforcement, and the desire for low-cost solutions with little regard to subsequent upkeep. The maintenance requirement may not become obvious for some years after construction when project funds have been finalized and the maintenance responsibilities passed to the municipal authorities.

5.5 Monitoring of Flood Risk Management Measures

Monitoring of flood risk management programs needs to be twofold: firstly, the implementation of measures must be monitored and evaluated; secondly, and perhaps more importantly the fitness of purpose of the implemented system (i.e., its ability to reduce risk) must be monitored in the long term, as systems may not be regularly tested by actual flood events. Just as deterioration of levees can lead to early breaches, and drainage systems can become blocked, other measures and systems can also become prone to failure. This may be due to inattention to maintenance, to obsolescence, or to the departure of experienced individuals. The responsibility for carrying out a monitoring program is, ideally, delegated to the agency which is responsible for maintaining and operating the risk reduction solution. However, it may be appropriate for the requirements and design of the monitoring protocol to be enshrined in regulation or legislation.

As a first step it is necessary to analyze why a measure may fail and whether a monitoring procedure can be put in place to prevent this failure route. Evaluation of flood disasters in the past can help with this process, if this is carried out in a scientific and structured manner. Failure types and their probably of occurrence are evaluated. In this way the most likely failure route and underlying cause can be identified. In this example failure caused by overflow and overtopping may be due to flows or levels exceeding the design standard. Regular updating of flood hazard maps should be used to establish whether the design standard is still appropriate. Techniques specifically to evaluate disaster risk management programs, including flood risk, are somewhat less developed, and certainly less ‘tried and tested’.

CHAPTER 6. FLOOD RISK ANALYSIS AND ASSESSMENT

People living in the typhoon prone countries in the Asia-Pacific region have accumulated abundant perceptual knowledge on frequently occurred floods and their destructive effect in the long history. However, during the rapid process of urbanization, the features of the catastrophic floods have changed dramatically (WMO & GWP, 2008). We have to develop a more effective flood prevention system and emergency response plan according to the information on potential distribution of flooding and damages under different scale of typhoon and flooding, but not only on the traditional experiences. Flood risk analysis and assessment may offer such valuable information for the decision makers and general publics. The basic concept and some practical methods are introduced in this chapter.

6.1 Definition of Risk Considering the Feature of Floods

6.1.1 Hazard assessment

The nature of the local flood hazard will determine measures that can prevent or mitigate damage from specific types of floods. Where is the flooding coming from? How severe is it? How frequent will the flooding be? And is it going to be much worse in the future? Hazard assessment can be conducted by:

- Identifying the type of flood and severity of it – its extent, duration, depth and velocity;
- Estimating the probability of occurrence;
- Using flood hazard assessment tools.

6.1.2 Vulnerability assessment

Location of flood events and vulnerable populations are important to determine the necessity, urgency and priority for implementing flood risk management measures. What can be the impacts of flooding? What population and assets occupy the potentially affected areas? How vulnerable are these communities and settlements? How are these planned or developed? And what do they already do towards flood risk reduction? Vulnerability assessment is conducted by:

- Understanding flood impacts;
- Flood damage assessment;
- Vulnerability assessment & mapping.

The framework of risk assessment illustrated by WMO (1999) indicates that evaluation of hazards and vulnerability assessment should proceed as parallel activities, in a consistent manner, so that results may be combined and comparable. The important thing for vulnerability assessment is the availability of organized data.

6.1.3 Disaster assessment

The decision-making process also depends upon other factors, such as perception of risk in relation to cost-benefit analysis, measures taken for risk reduction strategies or alternatives available for risk mitigation. It is recommended to include pre-disaster assessment and in-disaster assessment modules in a decision-making support platform for urban flood management.

- **Pre-disaster assessment**: Disaster assessment ahead of flood disaster happening. That is to analyze the economical losses and impacts under different flood scenarios by using a GIS-based disaster analysis module, which can be realized based on the data of water depth, inundation area and duration simulated by two-dimension flood simulation models, and , with the help of displaying the social-economic data on the spatial layers.

- **In-disaster assessment**: Disaster assessment just in the process of disaster happening. In the process of flood disaster, the real-time flood inundation area can be estimated based on the remote-sensing images. So, the disaster assessment can be undertaken by analyzing social-economic impact of flood over the inundation area with the help of GIS and spatial data base.

6.1.4 Risk assessment

Flood risk is commonly understood as a function of the flood hazard, of exposure to the flood hazard and of the vulnerability of receptors such as the community and the settlement to the flood hazard. One of the widely used definitions of risk regards that “Risk is the probability of a loss, and this depends on three elements: hazard, vulnerability, and exposure. If any of these three elements in risk increases or decreases, then the risk increases or decreases respectively.” (Crichton, 1999). Since flood hazard is predictable and controllable in a certain degree, that is a feature of flood differing than other hazards such as earthquake and volcano, and the capacities of flood forecasting and early warming, and flood control and flood fighting can be enhanced to mitigate flood disasters, the flood risk can be represented as follows (ADPC, 2010):

$$\text{flood risk} = \text{function}\frac{\text{hazard, exposure, vulnerability}}{\text{capacity}} \qquad (6\text{-}1)$$

in which, flood hazard can be quantified as flooded areas and duration, distribution of water depth and velocity corresponding to certain scales of typhoon, heavy rains and storm surges; while measures of exposure can include the number of people or types of assets in flooded areas, and vulnerability refers to “the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard” (UNISDR, 2009). The effects of vulnerability and capacity on flood risk can be represented as the increase or decrease of the loss rates of assets varying with water depth.

Another computable definition is given by Sayers (2002):

Risk = Probability × Consequence (6-2)

For flood risk, probability refers to the return period of flood event and consequence refers to the total flood losses. In order to calculate the flood risk for a certain region, the annual average expected flood damage is used by the integration of Eq.(6-2), which can indicate evolving trend of flood risk continuously in a long term.

6.2 The Characteristics to be Considered in Urban Flood Risk Analysis

The urban flood risk analysis discussed in this section is a part of the flood risk analysis in plane distribution. The affecting factors of the flood risk distribution over an urban area are more complicated than that in the ordinary rural areas. In addition, the scale of the city itself also makes different claims in flood risk analysis.

6.2.1 Medium and small cities

Normally, a medium city refers to the city with an urban population of 200,000 to 500,000; a small city refers to the city with an urban population less than 200,000. The features of flood risk are as follows:

(1) The medium and small cities are usually the local centers of the politics, economy and the cultures, as well as the hubs of communications. The urban areas of the cities are not so large in size, but the density of the population and assets are relatively higher. Among them, there are many newly developed cities in recent years with lower level of the flood control capacities and higher damages induced by flooding.

(2) Generally, the flood control standard for the medium cities is assigned against 50 to 100-year flood events and small cities against 20 to 50-year food events. However, limited by the economic and technical capabilities, most of the medium and small cities have not reached the statutable standards in the developing countries. There are obvious gaps between the demands of development and the real situations of the urban flood control and drainage systems. Today, the flood disasters hit the medium and small cities more frequently than the large cities, and cause the damages much higher than those in the former rural areas.

(3) The medium and small cities are widely scattered all over the vast plains, hills, deltas and coastal areas, with quite different environmental conditions for flood hazards and the differences of the flood risk features. Because of the unbalanced economic developments, the demands and the investments on the flood control system construction are also different among them. The flood risk analysis methods should be carefully selected to suit the local conditions.

6.2.2 Large cities

Among the large cities, the major cities refer to the city with an urban population of 500,000 to 1,500,000 and the essential major cities with an urban population over 1,500,000. The features of flood risk for large cities are as follows:

(1) The large cities are usually the national or regional centers of politics, economy and cultures, as well as the major hubs of the communications, with wide urban area and a high density of population and assets. In case a large city hit by a severe flood hazard, it will cause not only the extensive losses to the city of its own, but also the adverse impacts of the flood disaster exceeding far from those on the inundated areas.

(2) The flood control standards are required relatively higher for the large cities. The flood control standards for the major cities are assigned against 100 to 200-year flood events and the essential major cities against over 200-year food events. During the flood-fighting period, the large cities are always the key protected objectives.

(3) The large cities have commonly built relatively systematical flood control and drainage facilities in certain scales. However, most of them up to now have not reached the statutable standards. Some flood control facilities built in a former period are unable to meet the demands of urban development today. The newly expanded urbanized areas with lower flood control capabilities are facing higher flood risks.

(4) The large cities always suffer from flood hazards for different causes, such as river flooding, local rainstorm, torrential flood, debris flow, and storm surge, as well as their combinations. Each kind of floods or their composition may hit different part of the city.

For the large cities, in the flood risk analysis, we should consider not only various causes of the flood hazards and their compositions, but also the changes of the flood risks associated with the exploitation in river basin, expanding of the urban areas and the construction of the flood control works. Thus, the flood risk research for the large cities should adopt advanced means as much as possible.

6.3 Procedures of Urban Flood Risk Analysis

The procedure of the urban flood risk analysis includes basic data collecting, preliminary analysis and detailed analysis. In addition, the urban flood damage analysis should be considered if necessary.

6.3.1 Collection of basic data

Data collecting is a very important fundamental step, or even the most difficult step in flood risk analysis, particularly in developing countries. We require the local agencies to collect data as much as possible so that we can have more chances to compare, recruit and check the reliability of the data collected.

(1) Maps of the city. The topographic map and administrative division map of the objective city should be collected. It should be enlarged to the extent that includes all the areas necessary for the urban flood analysis. The scale of the maps should meet the needs of distinguishing the topographic level, the surface cover types, the urbanized region, the density of buildings, and the location of the flood control works. Generally, the scale of the maps should not be less than 1:10000. For some important parts, it should supplement maps with larger scale of 1:5000 or 1:2000.

Because of the rapid changes in urban areas, the maps collected should be processed artificially according to the latest aerial and/or satellite photographs, or information from urban planning authorities and other associated units. The newly expanded urban areas, highways, railways, bridges should be added on the maps. For the regions with rapid changes in elevation, the original data of elevation on the maps should be emended according to the present collected and measured elevation. The major flood protecting units, works, schools, hospitals, and so on, should be marked on the maps.

(2) Hydrological data for the stochastic features of

floods. Firstly, the flood rainstorm and hydrological data adopted in frequency analysis for urban flood/tide control planning or the present flood frequency analysis results should be collected. Then, the methods applied in former analysis, and the time series of data should be evaluated. If the method is suitable, and the time series is longer enough and there are not obvious changes since the former analysis, the present result can be used directly. Otherwise, it is necessary to collect the latest data and make an analysis again.

(3) River bed data. Data concerning river, such as cross-section, gradient and bed material, as well as the deformation of riverbed should be collected for those rivers which flow through the urban area, or for those overflows which may threaten the city. Because of the expansion of the urban area, some rivers that used to be the floodway out of the city in the past and have become drainage channels in the city today should be particularly surveyed.

(4) Large structures with effects on urban flooding and drainage. Data concerned with dike, levee and the embankments of railway, highway and conveying channel should be collected, such as the time of construction, the top level, the structures and qualities, and the foundation. The practically maintained flood control standards and possibility of failure should be evaluated for each reach of the river. The dams concerned and the flood control operating and emergency discharging schedules should be studied. The plan of sewerage system and the capacities should be surveyed. The layouts of bridges that may cause the backwater level and the culverts which cross the embankments should be collected. If there are detention areas around the city, the operating criteria should be understood.

(5) Data of historical flood events. The survey reports and other findings concerned with the flood events through history should be collected as much as possible. They are necessary to understand the cause, the background, the magnitude, the area inundated and the duration, the highest water stage distribution, and the population affected and the losses of various properties of each flood event. All data should be sorted out to sub-areas and categories. The reliability of the data should be analyzed and illustrated.

In the case of no sufficient literature records, a particular flood mark investigation should be organized to determine the range of the flooded areas and the highest water stage of big flood events in the past. Combining with the frequency analysis of flood peak discharges, the flood return period for the range of each inundated event can be determined preliminarily.

(6) Urban Flood Control Planning. It includes the urban flood control planning and the correlative river basin flood control planning, such as the construction plan of the dams on the upper reaches, the main dikes along the rivers and the coastal lines, detention projects, and river improvements.

(7) Relative Emergency Programs. The current emergency programs related to the organizations of Urban Flood Prevention, Flood Fighting, Flood Evacuation and Relief and Rescuing should be collected.

(8) Urban Developing Planning and other Relative Plans. Especially, the construction plans of the lifeline systems, such as traffic facilities, power supply, gas supply, water supply and communication facilities, should be collected.

(9) Statistical Yearbooks. The series of urban social and economic development data can be found in the urban statistical yearbooks.

(10) Major Flood Protection Objects. The basic data of the major flood protection objects including location, elevation, number of staffs and workers, as well as values and vulnerability of properties exposed should be collected.

6.3.2 Preliminary analysis

(1) Data analysis. For the urban areas, the data related flood might usually be collected from various sources with longer time series. However, the collected data may be in conflict with each other, insufficient or even unreliable. Thus, it is necessary to make a systematical analysis for all the collected data before to be utilized.

For most of the cities, the flood frequency analysis have been carried out, and for some of them, the flooding range maps associated with different typical flood return periods have been prepared already. However, in the following cases, the flood return periods and the associate flooding ranges should be reconsidered.

(a) The results have some irrationality that may be caused by hydrological records with something wrong, insufficient time series, or inadequate calculating methods.
(b) New data and advanced means can be used to find more reliable and detailed conclusions that are different from the original results.
(c) Obvious changes have been viewed in landscapes of the city and surrounding areas, as well as the carrying and storing capacities of the riverbeds.
(d) The flood frequency features have been obviously changed because of the dam construction, river regulation, and newly improved levee system and drainage systems, and so on.

(2) Flood causing analysis. The flood causing analysis should be carried out mainly depending upon the local flood events in the past, which follows the procedures as below:

(a) To learn the inundated ranges, the distribution of the highest water stages, and the flood routing processes, and flood damages of the previous flood events as detailed as possible.
(b) To recognize the causing of each flood event, such as flash flood and inner flood caused by the local rainstorm, overflow and levee breach caused by heavy rainfall or the emergency discharge of the dam in the upper stream which leads floods in excess of design standards of the urban streams, storm surge caused by typhoon in coastal cities. Actually, the floods occurred in urban areas are usually the combination of several causes noted above.
(c) To recognize the return period of each causing factor through the time series analysis.
Through the flood causing analysis, we may roughly understand about the types, the intensities, and the distributions of flood risks for a certain urban area.

(3) Flood risk factors variation analysis. At present, most of the cities in the coastal regions in Asian developing countries are in the rapid development period. They are the places where the flood risk causing factors have changed most obviously. The changes of the flood risk are usually resulted from both natural factors and man-made factors. The following factors should be stressed:

(a) The reservoirs being built upstream of the cities: Reservoirs can be operated to modify the peak discharge of big floods to reduce the flood risk for the downstream cities. However, since many reservoirs have turned to take water supply as their main functions, the possibility of emergency discharges during the flood season increases; in case of the dam failure, an extreme flood event may occur.

(b) The developments of the urban flood control and drainage systems: construction of the levee and dike, water gates, pump stations, bypass floodway, diverging channel, flood detention areas, may enhance the flood protection level of the large cities. But the real flood protection level of a city should be proofed, including the variation of the levees (freeboard, structure, quality, stability of the foundation, and maintenance state etc.), variation of the drainage level (drainage capacities, storage capacities, etc.), changes of rainfall-runoff features in urbanized areas (increase of peak discharge, sharpness of the peak shape, decrease of the corresponding protection level), and so on.

(c) The structural works constructed in or along the riverbed and river floodplains, and the variation of the river channel: the regulation of the urban river channels may increase the flood carrying capacities, and improve the urban flood protection level. However, the design flood hydrograph may be changed by newly constructed bridges, docks, or pipes across the river, silting up the riverbed, and so on.

(d) Newly urbanized areas and the economic developing districts of the city: such kinds of new districts are commonly expanded to the lower land with higher flood risk. In particular, development of the new urban districts may increase the flood risk of the old urban areas.

6.3.3 Detailed analysis

The aim of detailed analysis is to evaluate the intensity of a typical flood event with a certain return period, including inundated area, distribution of maximum water depth, duration of inundation, population afflicted, economic losses and the impact degree, and so on.

In the phase of detailed analysis, the typical flood events should be selected according to the practical flood control standard of the city concerned. Generally, a 100-year flood event is used as a based flood. Meanwhile, the 10-, 20-, 50-, 500-year flood events are asked for analysis. The detailed analysis is composed of hydrological feature analysis and hydraulic feature analysis.

(1) Hydrological feature analysis. Through the preliminary analysis, if the flood risk factors have changed obviously, the urban floods statistical analysis should be conducted again. At this time, the rainfall-runoff model should be used instead of the simplified data analysis. If such a kind of model does not exist or the existing model cannot reflect the influence of urbanization on the rainfall-runoff features, new model should be established.

(2) Hydraulic feature analysis. For the cities along rivers and surrounded by mountains and hills, the flooding extension might be limited in a narrow belt. In this case, the flood prone area might be estimated simply by the flood discharge hydrograph with different return periods, or calculated by one-dimensional hydraulic model. But for the plain cities, two-dimensional hydraulic model is needed.

The two-dimensional model for the simulation of flooding in an urban area should be able to reflect the influences of urban flood control and drainage systems and the density of buildings in the urban area. It should be able to consider the encounter of the different factors, such as river flooding, rainstorms and high tides.

By using of a more accurate model, we might get more information on flooding and decrease the inherent error of model predictions, but meanwhile, the better the model is in most cases, the more the data are required. If necessary data cannot be collected completely or there are errors in the data, errors in prediction may occur. Thus, in light of each particular region, the final selected alternative is always the result under the comprehensive estimation.

6.4 Procedures of Urban Flood Damage Analysis

Flood damages in urban areas are getting larger and larger during the process of rapid urbanization. The data of urban flood damages, recorded and predicted, should be very important for the urban flood risk assessment. However, the urban flood damage analysis is much more complicated than the flood damages analysis in rural areas.

6.4.1 Features of urban flood damage

(1) Because the flood control protection levels for the urban areas become relatively higher and the chances of flooding become relatively lower, the historical flood events are usually not sufficient and reliable for the flood damage analysis.

(2) Affected by the urbanization, the flood damages caused by the flooding due to the local heavy rainfalls tend to increase.

(3) Along with the social and economic development, the densities of population and properties have increased. Under the same condition of flooding, the flood damages will rise significantly.

(4) Since the modern cities have increased their dependence on the lifeline network systems, and enhanced their function as the centrality of economy, finance, traffic, communication, in case of disorder caused by flooding, the impacts may radiate to a vast area, and the indirect economic damages might be even larger than the direct losses.

6.4.2 The limitation of urban flood damage analysis

The range in an urban area for the analysis of the direct economic losses caused by flooding is usually asked to the potential extension of 100-year flood.

For the cities where the river flood protection levels have exceeded 100-year flood, the flood damage analysis can only concentrated in the area liable to floods caused by local rainfall with 100-year return period. 2-D flood model might be built to simulate the overflow or dike failure events for floods in excess of design standards if necessary.

6.4.3 The method of urban flood damage analysis

Up to now, there are no unified criterions and methods for urban flood damage calculation. In order to analyze urban flood damage combined with the flood risk map, the procedure is suggested as follows:

Step 1. Dividing the sub-regions: According to the features of the distribution of 100-year flooding and the administrative division (sub-districts, residential districts and large enterprises, etc.), the whole flood prone area should be divided into a series of sub-regions.

Step 2. Collecting the data of classified assets for each sub-region: Data of classified assets should be collected for each sub-region. Some data that cannot be collected directly should be obtained through sample investigation. If the data were only obtained several years ago, they should be adjusted by growth rate.

Step 3. Estimating damage rates of classified assets: The damage rates of classified assets at different level of water depth should be properly modified by taking into account the duration of inundation and the vulnerabilities of the assets.

Step 4. Estimating the direct economic losses of the classified assets: The direct economic losses of the classified assets depending on flood water depth in each sub-districts can be estimated separately according to the values of classified assets, relevant inundated area of flood events with different return periods and the damage rates.

Step 5. Estimating proportionality coefficients of direct and indirect economic losses: The proportionality coefficients of the direct and indirect economic loses of the classified assets can be selected according to the assessment of the vulnerabilities of the classified assets, and the effectiveness of the flood control and emergency response system.

Step 6. Estimating the indirect economic losses: The indirect flood damages of the classified assets can be estimated with the direct economic losses multiplied by the relevant proportionality coefficients.

Step 7. Calculating the total damages: The total damages relevant to the flood events with certain return periods can be calculated from the sum up of the direct and indirect flood damages of the classified assists in all sub-districts.

Step 8. Data updating: The data of the estimated flood damages should be updated. Since it is impossible to make an investigation for the flood damage assessment every year, the procedures from the Step 3 to Step 7 should be repeated by the use of the new growth rates.

It should be pointed out that the urban flood damage statistical data published in many developing countries up to now are in the form of self-reported by the local agencies. It is too rough to be used in making an analysis along the time axis or for comparison among the regions. To improve the above-mentioned schedule of urban flood damage analysis through sample investigation, and then, to combine Urban Flood Damage Model with the Flood Simulation Model will contribute to a reasonable assessment of the urban floods as shown in Fig. 6-1.

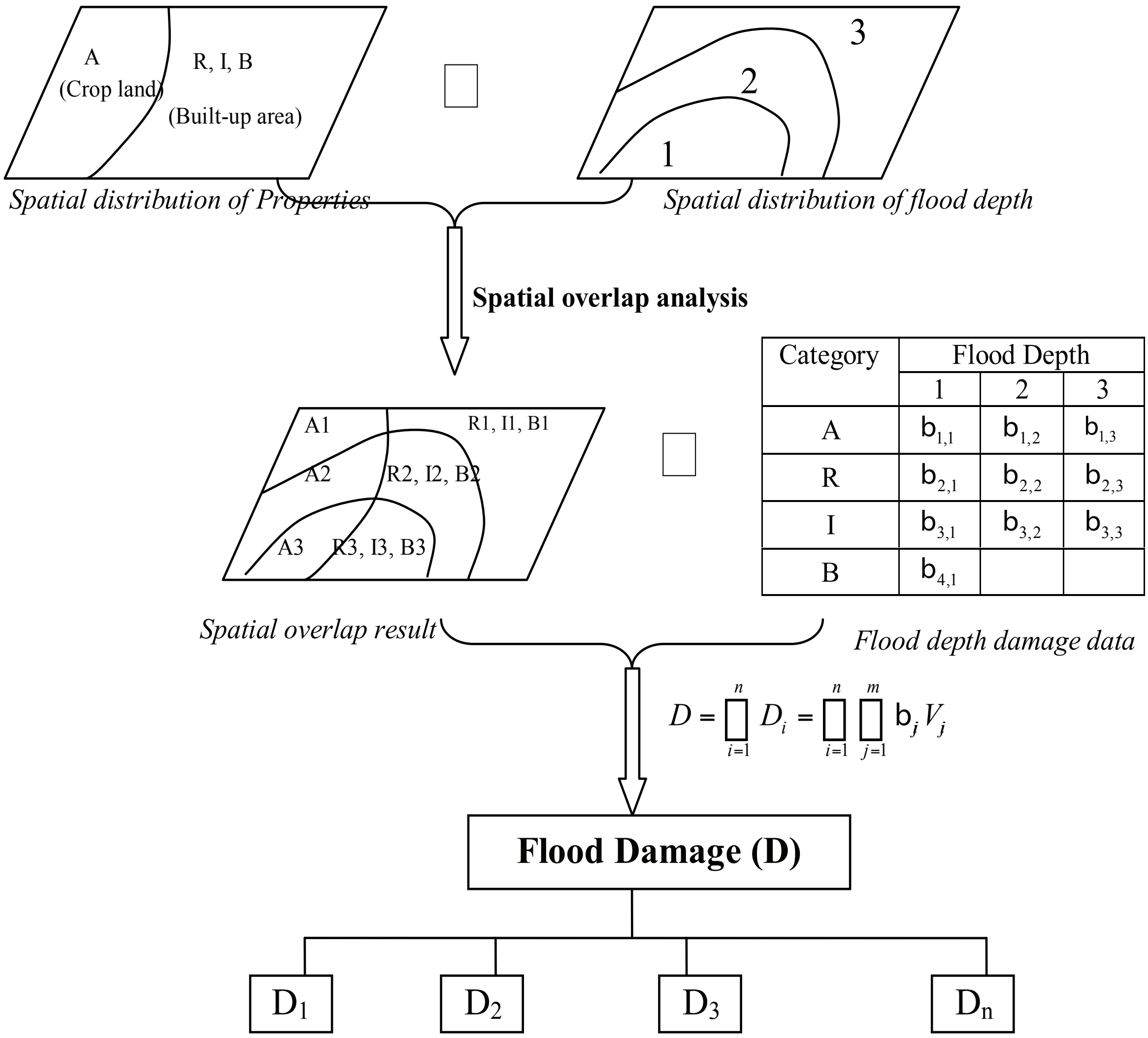


Fig. 6-1 Flow diagram for flood damage assessment model
Note: A=Agriculture output; B=Residential property; I=Industry assets; B=Business assets; Di=flood damage in category i; bij, **Vij=Loss rate, assets in category i under depth j, respectively.**

CHAPTER 7. DECISION SUPPORT SYSTEM FOR UFRM

7.1 Main Aspects of the DSS for UFRM

DSS for UFRM is based on computer network, GIS, flood monitoring and early-warning model, prediction and modulation model, flood disaster assessment model and database management technology. Through human-computer interaction, an information management platform is created according to same standards and norms to integrate and utilize information and data of rainfall, hydrology, engineering, danger degree, disaster conditions and socio-economy which are related to flood-control decision making. As a result, a visualized urban flood risk management system is created to support decision-making, and the system consists of functionalities of rainfall information, hydrological information, flood monitoring and early-warning, river flooding prediction, water project operation for flood control, urban storm water inundation model, disaster assessment, and emergency response.

for the urban areas and the river region the city is in.

Flooding monitoring and early-warning: Provide real-time rainfall and hydrological monitoring for key stations and compare gauged and predicted situation with actual water level. Early warning will be given when the water level exceeds warning value.

River flooding prediction: Forecast water level and discharge through key stations on the upper and down streams of the river(s) running through the city.

Water project operation for flood control purpose: Modulate water for the reservoir(s) and water storage area(s) that is related to urban flood control. This is mainly a simulation and analysis of influences that could happen when upper stream reservoir discharge and downstream tributary flooding meet and when water is diverted by water storage areas.

Flood simulation: Simulate through an urban

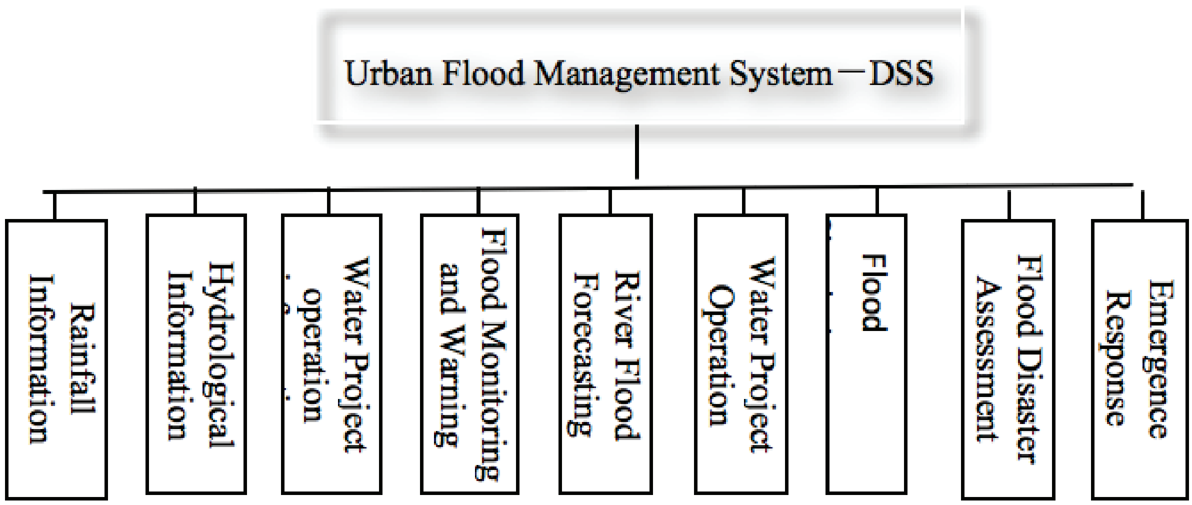


Fig. 7.1 DSS System General Functionality Organization

Rainfall information consulting: Provide rainfall information of the urban areas and key rainfall gauge stations on rivers running through the city.

Hydrological information consulting: Provide water level and discharge of the rivers running through urban areas and the key hydrological stations.

Engineering information consulting: Provide information of engineering related to flood control

flooding simulation model which can simulate flooding in different situations and the impact on the city. The model provides dynamic display of GIS-based simulated flooding to analysis flooding areas, front line at different times, timing of flood locations and highest water level.

Disaster assessment: A GIS-based disaster impact analysis module can utilize disaster analysis results and the city socio-economic data to proceed quantitative analysis about flooding consequences.

Emergency response: Classify early-warning and emergency management levels according to severity degree and impact range. This leveled early-warning and emergency response system is supported by a set of different quantitative initiating standards.

7.2 Integration of Disaster-related Information

Now, as disaster aspects show complex and compound disasters, integrated disaster information analysis is very important. The information regarding on urban flood disaster risk management are (i) the hydrologic and hydraulic characteristics of the river basin, (ii) strategy for risk management such as land-use planning, stream code, building code and guideline for enhancement of river basin, (iii) utilities such as natural drainage system within an urban area, (iv) urban flood risk management policy, and (v) the economic, political, socio-cultural and ecological environment of the flood prone area. These information are not provided by one institute or one government organization but by various institutes and government organizations who they provide information collected from monitoring and measuring, determined or estimated from integrated analyzing or/and modeling for their own objectives. For the urban flood disaster management.

Creating a flood-control decision-making system needs to collect and integrate basic materials of the river region where the urban areas and city are located. Specifically this will include flood control planning, water planning, flood-control planning for the river region, water modulation planning, geographical materials including landform, rivers, jurisdiction boundary, and elevation, hydrological information, historical flooding information (affected range and water level), draining engineering for flood control purpose (river section, gauging stations distribution, location of embankment, water slucegate, and pumping station, remote sense images, socio-economic information.

(1) Planning and preparatory plan
Urban flood control planning, drainage planning, flood-control preparatory plan, emergency response plan, and water modulation plan.

(2) GIS information
Landform: Urban landform map on a big scale at lease 1:10000
Rivers: Main stream and tributaries in the city and go-by rivers that could affect urban water level.
Road: Stem and general roads in the city area
Jurisdiction boundary: Boundaries at different levels of city, district, and street.

(3) Hydrological materials
Gauge stations: location of hydrological stations and rainfall stations.
Rainfall information: Rainfall process, design rainfall process.
Hydrological information: Water level and discharge of key stations, existing drainage capacity of rivers/waterways running through urban areas and the water level.
Historic and Typical flooding: General situation, flooded range, water level, loss, human damage and death.

(4) Drainage engineering for flood-control purpose
River section: Location of key river sections and gauged section data.
Embankment: Base elevation, top elevation, width
Pumping station: Drainage capacity, use policy, switch-on status
Sluice gate: Maximum drainage volume, use policy, switch-on status
Drainage area division: Run-off quotient, drainage modulus, area
Reservoir: Capacity, water-drainage capability, and information about the water catchments.

(5) Remote sense images
Air-aviation/space remote sense images of 2.5m, 1.0 m, 0.6m, or even closer distance and higher resolution.

(6) Urban socio-economic information
Community Committee is the bottom unit conducting statistics for socio-economic data survey, and subjects include population, household, industry, fixed assets, amenities and

public infrastructure. 9 industries are included: Industry and Mining, Commerce, Transportation, Communication, Construction, Government, Culture and Education, Agriculture (including grain and oil storage, seeds, agricultural machinery), goods storage and logistics.

7.3 GIS Based Information Management and Visualization

Geographic Information System (GIS) is a system that utilizes computer and its accessories to collect, store, analyze and describe the surface and spatial information of the whole or parts of the earth. For urban flooding risk prevention and emergency management, spatial information is widely involved in meteorological, rainfall, hydrological information analysis and treatment, flood development trend prediction, emergency plan making based on risk analysis, and urban flood control and drainage plan making and updating. GIS technique can manage, consult, analyze and present visually related data, explore hidden relationship among the data, thus provides a new supporting method for urban flooding risk management and decision-making.

The auxiliary tools for DSS for UFRM include:

(1) GIS-based Urban Flood Risk Management
The urban flood risk management database includes all types of hydrological data, disaster data, socio-economic data, and many kinds of image data, spatial data and experts data. For a city, such data could be of many types and forms with large volume and complicated relationship. How to manage and utilized them is one of the fundamental tasks of Decision Support System for UFRM.

The urban flood risk management system needs to establish and describe relationship between/among different kinds of subjects. To be specific, it is to define the urban flood risk information temporal and spatial data model structure and changes, event description/presentation method, change types definition and presentation methods, change dynamics description method. Based on the defined temporal-spatial data model, management of huge volume of data, temporal or spatial index, temporal-spatial element co-relating, consulting, and temporal sequence analysis, the urban flood risk management database is established that includes basic geographic data, hydrological and rainfall data, engineering data, meteorological data, modeling data, emergency response data, and flood simulating results data to handle, consult, search, update and maintain the spatial data, providing comprehensive data support for urban flood risk management.

(2) GIS Spatial Analysis and Visualization
The GIS technology provides an effective approach for flood risk analysis and division as it enables the weight assigning for natural, geographical and social factors related to flood risk management and their laying up spatially. In general, the GIS spatial analysis and visualized simulation provides real time data and optimize model parameters for hydrological forecasting, flood evolution, and disaster assessment models. City is usually characterized in terms of socio-economic conditions, wide influence, increased impervious area, bigger runoff. For these reasons, GIS plays more important roles in urban flood risk management as it can provide spatial character analysis and proceed high resolution data. Outstanding features of GIS in UFRM include urban water catchment and receding prediction, existing drainage facilities (pipelines and pumping stations) information management, water drainage facilities planning, design and construction management, 4D storm temporal-spatial analysis, socio-economic data spatial distribution by community/block, storm distribution and visualized presentation of water-logged community, and storage, maintenance and management of high-resolution, layered, multi-sourced, and frequently updated data.

The GIS spatial analysis and visualization techniques specially needed by urban flood risk management decision-making support system include hydrological analysis, space layering analysis, neighboring area calculation, data embedding and eccryption, network analysis, resource allocation, high-resolution data description, multi-dimension data presentation, real-time dynamic treatment, concurrent technology, interactive technology, and data visualization.

7.4 Flood and Inundation Simulation

7.4.1 Basin based flood mitigation analysis

Urban flood control standards are usually higher than those for rural areas of the same river region. When extraordinary flood happens, measures can be taken to lower water level and flow in the rivers to minimize flooding impact on the city. Such measures include cutting peak by upper stream reservoir water diversion and modulation, diverting flood through the spillway, and diverting/storing water in water retention area.

For flood-controlling cities located on major rivers, river region hydrological and hydraulic coupling model is created to simulate flooding. The hydrological model work for upper stream runoff prediction, key hydrological station flood prediction, key reservoir inflow process prediction, and outlets of key tributaries flow process prediction. A 1-dimension hydraulic model displays the stem waterway flood evolution process and is integrated with hydrological predictions results to simulate the conflux process. A 2-dimension flood simulation flood simulation model can simulate the flooding process in water retention area and connect with the 1-dimension river model to analyze and simulate the effect of water storage in reservoir or water retention area on the lower reaches urban water ways. A 2-dimension flood simulating model can connect with the above said 1-D and 2-D models to simulate flood prediction and modulation for going-thru rivers and analyze/calculate possible impact when flood overflows or breaks levees. The GIS-based system enables dynamic display of flood emulation results, analyze situation of flood-impacted areas, as well as frontier line at different times, flooding time of different locations and highest water level.

Coastal cities face risks brought by astronomic tide and storm surge the major threat. When the two threats meet, the coastal cities are usually devastated by severe flooding. For cities located at river estuaries, special attentions should be given to the extreme adversity when river flooding and storm surge happen concurrently. It is necessary to analyze sea tiding laws and then utilize flood simulation model to analyze the flooding risk in case of concurrence of river flooding and storm surge, as well as the possible impact when flood overspills or breaks levees.

7.4.2 Urban area storm waterlogging analysis

A 2-D hydraulic model can be used for early-warning and prediction of urban storm water logging and possible risk/impact when levees of urban water ways breaks. The hydraulic model should be able to reflect the impact caused by various buildings and structures such as road, railway, drainage ditch, bump stations, and high-density building blocks. Underground pipeline network, drainage network and boundary division, relation between water retention area and water storage water ways should be considered as much as possible. For areas with good information of underground drainage pipeline network, the model can simulate situations with accurate pipeline network information, while proceed with general estimate based on drainage capacity of the underground drainage pipelines. Considering water logging situation in urban area which continues to worsen, main roads can be treated as flood passage way in simulation calculation. For simulation of waterlogging in overfly areas, micro-landform and pump stations should be considered; for underground space water logging and drowning, the underground space area and elevation should be considered.

In calculating and analyzing, standards for 10-year, 20-year, 50-year, 100-year, and the most severe rainfall should be identified based on collected hydrological and meteorological information. Uneven temporal and spatial distribution of rainfall should be considered as well to calculate and simulate storm water logging before levees break, and proceed with prediction, early-warning and emergency management according to the simulation results.

7.5 Risk Prediction and Assessment

Disaster assessment is one of the key components of the decision-supporting system, which can be used to assess the flood and water-logging disasters in different stages, i.e. pre-disaster, in-disaster and post-disaster.

Pre-disaster assessment is to perform flood simulation and simulate the flood inundation process by using flood analysis models. In-disaster assessment is to undertake flood disaster loss assessment based on the real-time flood inundation monitored by means of remote-sensing. Post-disaster is to perform flood disaster analysis based on the investigated damage data after the disaster.

It is recommended to include pre-disaster assessment and in-disaster assessment modules in a decision-making support platform for urban flood management.

Pre-disaster assessment：disaster assessment ahead of flood disaster happening. That is to analyze the economical losses and impacts under different flood scenarios by using a GIS-based disaster analysis module, which can be realized based on the data of water depth, inundation area and duration simulated by two-dimension flood simulation models, and , with the help of displaying the social-economic data on the spatial layers.

In-disaster assessment：disaster assessment just in the process of disaster happening. In the process of flood disaster, the real-time flood inundation area can be estimated based on the remote-sensing images. So, the disaster assessment can be undertaken by analyzing social-economic impact of flood over the inundation area with the help of GIS and spatial data base.

7.6 Warning and Emergency Response

On the basis of geographic information system of urban flood, flood forecasting ad simulation system, flood dispatching system and database system, decision-making support system for urban flood risk management realizes the analysis of possible consequences under various water projects operation scenarios based on rainfall and hydrological information for a urban area, and drawing up emergency response countermeasures for supporting emergency action.

Emergency response can be considered as a series of sub-plans that address communication and public information management, search and rescue co-ordination, shelter management, stockpiling and distributing of food and supplies, contacting and requesting additional support, debris management, financial management, volunteers co-ordination and donations management.

The foundations of a flood emergency action are a mobilisation plan, comprehensive disaster plan and well co-ordinated and trained flood fighting corps.

A flood fighting corps may be mobilised to a state of alert with various stages: mobilisation, preparation and stand-by and dismissal. It is useful to have powers to call up the inhabitants when high water threatens, with preference given to volunteers.

Organisation and training of search and rescue teams are done locally, regionally or nationally but in real flood conditions, participation of volunteers, citizens and relatives is significant, thus requiring the co-ordination to develop as the action proceeds.

7.7 GeoLinking System (GLS)

In order to assess typhoon related disaster and share the typhoon related disaster information, GeoLinking approaches is powerful. The Typhoon Information menu has all the information of the typhoons from 1951 to 2010, which are stored in database of GeoLinking system including GIS. Similar typhoon can be checked out by the computer program running in background mode. The predicted track and the estimation of loss can be simulated and then compared with observation data and all historical typhoon trajectory and damages which all the typhoon information from 1951 to 2010 are listed below the system. You either click a name of typhoon or you can insert specific period from one date to another date, then the information on the typhoon will be shown. The character “I” icon is clicked, detailed information will be shown in table which includes latitude, longitude and central pressure and be shown.

When you select the Similar Typhoon search tab, a box will be displayed to insert the date, longitude and latitude, and central pressure can be inserted as shown in③of Fig. 1. To facilitate the input process, the text file can be imported. The detailed track information can be saved and exported as a text file format. Disaster Information shows all the damage related information based on the data obtained from the member countries.

Web GIS based system enables user to choose region or province of interest, the enhance view of which is shown to allow user to select any particular data displayed in the map. Another way of display the disaster information is to select a particular typhoon and then, related disaster data and information are shown in the Web GIS based system. The localized damages are estimated by localized KDFs of typhoon-related damages in the local regions and the results are converted to GIS map and overlapped to the various GIS information such as utilities, populations, land use, etc.

The GeoLinking system incorporates such an approach to enable disaster manager to access disaster information. The Web GIS based system enables user to choose region or province of interest, the enhance view of which is shown to allow user to select any particular data displayed in the map. When user click any interesting image icon displaced in the GIS map, the photo images and information such as media, report and portal information will be presented shown in ⑥ of Fig. 5-1 (Example of Geo-Linking services to display the typhoon related disaster information).

CHAPTER 8. TRAINING AND RESEARCH IN SUPPORT OF UFRM

8.1 Gaps on UFRM in the Typhoon Committee Area

There are in general two major aspects of development works relating to the UFRM project: (i) improvement in infrastructural measures, facilities and organization (e.g. river training, drainage systems, dykes, dams, coastal engineering works, reservoir management, etc.); and (ii) preparedness and emergency response to triggering events, such as tropical rainstorms or heavy rain associated with tropical cyclones (e.g. observation, monitoring, analysis, weather and hydrological forecasting, warning delivery, etc.), that may lead to critical urban and coastal flood risks.

In consideration of the scope of activities under the Typhoon Committee, discussion here will focus on the second aspect. Early Warning System (EWS), or sometimes referred to as Multi-Hazard Early Warning System (MHEWS) to give emphasis on the multi-facet capability of specific systems, is now often coined as a generic term for all kinds of technical systems to provide warnings and alerts for natural disasters (directly or indirectly related to weather, climate, climate change, as well as hydrological, oceanographic, geophysical and seismic activities).

Given that there will always be uncertainty in forecasts and warnings, a critical consideration in designing a good EWS is therefore in its ability and flexibility to make plans accordingly given the uncertainty involved. Forecasters should be able to update the warnings in a consistent and timely manner, as well communicating the uncertainty or confidence level effectively as more information comes in; and the relevant stakeholders should be placed at the appropriate level of readiness to make risk assessment and adjust plans for the best possible cost-benefit outcome.

An increasingly popular trend is to stress on the importance of an effective and efficient end-to-end warning service, hence from observation, analysis, forecast, warning, information flow, all the way to users' adequate awareness, understanding, and response to the warnings. As such, EWS is not just about accurate and timely forecasts and warnings. A comprehensive well-structured EWS should contain the following three key components:

(a) ***Issuance of warnings:*** adequate and reliable observational data in real time, with timely updated forecasts and warnings based on sound scientific analyses (often, for weather-related disasters in particular, the responsibility rests with the national meteorological services);

(b) ***Interpretation of warnings***: good understanding of the risk and vulnerability over a certain target region under different natural disaster scenarios (requiring scientific expertise in specialized fields with substantial local knowledge, e.g. hydrological assessment for flood forecasting given the varying intensity and distribution of rainfall over a river basin or catchment area); and

(c) ***Communication of warnings***: efficient information flow, an operation increasingly automated through the use of computers and information technology, between forecasters and key decision-makers, among stakeholders and operational units, as well as to user communities at risk (in most cases coordinated by a body comprising government departments, emergency response agencies and NGOs).

Underpinning all three key components is the human resources and capacity required in developing, operating and maintaining the EWS. In general, technical capacity needs to be built up in the following aspects:

a) awareness of warnings and alerts by users and recipients;
b) updated and well-maintained observational networks and systems;
c) usage of satellite/radar data, particularly for rainfall estimates;
d) application of global NWP data;
e) human resources and training, especially for forecasters and other technical support staff at the national/provincial levels;
f) hydrological modelling capacity;
g) power supply assurance during inclement weather situation;
h) coordinated reservoir management for flood control;
i) scenario assessment for risk management

purpose;

j) communication between provinces and communes, and among technical professionals, emergency units and key decision-makers; and

k) collaboration with academic institutes in leveraging resources for training and research support.

With emphasis on urban flooding and coastal inundation, the forecasting and warning challenges are: (1) wind and storm surge associated with tropical cyclones over the coastal region; (2) quantitative precipitation estimates and forecasts (QPE and QPF); (3) communication of warnings as well as forecast uncertainty; and (4) the need for effective large scale monitoring and forecasting capability in support of small scale region-specific EWS.

There is apparently limited capacity in hydrological forecasting techniques as well, relying mostly on statistical methods and lacking the more sophisticated approaches based on hydrological modeling. Inefficient information flow between the meteorological and hydrological communities can also sometimes lead to delays and misjudgment in flood risk assessment.

8.2 General Training Resources for Capacity-building

A major barrier to capacity-building in the region is the limited language proficiency such as English to facilitate an accelerated process of learning and to take advantage of technology transfer from abroad. While opportunities exist for overseas exposure, relatively few can really benefit. Under the circumstances, the more likely course would be: (1) establishing a regional EWS training hub in East Asia such that developing countries in the region may have the opportunity to become familiar with the latest technology available; (2) through a combination of "train-the-trainer" and "learning-by-doing" approaches, technical staff with sufficient English proficiency to be trained and re-trained at the regional hub on short-term attachment and assignment; and (3) through regular planned programmes, the trained trainer to train up local staff and technicians. The conceptual idea of a regional EWS hub may require collaboration with relevant WMO programs and funding support from potential donors.

Admittedly, for many Typhoon Committee Members, limited technical capacity remains an area of concern at both the national and provincial levels where tight manning situations also inhibit extended staff release for local, regional as well as overseas training opportunities. Progress will inevitably take time, but the hope is that relevant knowledge, skill and techniques will become more widely available as the national capacity is built up, and that pilot projects strategically aimed at specific regions of priority (e.g. the WMO Severe Weather Forecast Demonstration Project for South East Asia countries in Viet Nam, Cambodia, Lao PDR and Thailand) will help to establish much needed facilities and resources in disaster-prone areas.

Apart from taught courses and attachment training in other countries, expert missions and visits to target regions, as well as better utilization of online resources are also viable alternatives that would help to build up the technical capacity of operational personnel. Expert missions are most fruitful if strategic long-term collaboration can be established with advanced meteorological and hydrological centres, in many cases through sponsorship by international funding agencies. Such missions allow experts to get familiarized with local conditions and propose solutions to address specific needs. Follow-up actions can then be pursued for technology transfer or tailored training.

Even though online training resources are becoming more widely available these days (e.g. NOAA's COMET modules), there is a general feeling that such material is still very much under-utilized. Admittedly, these resources are often based on more sophisticated and well-equipped conditions in the developed world. However, the underlying principles and concepts can still be very useful for general education purpose. If English proficiency is a hurdle, then it may be useful to set up local study groups to work on the basic translation of such online resources, or facilitate the learning process through interpretation by members in the study groups who have a better understanding of the English language.

8.3 Training Strategies under the Typhoon Committee

8.3.1 Existing resources under Training and Research Coordination Group (TRCG)

TRCG plans to have more cross-cutting training and research initiatives among the meteorological, hydrological and DRR components of the Typhoon Committee, including the organization of joint meetings/activities. To maintain continuity and to encourage sustainable capacity building, follow-up activities will be pursued where feasible in support of training/research topics covered in roving seminars and ad hoc workshops; e.g. through more purposely planned research fellowship projects. For high priority project (e.g. UFRM) and research areas, the setting up of task forces comprising nominated experts from Members or through the mobilization of the TRCG list of resource persons can also be explored.

Roving seminars are primarily for capacity building purposes, with knowledgeable experts visiting Members' countries, and delivering lectures and training on subjects of topical interest. With financial support from the Typhoon Committee Trust Fund (TCTF), the travelling schedule of the annually held roving seminars aims to cover and serve as many Members as possible. For any seminar venue, participants from Members in the neighbouring regions are also invited and encouraged to attend.

Research fellowships serve to promote operational development works through the attachment of visiting scientists based on short-term bilateral arrangements, often with funding and logistic support offered by host Members. One of the merits of the scheme is that the visiting fellow has a chance to work closely with experienced scientists at the host's facilities. This provides an opportunity to acquire knowledge and skill with hands-on experience, and to transfer technology and latest research findings back home for operational applications.

8.3.2 Initiatives in support of UFRM

To best utilize the resources available to the Typhoon Committee and to take advantage of the mechanisms already established under the TRCG framework, past and anticipated training and research initiatives in support of UFRM are highlighted as follows:

- Roving Seminar 2011 was organized with the theme "Heavy Rain and Flood Hazards associated with Landfalling Tropical Cyclones", with participants from the UFRM pilot cities also attending. Key results and suggestions arising from the seminar were presented and discussed in a one-day QPE/QPF workshop held in conjunction with the Integrated Workshop in late 2011.

- The Sentinel Asia Typhoon Committee Urban Flood DRR Workshop was successfully held in Macao China on 27 Feb – 2 Mar 2012.

- Research fellowships with emphasis on QPE/QPF and relevant technology transfer will be actively pursued and promoted where feasible.

- More strategic planning in support of UFRM and other related cross-cutting initiatives will be taken into consideration in formulating the new 4-year cycle of TRCG work plan (2014 – 2017).

Based on the feedback gathered and the experience gained from the pilot phase, more long-term strategic planning for continuing training and research in support of Members' capacity-building can be mapped out. Guidance material and best practices can then be compiled and updated for reference as the UFRM project gradually extends to other cities within the Typhoon Committee area.

CHAPTER 9. CONCLUSION AND WAY FORWARD

Urban flood risks keep an increasing trend in the developing countries in the Asian-Pacific region. During the process of rapid urbanization, the cities accumulate not only high density of population and properties, but also the risks. Although every city has paid some efforts in protection against urban floods, as a matter of fact, the gaps between the higher security demands and worse risk situations are extending. There are pressing needs to give security against urban floods through the capacity building in enhancing Urban Flood Risk Management (UFRM).

Many of the cities in the Typhoon Committee Area (TCA) are suffered from different urban flood issues, and some data showed that urban flood events increased in recent years. Great achievements have been made on the structural measures for urban flood management in the TCA. And it was also proved that flood warning system was a very effective non-structural measure for avoiding damages caused by urban floods.

Flood risk management is an integrated approach to the development of flood risk strategies that involve engineering, settlement, development, public administration, community-based strategies and land use planning with environmental consideration. The best and holistic approach in URFM is an integration of structural and non-structural measures. Although the best solution may be condition specific, which may depend on factors such as climate, topography, geology and the level of development or urbanization. In recent years, soft approaches such as monitoring and forecasting, flood risk and inundation mapping, effective early warning system and enhanced education and awareness have proven to be effective.

Structural measures for flood control and drainage are still key measures to reduce flood risk especially in urban areas at present stage for most of the cities in the developing countries. While, the reasonable disposition and operation of the flood control and drainage system will put forward higher requirement for the development of the information management system, and flood risk assessment system and decision support system.

Recent survey to some TC Members on the improvement of urban flood risk management suggests the following needs Increase of budget allocation; Enhancement of the awareness and preparedness of communities in flood-prone areas; Enhancement of flood control planning in urban area; River management measures (maintenance, management and quality improvement of levees, maintenance of flood control channel and facilities). Among these needs, increasing budget allocation was regarded as the most important one in urban flood management. It should be emphasized that the budget should be properly reallocated for both structural and nonstructural measures, such as flood forecasting and warning system.

The major challenges for the improvement of urban flood monitoring and forecasting/warning system in the TCA included needs for Development of real-time flood forecasting system; Utilization of diversified data such as radar precipitation data, weather forecast, topographical data and land-use data; Announcement of evacuation advisory and instruction, distribution of flood information to local residents; Producing real-time flood-inundation warning maps for cities; and Establishment of a community based flood early warning system.

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APPENDIX A - GOOD PRACTICE ON UFRM FROM MODEL CITIES STUDY

Three model cities, namely Ansung of the Republic of Korea, Shanghai of China and Yokohoma of Japan, were selected for the sake of collecting good practices on UFRM this study.

a. Developing Comprehensive Urban Flood Management Strategies

In China, risk management ideas have been introduced into flood prevention and mitigation since 2003. A comprehensive strategy has been taken to manage urban flood, which is to combine strategies for flood risk and hazard mitigation, urban development, and countermeasures coping with climate change Flood risk management and disaster recovery and compensation are more stressed (Cheng, 2001, 2008). In flooding areas, community management is introduced to regulate human activities. Appropriate and feasible flood control standards were established together with flood prevention schemes and flood regulation plans, where a variety of measures are taken to ensure safety under the established flood control standard and minimize loss caused by exceeding-standard flood. Meanwhile, efforts are also being taken to utilize storm water as a complementary resource for water supply.

In Japan, comprehensive flood disaster prevention plans have been developed based on related acts. Preventive measures to basin such as installation of retarding basins and discharge ponds are promoted.

b. Highlighting Land Use Planning and Regulation

All the three model cities have taken the land use regulation as measures for avoiding damages by urban flood. In Yokohama city, according to the "Act on Countermeasures against Flood Damage of Specified Rivers Running Across Cities", developers must construct rainwater storage and infiltration facilities if the area is over 1,000 m^3 and owners of discharge ponds over 100 m^3 are obliged to maintain their function. The city has an ordinance to coordinate development by private sectors with city planning to promote creation of ideal urban environment. Based on the ordinance, the city directs developers to construct rainwater runoff control facilities and maintain open spaces to grow trees. Besides, Yokohama city designates "urbanization promotion area" and "urbanization restricted area", according to the city planning act. The designation functions as land use control to prevent development of areas to retain their function to flood damage alleviation such as conservation of forests, agricultural lands, and so on.

c. Improvement of Meteor-Hydrological Monitoring, Forecasting and Warning

In Korea, the National Institute of Meteorology Research (NIMR) uses MAPLE (McGill Algorithm for Precipitation nowcasting and Lagrangian Extrapolation) method to combine the point rainfall observed at the rain gages and the rainfall estimated by meteorological radar for better estimation of areal rainfall. This technique has been used in improving urban flood forecasting and warning for Ansung city. Operationally, hydrologic data wirelessly transmitted in real-time from the observation stations are sent and processed automatically into the database of Ansung Stream Flood Control Office. After that, the water level of rivers and flooding scale are calculated for the flood forecasting areas by using a distributed rainfall-runoff model. When water level rises over a pre-defined threshold, flood-warning or flood-alarm will be announced to the public through the mass media (broadcast, newspaper, etc) and related agencies so that citizens can prepare and evacuate against flood.

In China, an integrated typhoon and heavy rain Monitoring &Detection System was developed and has been put into operation in Shanghai Meteorology Bureau (SMB) for years. Based on WRF (Weather Research Forecast) meso-scale model a seamless prediction system has been established by Shanghai Typhoon Institute (STI) and used in routine operation named STI-WARR for 1-12h, STI-WARMS for 3 days and STI-EnWARMS for 5 days forecast, respectively. Some new numerical techniques for forecasting are developed, such as digital filter, cloud analysis, ADAS-3DVAR and hourly assimilation cycle. Except for rainfall some special products are output from it, such as radar reflectivity, wind profile, lightning index, and visibility and satellite-like. Also, STI is developing some new numerical techniques for TC forecasting such as BDA (bogus data assimilation) technique, satellite data assimilation, GRAPES_TCM TC model, relocation cycle, ensemble and air-land-sea coupled model, with them the track and intensity forecasts are significantly improved.

d. Remote Sensing and GIS Application in Flood Hazard/Risk Mapping

A variety of Flood hazard/risk maps have been developed in all the three model cities, which contribute to guidelines for land use planning and strengthening the capacity buildings for specific regions.

Flood hazard mapping in Shanghai consists of the one for downtown and Huangpu river flood-walls and the other one for the coastal area. Flood hazard mapping for the downtown area can be realized by using 2-D urban rainstorm flood simulation models to generate probable flood inundating scope, inundating duration and process of dyke failure or city rainstorm waterlogging under the condition of shanghai affected by rainstorm, tide and flood from upstream according to the most likely and harmful principles, and it can be implemented on GIS environment. Besides, flood hazard affected by tide in coastal area can be analyzed through the principle of hydrology and geography from the angel of genetic analysis; accordingly flood hazard mapping can be implemented. Additionally, another kind of flood hazard map is provided by the Shanghai Meteorology Bureau, in which the factors such as regional total rainfall, drainage capacity, and vulnerabilities were integrated to get the comprehensive risk map.

In Yokohama city, publication of flood-prone area maps was accomplished by the national government in 2007. Publication of flood hazard maps for each ward by Yokohama city for riverine flooding, with subsidy from the national government and the prefectural government.

In Ansung city, a flood hazard map of the Ansung Stream basin is being developed by MLTMA (Ministry of Land, Transport and Maritime Affairs) of Korea, which shows possibility for risk from flood.

e. Dissemination of Flood Warning Information to Individuals

Various public-level dissemination platforms have been established in each model city, such as the mass media, government spokesman system and the Internet.

In Korea, when there is a possibility of the damage to lives and properties from flooding, the announcement of flood-warning or flood-alarm will be issued to the public for prevention or reduction of damages. When water level rises over defined point, the flood-warning or flood-alarm will be announced to the public through the mass media (broadcast, newspaper, etc) and related agencies so that citizens can prepare and evacuate against flood.

In Japan, Flood advisories, warnings and forecasts are transmitted to municipalities via prefecture. FAX information from MLIT office is also sent to prefecture, cities and wards. Yokohama city disaster prevention information system sends information directly to residents by e-mailing information to mobile phones, and this information is also provided by the Internet, CATV or sirens. The MLIT office disseminates alert information to registered users by e-mail when rainfall, water level, inundation depth exceed certain values. Kohoku ward provide information by internet fax to underground facilities that are mainly used by aged people and infants.

In Shanghai, the spokesman system was developed by the flood control headquarters to ensure authorized announcing about flood-related information timely, accurately, objectively and roundly. Weather departments in SMB provide special services through multi agency cooperation involving governmental departments, and communications departments facilitate the distribution of early warning information in a timely fashion. The Public-level Dissemination Platform is effectively established and in operation in Shanghai. The first community warning light system of the nation has been constructed in Baoshan district, Shanghai. The system will be extended to the tallest buildings in each district. Cell phone massage dissemination mechanism for serious disasters has been implemented. Public warning dissemination network includes public electronic screens, billboard TV screens, and electronic road signs.

APPENDIX B - INFORMATION ON THE PRODUCTS TO UFRM

a) NWP outputs

Techniques introduced in the Good Practices

- A seamless prediction system used in the routine operation forecast established by Shanghai Typhoon Institute (STI) based on WRF meso-scale model, named STI-WARR for 12hours, STI-WARMS for 3 days and STI-EnWARMS for 5 days forecast respectively in Shanghai. Model outputs in the webpage of WMO Typhoon Landfall Demonstration Project (http://tlfdp.typhoon.gov.cn/ index.php?controller=listpic&pid=58);
- High resolution model named STI-WARR (STI WRF RAPID REFRESH) by STI in Shanghai.

Other information

- NWP grid point value (GPV) at each meteorological center's server under the framework of WMO (ex. WIS Portal - GISC Tokyo: http://www.wis-jma.go.jp/ and Beijing WIS Portal: http://wisportal.cma.gov.cn/wis/);
- NWP models used by the Typhoon Committee Members in the Chapter 3 of the Typhoon Committee Operational Manual (TOM http://www.wmo.int/pages/ prog/www/tcp/ operational-plans.html);
- WMO Technical Progress Report on the Global Data-Processing and Forecasting System (GDPFS) and Numerical Weather Prediction (NWP) Research for 2011 (http://www.wmo.int/pages/prog/www/DPFS/ProgressReports/2012/2011_GDPFS-NWP.html);
- NWP models operated by Hong Kong Observatory (HKO) : Operational Regional Spectral Model (ORSM) and Non-Hydrostatic Model (NHM) shown in http://www.hko.gov.hk/publica/reprint/r882.pdf. and that of NHM in http://www.hko.gov.hk/publica/reprint/r882.pdf.;
- NWP models operated by Japan Meteorological Agency (JMA) : Global Spectral Model and Meso-Scale Model in (http://www.jma.go.jp/jma/jma-eng/ jma-center/nwp/nwp-top.htm, http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev/text11-1.pdf) Meso-Scale Model operated by JMA in (http://www.jma.go.jp/jma/ jma-eng/jma-center/nwp/nwp-top.htm);
- Storm surge model for TCA operated by JMA in the Numerical Typhoon Prediction Website (https://tynwp-web.kishou.go.jp/) and (http://www.jma. go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev/text11-3.pdf, http://www.wmo.int/pages/prog/www/DPFS/ProgressReports/2012/2011_GDPFS-NWP.html);
- NWP models operated by Korean Meteorological Administration (KMA) : Global Prediction Model (GDAPS), Regional Prediction Model (RDAPS) and Regional Tide/Surge Model (RTSM) in (http://web.kma.go.kr/eng/biz/ forecast_02.jsp, http://www.ral.ucar.edu/jnt/events/wgne27/presentations/mon/KMA_CentreRep_27thWGNE.pdf), KLAPS (Korea Local Analysis and Prediction System) with 5km spatial resolution (http://app.nimr.go.kr/ radar/Doc/11th_workshop/ session/f01.pdf) and VDRAS (Variational Doppler Radar Assimilation System), specialized system for Seoul Metropolitan area with 1km resolution (http://app.nimr.go.kr/radar/Doc/11th_workshop/session/ p05.pdf, http://ral.ucar.edu/projects/wind_energy_workshop/presentations/ VDRAS_for_Wind_Ramp_Nowcasting_Sun_26.pdf);
- Forecast model prediction for South China Sea region developed by KMA (http://www.kma.go.kr/ema/nema03/rall/index.jsp);
- NWP maps CMA, KMA or JMA global models in the Numerical Typhoon Prediction Website of Regional Specialized Meteorological Center (RSMC) Tokyo – Typhoon Centre (https://tynwp-web.kishou.go.jp/) and WMO Typhoon Landfall Demonstration Project (http://tlfdp.typhoon.gov.cn/index.php?controller=listpic&pid=58) and Members websites);
- JMA upper level charts are shown in http://www.jma.go.jp/jp/metcht/kosou. html;
- Information provided under the Severe Weather Forecasting Demonstration Project (SWFDP) in South-east Asia in http://eng.weather.gov.cn/swfdp/, http://www.wis-jma.go.jp/swfdp/ra2_swfdp_sea.html and http://www.kma.go.kr/ema/nema03/swfdp/index.jsp.

b) Typhoon track forecast

Techniques introduced in the Good Practices

- GRAPES_TCM TC model, etc. developed by STI in Shanghai.

Other information
- Information on the track forecast used by TC Members in Chapter 3 of the TOM;
- Examples of probability maps of strong wind distribution by JMA in http://www.jma.go.jp/jp/typh/typh_prob.html;

c) Ensemble prediction system (EPS)

Techniques introduced in the Good Practices

- STI-EnWARMS by STI in Shanghai.

Other information
- Information on the NWP EPS models in the WMO Technical Progress Report on the GDPFS and NWP Research for 2011;
- Ensemble tropical cyclone track forecasts provided by WMO North Western Pacific Tropical Cyclone Ensemble Forecast Project (NWP-TCEFP) in http://tparc.mri-jma.go.jp/cyclone/login.php, and provided by WMO Typhoon Landfall Demonstration Project in http://tlfdp.typhoon.gov.cn/index.php?controller=listpic&pid=58;
- Consensus method applied to nine NWP centers' track forecasts in the Numerical Typhoon Prediction Website of RSMC Tokyo (https://tynwp-web.kishou.go.jp/);
- Ensemble TC Strike Probability Map provided by WMO NWP-TCEFP in http://tparc.mri-jma.go.jp/cyclone/login.php, and provided by WMO Typhoon Landfall Demonstration Project in http://tlfdp.typhoon.gov.cn/index.php?controller=listpic&pid=58;
- Multi-model (11 models) ensemble prediction developed by KMA in http://web.kma.go.kr/eng/weather/typoon/prediction.jsp.

d) Weather forecast guidance

Other information
- Information on the forecast guidance in the WMO Technical Progress Report on the GDPFS and NWP Research for 2011.

e) Quantitative Precipitation Forecast (QPF)

Techniques introduced in the Good Practices

- MAPLE (McGill Algorithm for Precipitation nowcasting and Lagrangian Extrapolation) method developed by National Institute of Meteorology Research (NIMR) in KMA (Korea Metrological Agency) and McGill University in Ansung City in Korea (ftp://ftp.wmo.int/Documents/PublicWeb/dra/rap/regionII/technical_conference/daegu2010/4-5_Chang_Korea.pdf)

Other information
- Very-Short-Range Forecasting Systems in the WMO Technical Progress Report on the GDPFS and NWP Research for 2011 (http://www.wmo.int/pages/prog/www/DPFS/ProgressReports/2012/2011_GDPFS-NWP.html);
- SWIRLS (Short-range Warning of Intense Rainstorms in Localized Systems) by HKO (http://www.hko.gov.hk/nowcast/prd/api/index_e.htm);
- Very-short-range Forecasting of precipitation by JMA (http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev/text13-2.pdf and images are shown in http://www.jma.go.jp/en/radame/;
- Satellite-based Tropical Rainfall Potential (TRaP) and Ensemble Tropical Rainfall Potential (eTRaP) in http://www.ssd.noaa.gov/PS/TROP/trap-img.html and http://www.ssd.noaa.gov/PS/TROP/etrap.html.

f) Storm surge model and guidance.

Techniques introduced in the Good Practices

- The Storm Surge Early Warning Subsystem used in Shanghai Meteorology Bureau, storm surge forecasting model using Princeton Ocean Model (POM http://www.aos.princeton.edu/WWWPUBLIC/htdocs.pom/) and Estuarine Coastal and Ocean Model (ECOM http://woodshole.er.usgs.gov/operations/

modeling/ecomsi.html) in Shanghai.

Other information
- JMA's storm surge prediction model and guidance in http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev/text11-3.pdf and the explanation in the SSWS page in the Numerical Typhoon Prediction Website of RSMC Tokyo.

g) Surface observation by manned stations

Other information
- Surface observations (SYNOP, SHIP) are available at each meteorological center's servers under the framework of WMO (ex. WIS Portal - GISC Tokyo: http://www.wis-jma.go.jp/ and Beijing WIS Portal: http://wisportal.cma.gov.cn/wis/).

h) Automated weather stations (AWS)

Techniques introduced in the Good Practices

- 98 auto-weather stations, 120 rain gauges installed in Shanghai under the Monitoring & Detection System.

Other information
- Regional Weather in Hong Kong by HKO in http://www.hko.gov.hk/contente.htm#, Auto Meteorological Data Acquisition System (AMeDAS) by JMA in http://www.jma.go.jp/en/amedas/, and by KMA in http://web.kma.go.kr/eng/biz/observation_01.jsp

i) Upper-air observation by radiosonde and wind profiler for the overview of atmospheric structure

Other information
- Upper observations (TEMP) are available at each meteorological center's servers under the framework of WMO (ex. WIS Portal - GISC Tokyo: http://www.wis-jma.go.jp/ and Beijing WIS Portal: http://wisportal.cma.gov.cn/wis/).

j) Satellite observation and analysis

Techniques introduced in the Good Practices

- 12 meteorological satellite receiving systems in Shanghai under the Monitoring & Detection System.

Other information
- CMA Fengyun satellite in http://www.nsmc.cma.gov.cn/NewSite/NSMC_EN/Home/Index.html
- JMA MTSAT in http://www.jma.go.jp/jp/gms/, http://mscweb.kishou.go.jp/index.htm
- KMA COMS in http://www.kma.go.kr/weather/images/satellite_basic03.jsp
- Tropical cyclone satellite analysis operated by Members are summarized in the documents in WMO International Workshop on Satellite Analysis of Tropical Cyclones http://www.wmo.int/pages/prog/www/tcp/IWSATC.html

k) Radar observation

Techniques introduced in the Good Practices

- 3 Doppler weather radars installed in Shanghai under the Monitoring & Detection System.

Other information
CMA radar composite maps in http://www.weather.com.cn/static/en_product.php?class=JC_RADAR_CHN_JB
HKO radar images in http://www.hko.gov.hk/wxinfo/radars/radar.htm
JMA radar composite maps in http://www.jma.go.jp/en/radnowc/
KMA radar composite maps in http://www.kma.go.kr/weather/images/rader_composite_ppi0.jsp
Department of Meteorology and Hydrology (DMH) of LAO P.D.R radar images in http://dmhlao.etllao.com/index.html
Malaysian Meteorological Department (MMD) radar composite maps in http://www.met.gov.my/index.php?option=com_weathersatellite&purpose=RADAR-MALAYSIA&Itemid=911
Thai Meteorological Department (TMD) radar images in http://www2.tmd.go.th/radar/pkt120Loop.php
Meteorological Service Singapore (MSS) radar images in http://www.weather.gov.sg/wip/c/portal/layout?p_l_id=PUB.1023.5

l) Quantitative Precipitation Estimation (QPE)

Other information

- Very-Short-Range Forecasting Systems in the WMO Technical Progress Report on the GDPFS and NWP Research for 2011 (http://www.wmo.int/pages/prog/www/DPFS/ProgressReports/2012/2011_GDPFS-NWP.html)
- SWIRLS (Short-range Warning of Intense Rainstorms in Localized Systems) by HKO (http://www.hko.gov.hk/nowcast/prd/api/index_e.htm)
- Radar/Raingauge-Analyzed precipitation by JMA in http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev/text13-2.pdf and images are shown in http://www.jma.go.jp/en/radame/
- Satellite-based precipitation for the flood monitoring operated by Sentinel Asia in https://sentinel.tksc.jaxa.jp/sentinel2/subsetControl.action?subset_name=Flood Monitoring

m) Synoptic weather maps

Other information

- CMA weather charts in http://www.nmc.gov.cn/publish/observations/weatherchart-h000.htm
- HKO weather charts in http://www.hko.gov.hk/wxinfo/currwx/wxcht.htm
- JMA weather charts in http://www.jma.go.jp/en/g3/ for surface and http://www.jma.go.jp/jp/metcht/kosou.html for upper levels

n) NWP model assimilation

Other information

- Monitoring of synoptic weather maps as outputs of NWP model assimilation in: JMA upper level charts are shown in http://www.jma.go.jp/jp/metcht/kosou.html

o) Hydrological index

Other information

- Soil water index and runoff index operated by JMA in http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev/text13-2.pdf

APPENDIX C - MAIN PARTICIPANTS OF UFRM PROJECT

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1. Bureau of Hydrology, the Ministry of Water Resources: Dr. LIU Zhiyu, Dr. CHEN Zuhua, Ms. ZHOU Li
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4. Bureau of Hydrology, Guangdong Province: Ms. CHEN Zhijing, Mr. WANG Zhijun, Mr. YANG Fan

Hong Kong, China

1. Hong Kong Observatory (HKO): Mr. LAI Sau-tak (Edwin)

Japan

1. International Center for Water Hazard and Risk Management (ICHARM): Mr. Toshio OKAZUMI, Mr. Katsuhito MIYAKE, Mr. Minoru KAMOTO
2. Japan Meteorological Agency (JMA): Mr. Masashi KUNITSUGU
3. Keihin river Office, Kanto Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
4. Yokohama city

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1. Malaysian Meterological Department (MMD)
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3. National Security Council under the Prime Ministers Department

Philippines

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3. Korea Institute of Construction (KICT): Dr. Gunhui CHUNG

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1. Thai Meteorological Department (TMD): Ms. Patchara PETVIROJCHAI
2. Royal Irrigation Department (RID): Ms. Kanokporn BOOCHABUN

Vietnam

1. National Hydro-Meteorological Service: Dr. Nguyen Dai Khanh, Mr. Pham Dinh, Dr. Dang Ngoc Tinh, Ms. Nguyen Thi Xuyen

APPENDIX D - ACRONYMS AND ABBREVIATIONS

ADB — Asian Development Bank
ADCP — Acoustic Doppler Current Profiler
ADVM— Acoustic Doppler Velocity Meter
AFWS — Automated Flood Warning System
ALARP — As Low As Reasonably Practical
AMDAR— Aircraft Meteorological Data Relay
AMV— Atmospheric Motion Vector
APFM— Associated Program on Flood Management
AWS — Automated weather stations
CAPE — Convective Available Potential Energy
CAPPI —Constant Altitude Plan Position Indicator
CAP— Common Alert Protocol
CBA— Cost-Benefit Analysis
CRED — Centre for Research on the Epidemiology of Disasters
DRR— Disaster Risk Reduction
DSS—Decision Support System
DST —Decision Support Tools
GDP — Gross Domestic Product
GPS— Global Positioning System
GRDP — Gross Regional Domestic Product
EM-DAT — Emergency Event Database
EWS— Early Warning System
GIS —Geographic Information System
GLS —GeoLinking System
IFM — Integrated Flood Management
IPCC — Inter-government Panel on Climate Change
JICA — Japan International Cooperation Agency
KDF— Kernel density function
MCA— Multi-Criteria Analysis
MCC— Meso-scale Convective Complex
MHEWS— Multi-Hazard Early Warning System
NDMI—National Disaster Management Institute
NDMS —National Disaster Management System
NGO—Non Governmental Organization
NEMA —National Emergency Management Agency
NNM — Nearest Neighbor Method
NWP—Numerical Weather Prediction
PR— Precipitation Radar
QPE— Quantitative Precipitation Estimation
QPF— Quantitative Precipitation Forecast
SSI — Showalter Stability Index
TC—Typhoon Committee
TCA —Typhoon Committee Area
UFRM — Urban Flood Risk Management
UVM— Ultrasonic Velocity Meter
VIL —Vertical Integrated Liquid Water content
VIRS— Visible and Infrared Scanner
WB — World Bank
WGDRR— Working Group on Disaster Risk Reduction
WGH—Working Group on Hydrology
WGM —Working Group on Meteorology
WGTCDIS — WEB GIS Based Typhoon Disaster Information System
TRCG - Training and Research Coordination Group

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