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AN EASSD DISCUSSION PAPER

# Grow in Concert with Nature

GREEN WATER DEFENSE FOR FLOOD RISK MANAGEMENT IN EAST ASIA

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THE WORLD BANK
Washington, DC

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with Contributions from

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Cover Photo: Rhine River Delta in the Netherlands (Source: Deltares)

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# Acknowledgments

The report *'Green Water Defense (GWD) for flood risk management in East Asia'* was prepared by a task team led by Xiaokai Li (Team Leader, Senior Water Resources Management Specialist, EASIN) and comprising Liping Jiang (Senior Irrigation Specialist, EASCS), Paulus Van Hofwegen (Senior Water Resources Specialist, EASIS), Toru Konishi (Senior Economist, EASVS), Weihua Li (Consultant), Tomoko Kato (Operational Analyst, EASIN) and Daniel N. Shemie (TWIWA). It is written based on the Green Water Defense study carried out by the team, with major contributions from Marcel Marchant (Deltares, the Netherlands) for the main study report and inputs from Dr. Trinh Thi Long (Vietnam) and Mr. Sawarendro (Indonesia) for the Vietnam and Indonesia case studies respectively. This study was undertaken under the guidance of John A. Roome (Sector Director, EASSD) and Vijay Jagannathan (Sector Manager, EASIN).

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# Acronyms and Abbreviations

| | |
|---|---|
| ABC | Active, Beautiful, Clean |
| BCA | Building & Construction Agency |
| CEA | Cost-Effectiveness Analysis |
| CVFPB | Central Valley Flood Protection Board |
| CWPPRA | Coastal Wetlands Planning, Protect and Restoration Act |
| CPRA | Coastal Protection and Restoration Authority |
| DP | Delta Program |
| DSS | Decision Support System |
| DWR | Department of Water Resources |
| EDD | Eco-Dynamic Design |
| EU | European Union |
| FEMA | Federal Emergency Management Agency |
| FIMA | Flood Insurance and Mitigation Administration |
| GWD | Green Water Defense |
| GDP | Gross Domestic Product |
| HCMC | Ho Chi Minh City |
| IPCC | Intergovernmental Panel on Climate Change |
| ICARBM | Integrated Coastal Area and River Basin Management |
| IPA | Individual Parcel Assessment |
| ISDR | International Strategy for Disaster Reduction |
| IWRM | Integrated Water Resources Management |
| LID | Low Impact Development |
| LMRB | Lower Mekong River Basin |
| MKD | Mekong Delta |
| MLIT | Ministry of Land, Infrastructure and Transport |
| MSL | Mean Sea Level |
| NASA | National Aeronautics and Space Administration |
| NFIP | National Flood Insurance Program |
| NOAA | National Oceanic and Atmospheric Administration |
| OECD | Organization for Economic Co-operation and Development |
| OSD | On-site Storm-water Detention |
| PUB | Public Utility Board |
| SRI | System of Rice Intensification |
| SUDS | Sustainable Urban Drainage System |
| TWM | Total Water Management |
| UNEP | United Nations Environment Program |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USACE | United States Army Corps of Engineers |
| WFRMP | Wuxikou Flood Risk Management Project |
| WMO | World Meteorological Organization |

# A Summary Note for Policy Makers

## KEY MESSAGES

This summary note presents the key concept and approach of Green Water Defense for flood risk management in East Asia. It is intended for policy makers at different institutional levels of the client countries. It endeavors to convey the following key messages about Green Water Defense:

- ❖ Green Water Defense (GWD) is a promising approach of water sector to green growth and sustainable development;
- ❖ GWD approach is more cost-effective and sustainable due to its multi-function/benefit orientation;
- ❖ GWD requires adaptive management of the spatial layers (ecosystem, infrastructure, and land & water use), key elements (land, water and ecological environment) and their dynamic interactions; GWD endorses participatory spatial planning and management;
- ❖ GWD approach calls for a water-resilient and efficient society;
- ❖ Water must be managed as a precious resource, a service media and a potential risk factor in different forms, which requires management in its totality (i.e. total water management) during all phases (i.e. water cycle management);
- ❖ GWD approach to water resources management is based on the principles of 'living and building with nature' and maximizing water productivity;
- ❖ Water development and management should be right-based, productivity focused and oriented towards multiple functions and wins (productive use, conservation and risk reduction);
- ❖ GWD approach to water management requires involving stakeholder, combining demand and supply-side management, balancing structural and non-structural measures; and
- ❖ Well-conceived incentive policies and market mechanisms are essential to behavior change in water use and risk management and in applying GWD approach.

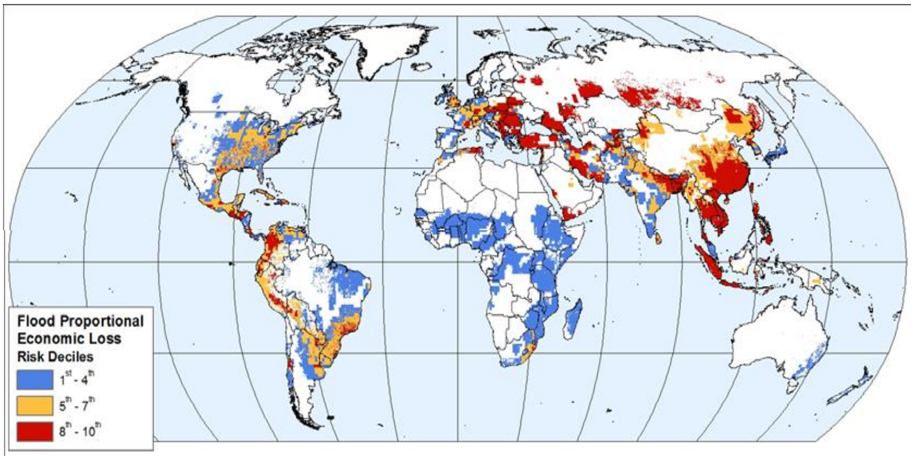
## Key Challenges for Managing Water Resources in East Asia

East Asia is home to more than a quarter of the world's population. It saw impressive economic growth in the past decade, accompanied by rapid population growth and urbanization. As a result, land and water resources in this region are under increasing pressure leading to over-exploitation, use conflicts, and other water insecurity issues. Under a changing climate, such pressure tends to intensify in terms of the area and population affected by flooding and water insecurity (See Figure E.1). The most compelling water resources management issues in East Asia can be summarized as follows:

- *Increasing water scarcity*. Although most East Asia countries are endowed with plenty of water resources, water scarcity in many regions is becoming more prominent in recent years due to spatial and temporal variability and changing climate. For example, the 2010 drought in the Mekong Delta affected more than 1,300ha of rice fields, with enormous economic losses (OECD, 2010);
- *Rising cost of flood damage*. Flood damage caused by such factors as improper land use, extreme weather and sea level rise is more frequent in East Asia, especially in the low lying deltas where many of the large cities (Bangkok, Jakarta, Manila and Ho Chi Minh City, etc) are located, as reflected by the 2011 floods in Thailand and the Philippines;
- *Water pollution and ecosystem degradation*. Many rivers and lakes in the region are heavily polluted, e.g., Hai River in China and rivers in Jakarta area of Indonesia, endangering the biodiversity and proper functioning of these water systems to provide critical water services. This condition is a result of both improper land use (leading to land erosion and sedimentation) and point and non-point source pollution caused by different water users; and
- *Climate change and variability*. Many parts of East Asia, especially the coastal and low-lying delta regions, are very vulnerable to climate change impact in the form of extreme climate events, storm surge and sea level rise, etc. The climate variability observed in recent years is expected to continue and possibly become more extreme in the coming decades, posing an enormous challenge to water management in the region.

The purpose of the 'Green Water Defense in East Asia' study is to take stock of advances in management practices, institutional and technological innovations for managing water resources under changing climate. The focus of this note is on green water defense for flood risk management in deltas and other areas vulnerable to flooding.

**Figure E.1: Economic Loss Due to Flood as a Proportion of GDP**




Source: Dilley M., et al., 2005

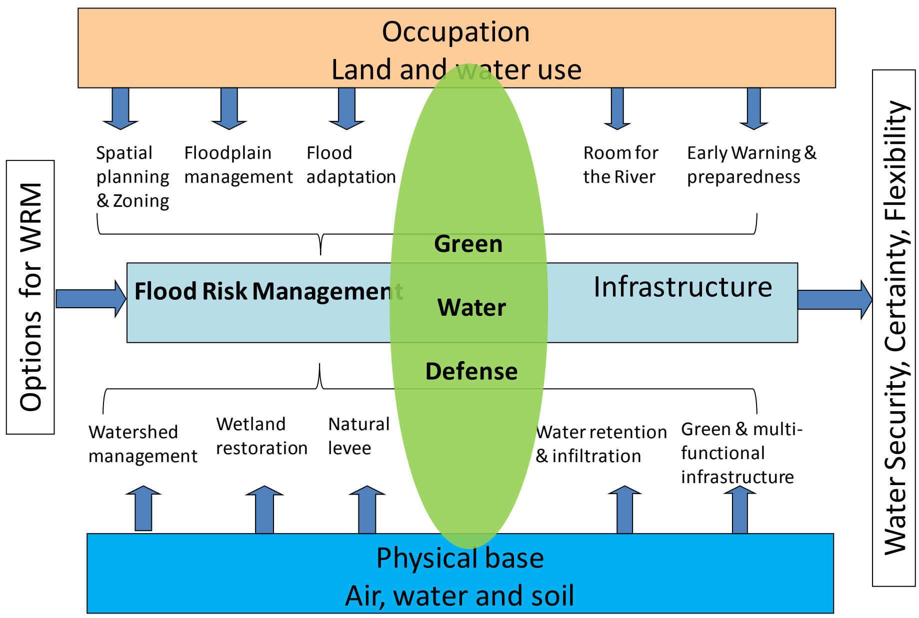
## Green Water Defense – Conceptual Framework and Approach

### *GWD Conceptual Framework*

Green Water Defense is an adaptive management philosophy and approach which seeks to spatially integrate natural forces and artificial interventions, and to balance incentive-based and supply-driven measures, with minimum footprints and externalities in sustainably providing water services and managing related climate risks. It is enlightened by the green growth thinking and builds on a number of other concepts and approaches, including (a) Live with nature and build with nature; (b) Green adaptation and low impact development; (c) Integrated river basin and coastal zone management; (d) Productivity-based agricultural water management (produce more with less); and (e) Water-sensitive urban design and eco-dynamic design.

Conceptually GWD can be illustrated by a simple spatial model (See Figure E.2) that consists of three spatial layers - the Base Layer (representing the ecosystem - air, water and soil), the Network Layer (representing the infrastructure system) and the Occupation Layer (representing the human actions in land & water use), each with different but interrelated temporal dynamics and public-private involvement (VROM, 2001). The model indicates a physical hierarchy in which the Base Layer influences the other layers through enabling and constraining factors, similar to the dynamic interactions and connections among economy, society and the environment. For instance, the soil type in the Base Layer determines to a large extent the kind of agriculture that can be performed in the Occupation Layer. Unfavorable conditions (constraints) posed by the Base Layer can be mitigated to a certain degree through adaptations in the Network Layer or Occupation Layer. The GWD approach serves to promote the dynamic and healthy interactions among the three layers in an integrated manner, and to achieve sustainability of ecosystem, water and land use in providing the required services and managing related risks.

**Figure E.2: Green Water Defense (GWD) Conceptual Framework**




Source: Authors

Conventional approaches to water management tend to emphasize the utility of expensive water infrastructures such as reservoirs and river works for flood control and water supply purposes. The GWD approach makes full use of the ecosystem function (in the forms of natural forces and processes), and seeks to balance non-structural and structural measures, and promote effective land and water development and ecosystem enhancement. For example, changes in land and water uses (in the Occupation Layer) can impact positively or negatively the health and functions of ecosystem (the Base Layer) and lead to new requirements on infrastructure development and operation (the Network Layer). Similarly, payment for ecological services through mangrove forest protection (in the Base Layer) enables the farmers to live and cultivate along the coasts (in the Occupation Layer). The three spatial layers linked by the GWD concept, function as a dynamic system in contributing to water security, certainty and flexibility.

### *Key Principles, Elements and Measures of GWD Approach*

<u>Key Principles of GWD Approach</u>

The GWD approach adheres to the following basic principles:

(a) It adopts sustainability as the overarching principle in integrated water-land-ecosystem use planning and management, which covers technical, institutional and financial aspects;
(b) It examines issues and solutions from a spatial perspective and in a dynamic manner, supported by modern tools and information technology in robust decision making;
(c) It makes best use of natural forces and processes through ecological services, and maintains healthy dynamics between natural and built environments;
(d) It advocates stakeholder involvement and cross-sector collaboration in finding multiple win solutions through alignment with stakeholders' interests;
(e) It seeks to integrate supply and demand-side management measures in adaptive water management;
(f) It endeavors to balance structural and non-structural measures for more sustainable solutions; and
(g) It adheres to the cost-effectiveness criterion for options assessment and measures prioritization and selection, based on the concept of 'buying-down the risks' taking into account the associated social and environment costs and benefits.

<u>Key Elements of GWD Approach</u>

In designing the flood risk management system under GWD approach, the key elements should include at least the following:

(a) An integrated cross-sector management organization setup with dedicated staff and resources, and stakeholder involvement mechanism for decision making;
(b) A good flood management information system with functional data-collection system (e.g., hydro-met monitoring network) and shared database (preferably GIS database), and necessary decision-support tools such as Decision Support System (DSS);
(c) A basic flood management infrastructure network compatible with local conditions (including dikes, reservoirs, river works, sluice gates, detention areas and storm drainage depending on the circumstances);
(d) Catchment management and flood adaptation measures such as land use zoning, soil conservation and building codes;
(e) Flood forecasting and early warning systems, particularly for areas affected by river floods;
(f) An effective flood emergency preparedness and response system; and
(g) Risk-sharing and investment funding mechanisms, including flood insurance (commercial and/or government-supported), public private partnership in flood risk reduction investments, flood protection charge or tax on beneficiary communities and entities and special flood management funds established by government.

<u>Key GWD Measures from Selected Case Studies</u>

The following is a brief summary of the emerging best practice measures of GWD from the selected case studies:

- 'Living with Nature (Flood)' is an effective and sustainable strategy and should be promoted as an overarching guiding principle for low-lying countries and regions in managing their flood risks and adapting to climate change;
- Adopting a comprehensive flood risk management approach, characterized by a balanced mix of eco-friendly structural measures and carefully selected non-structural measures, places a country or a region in a very strong position to manage the flood and related risks in a dynamic manner, and in response to the changing climate and operating environment. These measures should address different aspects of flood risk: hazard, exposure and vulnerability;
- A total water management strategy leads to an integrated solution to multiple inter-connected water issues with satisfactory results;
- Successful implementation of flood defense strategy and management programs requires involving stakeholders in the entire process through an appropriate institutional arrangement and aligning the interests (benefits and risk-sharing) of different levels of governments and relevant agencies, the communities and private sectors;
- A good legal framework creates an enabling environment for integrating flood prevention and risk reduction into the urban planning process to minimize flood risk escalation due to new development;
- A well functional flood management organization with clear responsibility division, line of command and collaboration mechanism plays a critical role in successful flood disaster management, as demonstrated in Japan;
- Well designed target programs, such as the 'Room for the River' program in the Netherlands, with dedicated organization and financing are efficient ways to achieve specific objectives and targets of flood risk reduction and management;
- 'Building with Nature' as a green flood defense practice, utilizing ecological service and other natural forces and processes for flood protection in coastal and delta areas, has a very promising prospect, despite the fact that its application is still in the early stages and the cost efficiency can be further improved;
- Green adaptation through such measures as wetlands restoration, as in the case of Louisiana, yields high returns to investments, especially for coastal areas subject to storm surge impact and land erosion;
- A 'Room for the River' program for riverine flood management provides various interventions to increase discharge capacity and lower water levels (and flood risks) in the floodplains of rivers;
- The 'Water City' concept, characterized by forward-looking spatial planning (integrating land–water–ecological environment management) and water-sensitive design (e.g., multifunctional facilities and green infrastructures), can be very catalytic in successfully promoting integration of flood risk management with urban development;

- Advances in technologies for information collection, monitoring, decision support analysis, flood forecasting and warning, improve scientific decision making, and enhance the entire process of flood awareness, preparedness, mitigation, response and recovery (See Table E.1 for examples of spatial tools and examples of their applications);

**Table E.1: Selected Spatial Tools, Database and Examples of Applications**

| Function | Spatial Management Tools & Database | Information resolution and indicative cost | Accessibility | Example of application |
|---|---|---|---|---|
| **Global monitoring & data dissemination** | GEONETCast | 5km and up<br>Near real-time<br>Low cost[1] | Globally accessible | AMESD[2] Program in Africa |
| **Flood & Hurricane Forecasting** | NEXRAD | 1km~460km<br>Near real-time<br>Free | Currently available in US, and international collaboration possible | Hurricane Katrina |
| **Land information and data assimilation system** | NASA_LIS | 1km and finer<br>1 hr and finer<br>Low cost | Currently available in US, and international collaboration possible | Used in numerous case studies |
| **Groundwater monitoring** | GRACE | 360km<br>Monthly<br>Low cost | Globally accessible | Groundwater mapping in India |
| **Spatial land cover information** | EROS Data Center | 1km and up<br>Low cost | Globally accessible | FEWS NET[3] in Africa |
| **Flood monitoring & inundation mapping** | Global Flood Detection System | 5km and up<br>Near real-time<br>Free | Globally accessible | Numerous applications in Europe and Asia |
| **Hydrological & hydraulic modeling** | HEC center | Depending on data quality<br>Free | Globally accessible | Used in numerous case studies |
| **Agricultural watershed database** | STEWARDS | Depending on data quality<br>Free | Currently available in US, and international collaboration possible | BARD[4] |

Source: Authors

1. An entire receiving station can be purchased and installed for $2,000–3,000.
2. The African Monitoring of Environment for Sustainable Development.
3. FEWS NET was designed to monitor (and forecast when possible) incidence of drought and flooding in Africa.
4. BARD: United States – Israel Bi-National Agricultural Research and Development Fund.

- Multi-functional facilities such as super levees, water parks and green infrastructures are cost-effective measures of green flood defense in flood-prone cities with limited land space for development;
- Changing climate and spatial environment (economic growth, urbanization and population expansion) increase flood risk and require constant search and close collaborations by government entities and professional organizations to find innovative solutions to sustainable flood defense;
- Continued public awareness-raising, flood hazard information sharing (e.g., by publicizing hazard maps) and flood warning are crucial to ensure high level of alert, preparedness and response for dealing with flood disasters; and
- Sharing flood risks among governments, individuals and private sector, through insurance programs and disaster recovery financing from public flood relief funds, etc., is a powerful mechanism for enforcing land use and floodplain development regulations.

## Towards a Roadmap for Green Flood Defense in East Asia

*General Process of GWD Application*

In recognizing the fact that the applications of GWD approach in terms of selecting the key measures are very location specific, the following provides a general guide for the overall process for GWD application in flood risk management.

***(a) Understanding the water system and flood risks***: Flood risk management starts with understanding the target water system, whether it is a river basin (or catchment), an urban system or a coastal zone, and the associated risks. For this purpose, the flood management information (knowledge) system needs to be in place, which concerns the hydrological, meteorological, socio-economic and demographic information, the natural environment (eco-system) and built environment. For quick assessment and particularly where important information is missing, the spatial technologies such as satellite and remote sensing can be very valuable in filling in the data gaps. After flood sources and hazard scale, level of exposure (people, services and assets) and their vulnerability, etc. are identified based on field survey and data analysis, flood hazard (or risk) maps can be developed. These maps can be used to raise public awareness, and to guide development (land use) planning and emergency response;

***(b) Defining shared vision and objectives through stakeholder involvement:*** To align the interests of the government, communities concerned and ecological system preservation, it is critical to formulate a shared vision and objectives of flood risk management through stakeholder involvement, in light of the more broad development goals. For example, a city may want to become climate-resilient with deign protection level against flood (or rainstorm storm) of 1-in-200-year return period. The shared vision and management objectives will serve to influence the related policies for land and water use management, and investment funding. The vision should be in line with the overall principle of 'live with and adapt to floods' and the objectives set realistically depending on the hazard level and socio-economic development conditions in the target areas;

***(c) Master planning - configuring an integrated flood risk management system:*** An integrated flood risk management system (IFRMS) reflects the paradigm shift from protection to adaptation in overall management strategy and from flow control to risk-based approach. The system design gives priority to utilization of the natural system and process, and cost-effective non-structural measures, on top of the very essential infrastructure. Furthermore, the system promotes the practice of total water management, namely, managing water in different forms: rainfall, surface runoff, water in water bodies, groundwater and wastewater;

***(d) Investment planning and programming.*** As a critical part of the decision process for flood management, investment planning involves option identification, assessment and prioritization, leading to investment programs for different time horizons. A portfolio of applicable green water defense measures can be developed to address flood hazard, exposure and vulnerability issues. These measures should build on the strengths, where applicable, of the existing defense system. A number of different investment options can be formulated on that basis, to achieve the intended management objectives. The next step is to prioritize the options according to cost-effectiveness, following one of the main GWD concepts – 'buying down risk'. The results of the selected options can be turned into investment programs through more detailed technical analysis. In order to ensure robust decision making in option assessment, prioritization and selection, the use of a decision support system (DSS) is highly recommended to look into different development and climate scenarios and weigh the tradeoffs as part of the participatory decision making process. Depending on the level of the risks, near and longer term investment programs with dedicated resources and organizations can be designed to achieve intended objectives. In the same token, resources and efforts can be dedicated towards piloting or demonstrating some of the innovative GWD measures for future replication and scaling up;

***(e) Designing management measures to achieve optimal results and sustainability***. The GWD design should keep in view the inter-linkages between different parts of an integrated management system and its long-term sustainability. In designing the major structural measures (infrastructure), care should be taken to ensure they are water sensitive and compatible with the natural environment, and that they provide multiple-benefits as much as possible. The non-structural measures such as flood forecasting, need to be designed to capture potential co-benefits (e.g. flood forecasting serves to reduce flood impacts and to help optimizing reservoir operation for multiple benefits as well);

***(f) Institutional development and capacity-building.*** The institutional development should aim to establish an integrated organizational arrangement which involves stakeholders with effective information sharing, communication, coordination and decision-making mechanisms, and a functional regulatory system. The capacity building should target the decision makers, the operational staff and communities with particular attention to strategic planning and decision making, hazard reduction operation, adaptation and responses respectively. On-the-job training through projects has proved to be a most effective way of capacity-building; and

***(g) Emergency preparedness and response system***. The importance of a fully operational emergency preparedness and response system cannot be over emphasized. The system includes a well-conceived emergency preparedness plan covering such key elements as warning, communication and evacuation facilities and arrangements. It needs to be highly participatory and used in close coordination with the forecasting system, covering both natural flood events and other flood disasters such as dam failures or dike breaches.

### Focus of GWD Approach Applications

Floods occur at different scales (basin-wide or localized), from different sources. Local conditions of the spatial layers are not identical either. Therefore, in formulating the management strategy and selecting GWD measures, the decision on the focus areas should be based on the flood types (causes), e.g., riverine (fluvial), pluvial, coastal or a combination, and consider the local, natural and socio-economic conditions:

- For managing riverine or fluvial floods, special attention should be given to floodplain (land use) and river management, watershed management, flood management information system, flood forecasting and early warning, flood regulation and detention and emergency responses;
- For managing coastal or delta floods, the focus must be on spatial planning, making best use of natural defense and ecological services (such as mangroves and wetlands), groundwater management, flood adaptation and local protection and emergency preparedness; and
- In dealing with pluvial or urban floods, such management measures as integration of flood risk management with urban development (land use) planning and management, sustainable drainage system, building codes, green and multiple-functional infrastructures for total water management deserve particular consideration.

To illustrate the application of GWD approach in managing flood risk, three practical cases in East Asia are presented in Chapter 5.

# CHAPTER 1

# Time for a Change

## Deltas in Times of Climate Change

Many developing countries spend 2% to 6% of their Gross Domestic Product (GDP) on infrastructure development. In Asia alone, public funding of infrastructure by 2020 will total US$400 billion (Robichaud, 2010). The Organization for Economic Co-operation and Development (OECD) estimates that approximately 40% of these development investments are at risk due to climate change (OECD, 2005). Water infrastructure is especially vulnerable to climate change, as the hydrological cycle responds to subtle shifts in climate and this response is often unpredictable (IPCC, 2007). The UN World Water Assessment Program states that, for humans, “climate change is water change” (UNESCO and Earthscan, 2009).

Located between the sea and rivers, the highly populated deltas of the world are very vulnerable to changing climate and other anthropogenic influences. Rivers flowing through the deltas are an important source of fresh water and nutrients critical for sustaining life. At the same time, these rivers carry polluted water originating from upstream waste discharges and may cause serious pollution problems. The mix of salt and fresh water in their estuarine portion creates environmental flora and fauna. Thus, delta ecosystems are among the most valuable and productive ecosystems on earth. However, situated in low-lying areas, deltas are also vulnerable to flooding and drainage issues. Safe living and working in deltas has always required human interventions: land reclamation, irrigation, soil drainage and embankments.

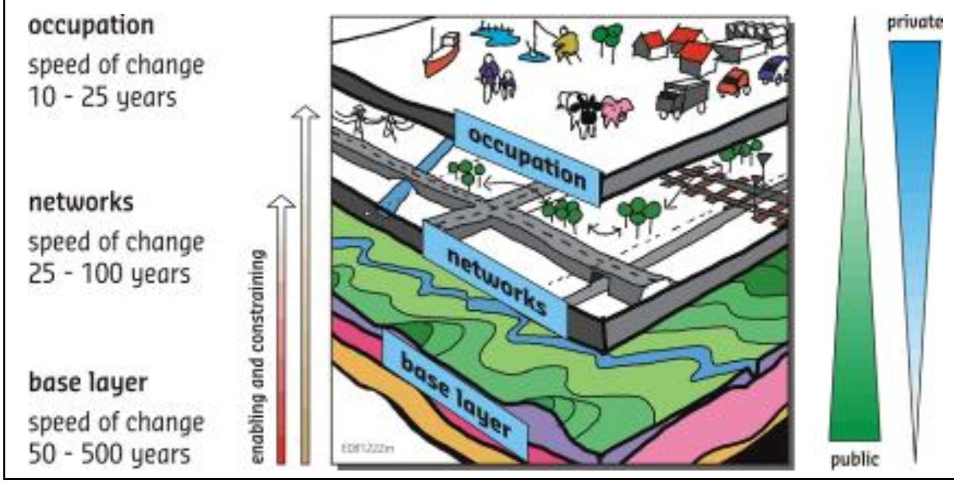
This report addresses integrated water resources planning and management for delta regions, focusing on flood risk management under a changing climate. Flood risks are part of a wider problem in which local and regional changes in land use interact with regional and global environmental changes, such as subsidence, sea level rise and climate change. Climate change in combination with other human induced changes, such as population growth, economic development and urban migration, pose a great challenge in the medium to long term. Flood risk management should therefore be considered in the wider framework of adaptive, integrated water resources management, where rainfall patterns, spatial planning and land use, environmental conservation, urban drainage, etc. all play an important role. The roles and beneficial utility of natural processes deserve renewed attention. Creation (or restoration) of room for natural processes can lead to a significant reduction of flood risks and promotion of different ecological services as well. Conventional civil and ecological engineering are complementary, key elements of the solution to flooding issues.

### Flooding, Coastal Development and Climate Change

Flood risk may increase due to changes in the coastal and delta environments, resulted from physical, socioeconomic and demographic drivers. The section below presents a general assessment framework, based on the spatial layers model for deltas and discusses the interrelations between flood risk and different drivers.

Understanding how drivers lead to changes in the flood risk of a delta requires consideration of a multitude of relations between human activities, physical and ecological delta conditions. For this purpose, a simplified structure of a delta in the form of a *Layer Model* provides insight into this complex system. The layer model recognizes three physical planning layers (See Figure 1.1): the Base Layer (air, water and soil), the Network Layer (infrastructure) and the Occupation Layer (land and water use), each with different but interrelated temporal dynamics and public-private involvement (VROM, 2001). The model displays the physical hierarchy in which the Base Layer influences the other layers through both enabling and constraining factors. For instance, the soil type largely determines the type of agriculture possible in the Occupation Layer. Unfavorable conditions (constraints) posed by the Base Layer can, to a certain extent, be mitigated by adaptation measures in the Network Layer or Occupation Layer. However, these adaptations to the original physical geography of an area require investment and management.

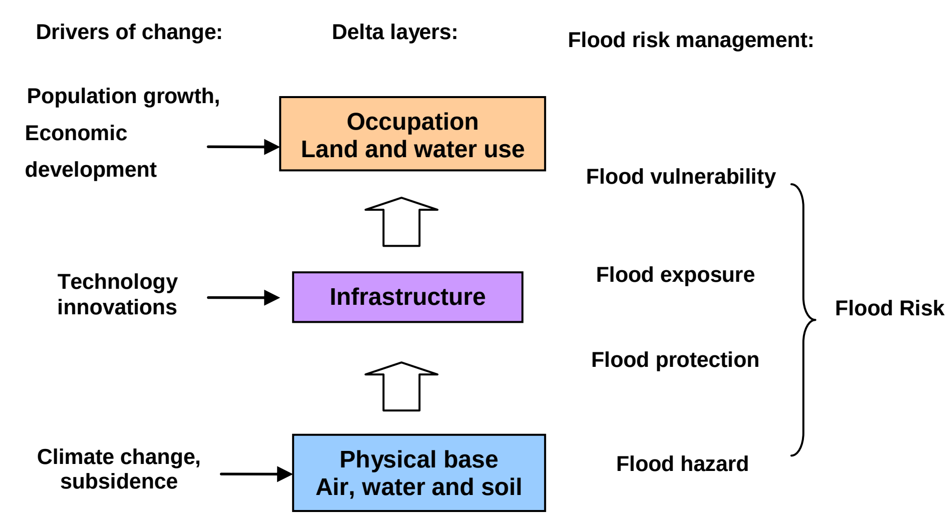
**Figure 1.1: The Layer Model for Deltas**




Source: VROM, 2001

Applying this model to flood risk management allows adding the elements of hazard, protection and vulnerability to the Base, Network and Occupation Layers, respectively (See Figure 1.2). Floods originate in the physical base of the delta itself and from the geophysical relations of the delta with upstream (the river basin) and marine/ocean environments. Delineation of the interactions among different spatial layers and their drivers of change provide an understanding of the hazards and effective ways to manage the risks. Flood protection measures, such as dams, dikes and drainage systems that are part of the Network Layer, mitigate the impact of a high water event. Technical innovations drive change in this layer, and its vulnerability has an eventual impact on society due to failure of the protection system. Occupation patterns and human activities, driven by population growth and economic development in the Occupation Layer, determine the impact of the failure.

**Figure 1.2: Spatial Layer Model Applied to Flood Risks in Deltas**




Source: Deltares, 2009

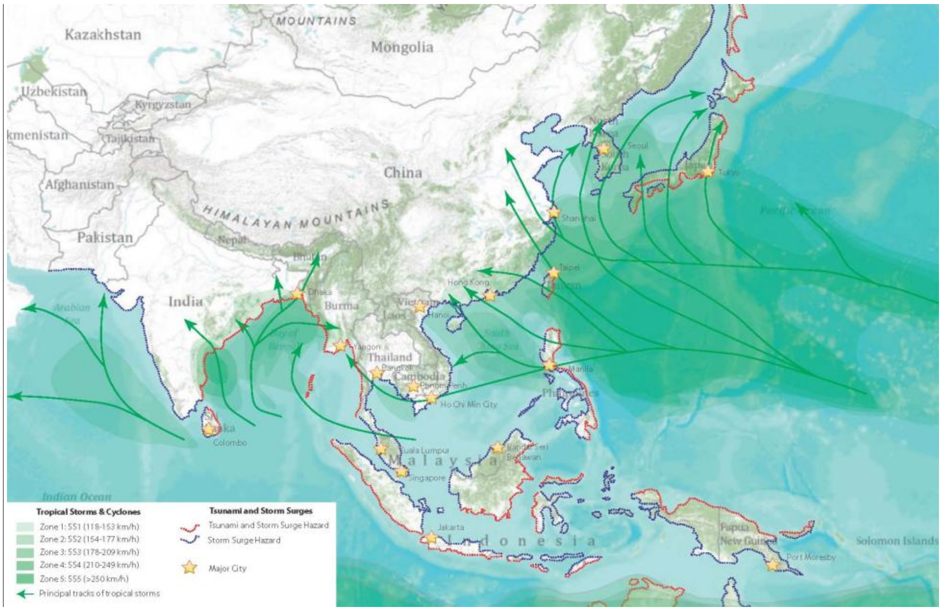
The above analysis reveals the following messages:

- Flood risk management involves hazard, protection (exposure) and vulnerability management measures. Hazard reduction, improved protection and increased resilience leading to reduced vulnerability, can decrease the over-all flood risk. Successful flood risk management should therefore address these three components together in an integrated manner;
- Future changes in flood risk are a combination of different drivers of change. Some of the most important drivers are climate change and variability, subsidence, population growth and economic development; and
- Flood protection or defense measures can be improved through technological and institutional improvements and innovations, but also with ecological engineering techniques to reduce the hazard and/or exposure.

## Current Flood Vulnerability and Outlook for the East Asia Region[1]

In the past decades, the coastal zones in East and Southeast Asia saw dramatic urban development. Globally, fourteen of the world's seventeen largest cities are located along coastlines. Eleven of these cities, including Bangkok, Jakarta, Singapore, Manila and Shanghai, are in Asia (Creel, 2003). Many of these cities are located in deltas or low coastal areas, making them vulnerable to flooding from three major sources: heavy local rainfall, river floods and storm surges. Additionally, many coastal regions in Asia are exposed to a tsunami risk (See Figure 1.3). Two recent major tsunamis, the 2004 South Asia tsunami and the 2011 Japan tsunami, showed the immense force of nature and the intense damages and sufferings it can generate. It was estimated that the 2004 tsunami affected between 10 and 20 million people who lived within 1 to 2 km of the coastline (Balk et al., 2005).

**Figure 1.3: Natural Flood Hazards in East Asia**




Source: ISDR World Map of Natural Hazards

Table 1.1 shows a list of recent major water related disasters in Asia. These disasters caused more than 300,000 deaths and property damage exceeding 300 billion US dollars. There is often large difference in losses and the number of casualties among the various types of disasters. For instance, tsunamis have caused much more casualties and

[1] East Asia includes the following countries: Brunei Darussalam, Cambodia, China, East Timor, Indonesia, Japan, Laos, Malaysia, Myanmar, North Korea, Papua New Guinea, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

damages. Floods from rivers tend to cause fewer casualties but can also be devastating in economic damage. The actual human and economic losses from a water related disaster depends on a combination of factors: type of exposure, population density of the location and its socio-economic condition, level of preparedness, etc. In general, reducing vulnerability to floods requires a broad set of measures ranging from flood protection to early warning and to flood resilience (Marchand, 2009).

Flooding is caused not only by the external hazard, such as excessive rainfall or a storm surge, but also by such factors as continued land subsidence (e.g., Bangkok 2 – 5 cm/year; Jakarta up to 20 cm/year) and insufficient drainage capacities. In addition, the vulnerability increases because of higher population densities in low lying areas and vital economic infrastructure that is easily affected by inundation (e.g., subways, (nuclear) power plants).

**Table 1.1: Major Water Related Disasters in Asia in the Past Decade**

| Year | Type of flood | City/ country | Number of casualties | Damage ($) | Source |
|---|---|---|---|---|---|
| [2]**2011** | Floods | Thailand | 270 | 2 billion | The Assosiated Press, 2011 |
| **2011** | Tsunami | Japan | 25.000 | 309 billion | National Police Agency of Japan, 2011 |
| **2010** | Typhoon Fanapi | Taiwan, China | 105 | 115 million | Taipei Times, 2010 |
| **2010** | Floods | China | 3.185 | 51 billion | Xinhaunet, 2010 |
| **2010** | Floods | Thailand | 250 | 1,6 billion | Bangkok Post, 2010 |
| **2010** | Floods | Philippines | 110 | 48 million | NDRRMC, 2011 |
| **2009** | Typhoon Ketsana | Manila | 464 | 237 million | NDRRMC, 2009 |
| **2008** | Cyclone Nargis | Myanmar | 138.000 | 4 billion | Swiss Re, 2008 |
| **2007** | Floods | Jakarta | 54 | 879 million | Rukmana, 2009 |
| **2007** | Cyclone Sidr | Bangladesh | 4.000 | 1,7 billion | KNMI, 2007 |
| **2004** | Tsunami | Banda Aceh | 160.000 | 5 billion | Asian Development Bank, 2005 |

In summary, a delta's vulnerability to flooding depends on a number of factors, each of which carries its own level of uncertainty. The primary factor in vulnerability is the growth of cities, which has the least uncertainty. Such growth will probably continue for a number of decades, exposing more people and assets to flood hazards.

[2] At the time of writing

The second factor is climate change and associated sea level rise. Studies have shown that expected sea level rise on a global scale is between 18 and 60 cm for the 21st century. However, there are significant regional differences in sea level rise, due to a combination of drivers. Increases in storm intensities are likely, but no trend has been identified in storm frequencies (IPCC, 2007).

Further, subsidence of deltas due to compaction and extraction of groundwater or fossil fuels will continue over the next few decades unless effective countermeasures are implemented. When sea level rise combines with lack of sediment inflow and ongoing subsidence in most deltas, flooding issues become more complicated. Many of the Asian deltas are considered 'in peril' or 'in greater peril', because land aggradation rates are far too low to compensate for the sea level rise (See Table 1.2). Currently more than 200 million people live in these delta areas; the number of vulnerable people in the next decades will certainly rise sharply if no additional measures are taken.

**Table 1.2: Overview of Flood Issues in Major Deltas and Coastal Cities in East Asia**

| Country | Delta and / or City | Population estimate *($10^6$) | Flood hazards | SLR Risk level** |
|---|---|---|---|---|
| **Myanmar** | Irrawaddy delta, Rangoon & Pathein | 10 | Typhoon / Storm surge / Tsunami | 4 |
| **Thailand** | Chao Phraya, Bangkok | 14 | Tidal surge, River flood | 5 |
| **Malaysia** | Kuala Lumpur | 1.5 | Flash floods | |
| **Singapore** | Singapore | 5 | Pluvial, flash floods | |
| **Vietnam** | Mekong Delta, Ho Chi Minh city | 17[3] | River flood / storm surge | 4 |
| | Red River Delta, Hanoi & Haiphong | 19[3] | Typhoon / storm surge | |
| **China** | Yangtze Delta, Shanghai & Ningbo | 20-85[1] | Flash flood / floods / landslides / typhoon | 5 |
| | Yellow River Delta | 5.2[4] | River flood | 5 |
| | Pearl River Delta | 20[5] | Typhoon | 5 |
| **Indonesia** | Ciliwung Delta | 23[1] | River, Pluvial, Tidal, Tsunami, flash floods | |
| | Mahakam Delta | 0.02[5] | | 1 |
| **Papua New Guinea** | Fly Delta | 0.005[6] | Tsunami | |
| **East Timor** | Dili | 0.2 | Tsunami | |
| **Brunei Darussalam** | Bandar Seri Begawan | 0.2 | Pluvial, tidal | |

[3] Bucx et al. (2010)

[4] China today (2011)

[5] Bookshelf (2011)

[6] Overeem & Syvitski (2009)

| | | | | |
|---|---|---|---|---|
| **Philippines** | Manila | 1.6 | Typhoon | |
| **Japan** | Tone, Chiba Tokio | 31 | Typhoon / Tsunami | 5 |
| **Taiwan** | Taipei | 2.6 | Typhoon / Tsunami | |
| **North Korea** | Pyongyang | 3.2 | | |
| **South Korea** | Seoul (Han river) | 10.5 | Typhoon / flash flood | |
| **TOTAL** | | 184 - 249 | | |

* Total number of population depends on the definition of the delta
** The Sea Level Rise risk level of deltas is defined as follows (following Syvitski et al., 2009):
1: Deltas not at risk: aggradation rates unchanged, minimal anthropogenic subsidence
2: Deltas at risk: reduction in aggradation, but rates still exceed relative sea-level rise
3: Deltas at greater risk: reduction in aggradation where rates no longer exceed relative sea level rise
4: Deltas in peril: reduction in aggradation plus accelerated compaction overwhelming rates of global SLR
5: Deltas in greater peril: virtually no aggradation and/or very high accelerated compaction

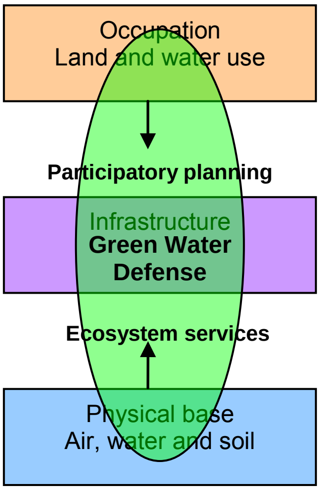
## Green Water Defense: a Promising New Approach

Floods and storms are an integral part of ecosystem dynamics, and they have both positive and negative impacts on human well-being. Floods directly affect floodplain ecosystems while storms affect coastal and estuarine ecosystems. Public perception and response to floods and storms are largely driven by the short-term and negative impact of these disasters. Therefore, historically, the responses to both have been focused on interventions to modify and control natural flood regimes through structural measures (e.g., dams, embankments and drainage canals). Although these structures (if properly designed) protect communities and properties, they often create irreversible damage to ecosystems and ecosystem dynamics.

Green Water Defense is based on the 'Green Growth' concept and is a sustainable alternative to the conventional approach to water resources management and flood protection (management). GWD seeks to address flood protection in a more holistic and natural way: instead of keeping the three spatial layers separated from each other, it emphasizes the interactions among them. Rather than depending primarily on building a dike or concrete wall against a flood hazard, GWD adopts a balanced structural and non-structural approach, including maximum use of the ecosystem services from the Base Layer to reduce the flood hazard, and promotes participatory spatial planning wherever possible. Its use provides room for rivers, green corridors and urban space (See Figure 1.4).

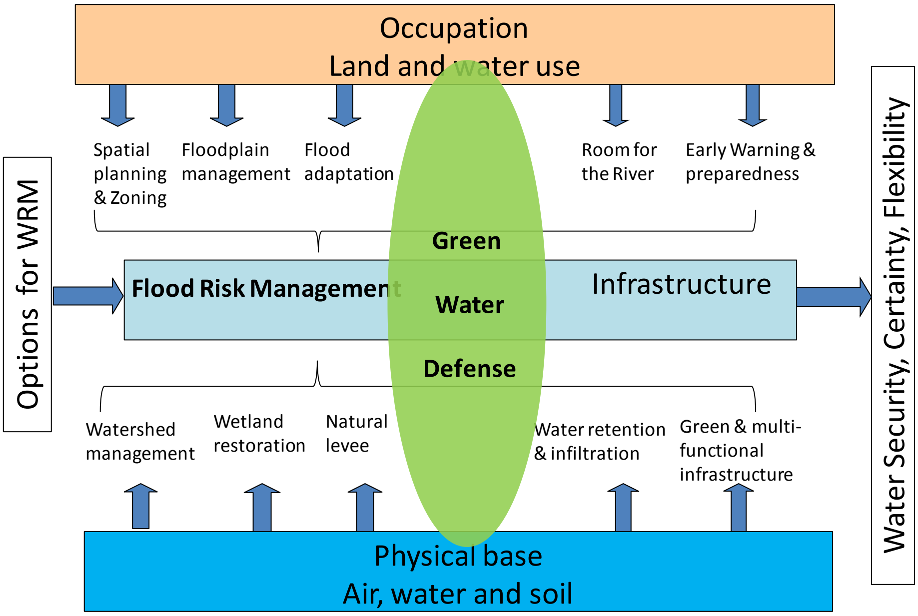
Figure 1.5 illustrates the interactions between the spatial layers. In the Occupation Layer, management measures such as spatial planning and land use zoning, allowing room for rivers/floods, early warning and preparedness, can contribute to better GWD. The Network Layer should embrace essential structural measures such as dikes, reservoirs and drainage systems. These infrastructure works can be multi-functional and green structures, operating in conjunction with the non-structural measures in a mutually complementary way, and contributing to enhancing ecological services. Examples of ecosystem services relevant for flood risk management are also shown in the Figure (e.g., wetland restoration and watershed management). Chapter 2 provides a more extensive description of these services.

**Figure 1.4: Green Water Defense Integrating the three Layers**




Source: Marchand et al., 2012

**Figure 1.5: Conceptual Framework of Green Water Defense**




Source: Authors

# CHAPTER 2

# What is Green Water Defense?

## A Working Definition

Although there is no universal definition of Green Water Defense (GWD) yet, the GWD concept as conceived by the study team is defined as follows: *Green Water Defense (GWD) is an adaptive management philosophy and approach which seeks to spatially integrate natural forces and human interventions, and to balance incentive-based and supply-driven measures, with minimum footprints and externalities in sustainably providing water services and managing related climate risks.*

Green Water Defense is a truly integrated approach to water resources and flood risk management. The word defense is used here in a broad sense, to include both 'hard' and 'soft' measures. Examples of concepts and approaches that reflect the spirits of Green Water Defense include:

- '***Building with Nature'***. J.N. Svašek first initiated this concept in 1979, based on morphological theories, using 'soft' solutions for coastal defense and focusing on materials and forces presented in nature. Waterman (2010) defines the essence of the concept as: 'Flexible integration of land-in-sea and water-in-the-new-land, using the materials, forces and interactions presented in nature, where existing and potential nature values are included, as well as the bio-geomorphology and geo-hydrology of the coast and seafloor.' This concept focuses mainly on coastal defense;
- '***Eco-dynamic Design'***. The Eco-dynamic design is defined as 'the design of sustainable ecosystems that integrate human society with its natural environmental to promote both' (Mitsch and Jørgensen, 2003). The self-organizing principle of nature is essential to this concept;
- '***Green Adaptation'*** is an application of eco-engineering and aims specifically at adapting to the negative impacts of climate change by making use of ecosystem services, which naturally adapt to environmental changes. The approach has a strong connection with moderating climate change impacts on local populations and their livelihoods;
- ***Integrated Water Resources Management***. This concept is decades old. It requires integrating land and water use planning and management with environmental management in a water system (basin or sub-system) to achieve multiple-wins and sustainable results. It covers management of the entire hydrological cycle: precipitation, evapo-transpiration (ET), infiltration, runoff and drainage, and addresses the inter-related issues of water scarcity, water quality and floods in a

holistic manner, institutionally and operationally from the supply and demand sides;

- ***Water Sensitive Design***. Evolved from the Sustainable Urban Drainage System (SUDS), this concept advocates that land and infrastructure development decisions in an urban setting should be informed and influenced by the effects of such development on water related services and risks (Zevenbergen *et al*., 2011). It represents a practical way of integrating water/flood management and climate change adaptation into urban development planning and management. Eco-city, climate-proof buildings, multi-functional water management structures, green infrastructures and eco-restoration of urban rivers/canals are examples of this concept;
- ***Total Water Management***. Total water management or water portfolio management refers to the practice of managing water in different forms or at different stages along the water cycle in an integrated manner, to meet the requirements of various water services (water supply, sewage treatment, ecological service and drainage, etc.) and risk management (storm/flood management, drought mitigation and water pollution reduction). It advocates integrating institutions and operational planning and management of water affairs and is another form of integrated water management;
- ***Produce More with Less***. Freshwater scarcity worldwide requires that water users step up their efforts to conserve water and use it more efficiently. The concept of 'Produce more with less' originated from the irrigated agriculture sector. It promotes the practice of productivity-based water use efficiency improvement by increasing the product (value) of per unit water consumed. Examples of this approach include ET-focused water conservation for agricultural productivity improvement and water saving, and system of rice intensification (SRI).

This report focuses on green defense for flood risk management with particular attention to deltas and coastal regions. The following section presents a typology of example GWD measures in relation to the spatial layers, followed by discussions on the scale levels at which these measures can be applied.

## A Typology for Green Water Defense Examples and Practices

As indicated above, Green Water Defense has many manifestations. For clarity of presentation, this section is divided into five parts: (a) types of flood hazard; (b) the ecological processes and services used for GWD (Base Layer); (c) measures typically related to the Occupation Layer – land and water use; (d) a long list of GWD measures and (e) scale levels.

### *Types of Flood Hazards*

Normally, flood hazards (types) fall into three groups: coastal, fluvial and pluvial floods. These are discussed separately below.

***Coastal floods.*** Coastal floods are caused by storm surge (from a depression or hurricane), a tidal action or tsunami. Storm surges are waves originating from coastal storms. Coastal storms can be divided into two main categories: (a) the extra-tropical storm, which is characterized by (intense) momentum transfer from the atmosphere to the ocean and (b) the tropical storm, which extracts energy from the warm ocean water to sustain itself and to grow in strength. Tropical storms are known by different names: cyclones (Indian subcontinent), typhoons (Southeast Asia) or hurricanes (Americas), but their physical characteristics are essentially the same. Both the storm induced surge and wind waves cause hazards for navigation and port operations. They can cause severe damage to coastal defenses, such as dune erosion and dike collapse as a result of saturation due to sustained wave overtopping and or pressure on the dike due to surge and wave forces (Jonkman *et al.*, 2012).

A tsunami has a very different origin. It is a wave caused by sudden rise or fall of the ocean floor, or by large masses of earth falling or sliding into the water; most are triggered by strong earthquakes below the ocean floor. Tsunamis propagate as consecutive, very long period ocean waves over long distances. Typically, at sea, even large tsunamis with amplitudes of only a few decimeters do not register due to the enormous wavelengths of several hundred kilometers, and they cause no risk to ships on the high seas. It is only in the shallow waters of the coastal areas that the dangerous waterfronts build up to several 10 m (Bormann, 2006).

Coastal floods can cause large numbers of fatalities, as they have severe effects (large depths, flow velocities and waves). Further, coastal storms often occur unexpectedly and without warning. This allows little or no time for preventive evacuation of the large exposed populations.

***Fluvial floods.*** Fluvial or riverine flooding originates from a river discharge that exceeds the capacity of the main river channel, leading to spill over onto the floodplain. Flash floods are a special case of fluvial flooding. Flash floods occur after a few minutes or hours of excessive rainfall, thunderstorms and heavy rains from hurricanes and tropical storms. They can occur from a dam or levee failure or from a sudden release of water held by an ice jam. Although flash flooding occurs most often along mountain streams, it is also common in urban areas where much of the ground is covered by impervious surfaces (Mirza *et al*., 2005), or where drainage systems are blocked by (solid) waste disposal.

***Pluvial floods.*** Pluvial or rainfall floods are a form of localized flooding due to intense rainfall occurring over a sustained period of time and the consequent drainage congestion (Mirza et al., 2005). Pluvial flooding occurs when the local drainage system is not able to collect and convey surface runoff. The flooding may be caused by (a) the lack of a properly designed and built storm drainage and sewer system; (b) heavy rainfall in excess of the 'design storm'; (c) catchment conditions worse than those assumed when the drainage system was designed; (d) partial or complete blockage of inlets and/or sewers pipes due to poor maintenance and/or (e) failure of pumping stations and collapse of trunk sewers, etc. (Zevenbergen *et al.*, 2011).

### *Ecological Services for Flood and Storm Control ('Base Layer')*

Ecological services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulation services such as regulation of floods, drought, land degradation and disease; supporting services such as soil formation and nutrient cycling and cultural services such as recreational, spiritual, religious and other nonmaterial benefits (Millennium Ecosystem Assessment, 2005). Ecosystems play an important role in modifying and regulating hydrological and meteorological processes, and thereby affect the positive as well as the negative consequences of floods and storms. The functions of ecosystems range from regulating surface and sub-surface flow to modifying wave dynamics in coastal and near-shore areas. Normal and flood flow regimes are affected by vegetation and its characteristics. Hence, one important ecological service is to control floods and storms (Mirza *et al.*, 2005) by managing the following:

(a) Wave energy dissipation (by coral reefs, vegetation and geomorphology);
(b) Barriers to flooding (by natural terrain elevation, dunes, etc.);
(c) Coastal stabilization, erosion control and sediment retention;
(d) Reduction of water logging, improving infiltration and drainage; and
(e) Lowering flood levels and flood water retention.

It is evident in nature that most ecosystems provide more than one of these services beyond storm and flood control. For instance, a mangrove forest provides wave energy dissipation, sediment retention, nutrient cycling, nursery area for fish and shellfish, habitats for birds, etc. Furthermore, in undisturbed environments, individual ecosystems such as mangroves and coral reefs often border each other, resulting in dampening of waves, first by the shellfish reef, then by the sea grass bed behind the reef and, finally, by the adjacent salt marsh. These so-called 'service cascades' may be more efficient than the sum of their individual services (Hulsman *et al.*, 2011).

An additional characteristic in nature is the non-linearity in ecosystem services. Since natural processes tend to vary over time and space, the ecosystem services are also highly variable. For instance, the wave attenuation of coastal vegetation is largely determined by the vegetation structure and biomass, which in temperate regions often vary over the seasons. Clearly, protection will diminish if storms occur when plant biomass and densities are low. In tropical areas, biomass tends to be less variable over time, and therefore provides more predictable coastal protection throughout the year (Koch *et al.*, 2009).

***(a) Wave energy dissipation.*** Reducing high waves is especially important in coastal environments, where storm surges and tsunamis are the most destructive forces of nature. In inland lakes and riverine environments wave reduction can also be important, but to a lesser extent. Coastal ecosystems such as mangroves, coral reefs, sea grass beds and salt marshes constitute elements that can physically exert an effect on waves. They create hydraulic resistance that can break the waves and reduce their velocity, thereby reducing the waves' energy. Especially mangroves are able to significantly reduce the energy of huge waves such as storm surges that accompany cyclonic depressions (See Boxes 2.1 and 2.2). As a result, there are substantial mangrove rehabilitation efforts worldwide. Over the years these efforts have shown mixed results, so it is crucial to learn from these experiences in order to increase the success rate of mangrove restoration (more details are provided in Chapter 3).

**Box 2.1: Mangroves Protect Sea Dikes in Vietnam**

To protect sea dikes, people of Thai Thuy and Tien Hai (Thai Binh province) and Xuan Thuy (Ha Nam province) planted stretches of pure *Kandelia candel* forests outside the sea dikes. These have provided protection for dikes and soil for the last several decades. *Kandelia candel* plantings also helped in the natural regeneration of some species such as *Aegiceras corniculatum* and *Acanthus ilicifolius* (Hong & San 1993).

***(b) Barrier to flooding and elevated areas.*** Geo-morphological features such as dunes and river levees serve as natural flood protection systems by providing barriers to flooding and higher grounds, keeping vulnerable areas protected. Typically, dunes are formed at the interface between the coastline and the sea. They have an elevation which is significantly higher than that of the land behind it. In some places this land can even be below sea level, especially in delta areas (for instance in the Netherlands). Although the naturally formed dunes are usually characterized by small inlets and wash-over, people often close these sea intrusions and thus form a continuous high dune area that effectively protects the hinterland from flooding.

Historically, humans began settling first on the higher, sandy natural levees along the rivers and old beach ridges along the coast. Often, towns and cities expanded along these natural features, but later also settled in newly reclaimed land that had previously consisted of marsh or peat. Extreme flood events are likely to cause major damages and casualties in these low lying parts of the city (e.g., New Orleans).

***(c) Coastal stabilization, erosion control and sediment retention for deltas.*** Coastal erosion is the process of wearing away material from a coastal profile due to imbalance in the supply and export of material from the coast. It occurs mainly during strong winds, high waves, high tides and storm surge conditions. During calmer periods, some of the sediment may return to the coast through natural coastal wave and wind processes. Many coasts, including delta coasts, show a dynamic behavior of accretion and retreat over both short and long time scales, due to the interplay between natural factors, such as tides, storms and sea level changes, ecosystem responses and human interferences. Coastal vegetation plays a significant role in mitigating coastal erosion and promoting sediment deposition. Mangroves and salt marshes are typical examples of 'ecosystem engineers', because they modify their local hydrodynamic and sedimentary surroundings (See Box 2.2). Their influence enables these ecosystems to adapt to rising sea levels provided the tidal movement is not restricted by human interference.

Natural sediment dynamics play an important role in delta formation and sustainability. Evidently, deltas are relatively young landforms shaped by the interplay of coastal and riverine processes. For example, the entire Yellow River Delta was formed in a period of slightly more than a century. Since 1855, when the Yellow River shifted its course from debouching in the Yellow Sea to flowing into the Bohai Sea, each year up to several thousands of hectares of new land was formed (Liu and Drost, 1997). This rapid expansion of the delta was caused by enormous quantities of sediment transported by the Yellow River from the extensive Loss Plateau. Other deltas were formed by the sediments brought in by the respective rivers and shaped by the interplay of tides, waves and currents.

**Box 2.2: Mangroves as Coastal Protection Forest**

Mangroves are tidal forests commonly observed along the sheltered shorelines of most tropical and few subtropical countries. Situated between land and sea, the mangrove forest is host to some 69 species of plants called mangroves. More landward mangrove tree species mix with freshwater-adapted species, which in truly freshwater or terrestrial environments, outcompetes the mangroves.

The protective function of mangrove forests can be grouped into three types: (a) wave attenuation, mitigation of the hydraulic forces of storm surges and tsunamis; (b) storm protection through windbreak and (c) shoreline stabilization, sediment retention and erosion control.

Wave reduction by mangrove forests can be considerable. Significant protection against storms is possible especially in delta and coastal areas where a large natural belt of healthy mangrove exists. Both experimental tests and field observations have proven the dampening impact of waves by mangrove vegetation through hydraulic roughness. For the more powerful waves of a tsunami, the mitigating effect of mangrove forests is less than that of a storm surge. Coastal forests generally collapse under a tsunami of over 4m height. However, in the case of lower tsunami waves, a healthy mangrove forest of 200 m wide can reduce the tsunami inundation depth to 50-60% and flow velocity to 40-60% (Nippon Koei, 2005). Mangrove trees may reduce wind speeds up to a distance about 20 to 30 times their height of the trees. Hence, the impact of mangrove trees up to 10m high on wind velocity can stretch to a distance of approximately 0.25 km (Mohapatra & Bech, 2001).

Mangroves are capable of reducing coastal erosion due to their positive effect on local sedimentation  An important precondition for sustaining this feature is that the tidal movement of water in and out of the mangrove forest is not disturbed (Winterwerp et al, 2005) so that they can trap up to 1000 tons of sediment per km$^2$ (Ellison, 2000).

**Box Figure 2.2.1: Mangrove Forecast**

*Source:* Marchand et al., 2012

Many deltas suffer from a sediment deficit (Syvitski *et al.*, 2005 and 2009), partly because of sediment starvation due to upstream developments (e.g., storage dams), but also as the result of flood control measures. If regular flooding of the delta is prevented, a river is not able to deposit sediments any longer. In addition, when people are protected from floods, the benefits of flooding are lost, which, in combination with delta subsidence, leads to the problems faced by many deltas (See also Table 1.2).

***(d) Reduction of water logging, improving infiltration and drainage.*** Vegetation can have a mitigating effect on the impact of heavy rains in catchments and urban areas. Foliage acts as an umbrella to reduce raindrop impacts on the soils, thereby decreasing the risk of erosion and landslides. Roots strengthen the soil and improve soil texture, which increases the retention (sponge) capacity. Organic matter from roots and leaves improve soil structure and increase both infiltration rates and water-holding capacity, that is, the ability of the soil to retain water against gravity (Mirza *et. al.*, 2005).

Changed vegetation cover affects the hydrological behavior of a catchment. The influence of deforestation on the deterioration by flood disasters has been analyzed using data collected between 1990 and 2000 from 56 developing countries (Bradshaw *et al.*, 2007). The studies found that flood frequency is negatively correlated with the amount of remaining natural forest and positively correlated with natural forest area loss (after controlling for rainfall, slope and degraded landscape area). Although not uncontested (Van Dijk *et al.*, 2009), these findings may indicate that unabated loss of forests increases and/or exacerbates the number of flood-related disasters.

**Box 2.3: The Urban Hydrological Cycle**

In urban areas, water exists in different states: rain/storm water, groundwater, surface water and wastewater. Wastewater from households and industry is transported to a treatment facility by a sewer system, then discharged into surface water bodies, often by a combined sewer system that conveys both wastewater and storm water runoff. However, during heavy rainstorms, the capacity of the combined sewer systems may be exceeded, causing combined systems to overflow, leading to the emission of diluted wastewater and sewage sludge into the urban surface water. It is now generally accepted that relatively clean storm water should not be mixed with wastewater flows. Therefore, separate sewer systems that drain storm water to the urban surface water and wastewater to the treatment plant are becoming a standard practice in contemporary urban drainage systems (Zevenbergen *et. al.*, 2011).

Over the past decade there has been a great deal of attention paid to reducing water logging and flood problems in urban areas. Hydrological processes in the urban areas are complex and relate to both water quantity and quality (See Box 2.3). One of the most prominent features is the high percentage of impervious surface that can cover from 75% to 100% of the urban area. This can lead to more than half of the precipitation flowing down as run-off, compared to 10% under natural conditions (Zevenbergen *et al.*, 2011). Permeable paving for roads and parking lots, urban wadis and more green space can lead to increased infiltration capacity, thereby reducing the flood hazard. Green areas such as parks and water bodies also act as (temporary) retention areas. To reduce peak flows from surface runoff, and increases storm water infiltration, sustainable urban drainage systems

(SUDS) have, since the late 1990s, been increasingly implemented (Zevenbergen *et. al.*, 2011).

Green roofs are also rapidly growing in popularity (See Box 2.4). Green roofs not only provide a habitat for insects and birds in a densely urbanized area, but also have the capacity to immobilize up to 200 g of dust and harmful air particles, purify nitrates and other pollutants in the water annually, and are capable of retaining 50% to 90% of rainfall (Reinberger, 2009).

**Box 2.4: Encouraging Green Infrastructure through IPA (Germany)**

In many European countries, urbanization and climate change are interlinked problems. The population density increases the spatial pressure and leaves little room for greenery and water. Many cities seek possibilities to use space in a multifunctional manner and to realize different co-benefits, e.g., storm water management and environmental quality improvement. These so called Green technologies are referred to as Green infrastructure.

There are many technological concepts for multiple uses of space and infrastructure. The question is: how does one get private parties to invest in a common good, like flood safety and climate adaptation? In Germany, it is required by law that any new land development be paired with compensation for lost ecological value. The use of green infrastructure is one solution. In addition to the normal functions, green infrastructures such as vegetated river banks increase the aesthetic value of the landscape.

Since the 1970s, most German households have been charged for storm water services based on an estimate of storm water burden generated from their properties. This approach of individual parcel assessment (IPA) differs from most other countries, where a collective rate is charged for a certain area, uninfluenced by measures taken to decrease the pressure on storm water management infrastructure. In Germany, using individual parcel assessments to assess fees that relate directly to conditions present on specific parcels and land-use decisions (like paving a driveway or installing a Green roof) have major impacts on the amount of storm water leaving a property; as a result, this approach creates incentives for individuals to incorporate Green infrastructure on their properties (Buehler *et al.*, 2011).

**Box Figure 2.4.1: Examples of Green Infrastructure**

*Source*: Marchand et al., 2012

***(e) Lowering of flood levels and flood water retention.*** River floodplains and wetlands act as natural buffers during high river discharges by enabling horizontal expansion of water mass and thereby reducing the maximum high water levels. In many countries, the area available for rivers has been decreasing gradually. Lowland and delta rivers nowadays are often embanked in order to protect agricultural fields and urban areas from flooding. For instance, as a response to the disastrous Mississippi River flooding in 1927, the United States built the longest system of levees in the world to minimize flooding and improve navigability. However, during the 1993 flood, 40 of these 229 federal levees and 1,043 of 1,347 non-Federal levees were overtopped or damaged (NOAA, 1994). In the Netherlands, river canalization and embankment strengthening began centuries ago; floods in the early 1990s served as wake-up calls to their conventional approach of flood management, and led to changes in thinking towards providing 'Room for the River' (See section 3.1).

As examples of flood retention by ecosystems, there are many cases worldwide of constructed or restored wetlands acting as buffers and water filters for improving the quality of the out-flowing water.

### *Planning and Adaptation Measures ('Occupation Layer')*

At the Occupation Layer, reducing the vulnerability of communities to floods often calls for a mixture of nonstructural (e.g., land use zoning) and structural measures (e.g., flood-proof buildings). How land and water are used must be viewed differently, towards adapting to floods and changing climate. Different actors are involved in designing and implementing these measures. Examples of important management measures at the Occupation Layer include: (a) flood adaptation; (b) zoning and coastal setback lines; (c) multifunctional infrastructure and (d) early warning and evacuation.

***(a) Flood adaptation.*** Flood adaptation is a very broad category of measures to reduce flood impact, consisting of structural measures and coping mechanisms by which people adapt their way of living and livelihoods to regular or incidental flooding. Examples include building houses on elevated land or on poles, growing flood-resistant crops, and diversifying livelihood, etc.

***(b) Zoning and coastal setback lines.*** Traditionally, populations tend to choose areas to live that are relatively safe against flooding. Because of growing population pressure and urbanization, many people now live at or near hazardous locations. Zoning regulations can help keep the most hazardous places uninhabited, and coastal setback lines allow room for coastal dynamics. A setback line is the landward limit of a buffer zone along the coastline where building restrictions or prohibitions are applied.

***(c) Multifunctional infrastructure.*** The most evident example of multi-functional infrastructure in flood management is the use of a dike for transport purposes. There are many more opportunities for similar combinations, some of which have been utilized only recently, including using parking garages or sporting fields for temporary water storage and wetlands for flood retention.

***(d) Early warning and evacuation.*** Many parts of the world are developing and using early warning systems at an increasing scale, mainly due to the improved ability to predict floods through a real-time data collection and model analysis. Early warning and evacuation whenever needed can significantly reduce the number of flood casualties, provided that the warnings are channeled to the local communities in time and that the inhabitants know how to respond. Evacuation plans and refuge areas are equally important.

### *Long List of Measures*

Based on literature review in light of the above discussions, a long list of management measures is developed (See Table 2.1). The list also includes conventional measures such as dikes and barrages which can now be designed and built differently using GWD approach. In practice, a combination of (a) engineering works and (b) more ecosystem-based flood protection measures is usually required. However, traditional designs can be improved by making better use of ecological services. For instance, the combination of a dike with willow forest protection on the water side reduces wave impact and provides more robust flood defense than a dike alone.

**Table 2.1: Long List of Measures for Green Water Defense**

| Measure / ecosystem | Explanation |
|---|---|
| Buffer zone / setback line in coastal areas | The landward limit of a buffer zone along the coastline where building restrictions or prohibitions are applied and which allows room for coastline dynamics. |
| Bypass / Green river | Artificially created waterways, which will redirect excessive (river) discharge. |
| Detached breakwater | Structures parallel to and at a certain distance from the shore, used to change the transport capacities both along and perpendicular to the coast. |
| Dike / embankment | Constructed to keep water out, and may consist of sand, clay or peat soil; usually protected from erosion by a grass, stone, rubble or concrete layer. High growing vegetation, such as trees is normally not allowed to grow on these for safety reasons. Grass / shrub vegetation often provides good erosion protection. |
| Dunes | Natural elevations consisting of sand, fixed by vegetation. Act as natural flood defense. |
| Early Warning | A non-structural measure which warns people about an imminent flood danger |
| Evacuation | A temporary moving of inhabitants out of an area that (may) flood(s) |
| Flood adaptation | A range of measures and approaches by which people have adapted their way of living and livelihood to regular or incidental flooding. |
| Flood retention areas | Areas designated to retain water from inundation (in emergency situations) |
| Flood proofing | Buildings that will resist floods and dissipate wave energy, as well as decrease current velocity. |
| Green roofs | Vegetated roofs that retain rainwater, reduce heat stress, improve air quality and increase insulation of buildings. |
| Green space / parks in urban areas | Green areas such as parks and water bodies that act as (temporary) retention areas and also improve the infiltration capacity |
| Groynes | Typically found in river systems to maintain a certain navigational depth. Also applied along the coast to reduce the long shore sediment transport capacity and thus the coastal erosion. |
| Infiltration constructions | Constructions, such as infiltration crates, placed under a paved surface to retain and infiltrate rainwater; also, permeable paving for roads and parking lots. |
| Lakes, ponds, lagoons | See wetlands. |
| Lowering of floodplains | Method to allow flooding more often, creating a larger wet surface and lowering the water levels, thus preventing floods elsewhere along the river. The higher flood frequency results in more sedimentation and stabilization of the dikes. |

| | |
|---|---|
| Lowering of groynes | Action to reduce hydraulic resistance in a river, leading to a reduction of high water levels. |
| River dredging / Lowering riverbed | Allows a river discharge more water and reduces flood water levels. |
| Managed realignment / dike relocation | Used along the coast: reconstruction of dike or seawall inland in order to create a buffer zone (coastal wetland, salt marsh). Along rivers, relocating a dike provides more room for the river. |
| Mangrove | Mangroves grow in the supra-tidal and intertidal zone of (sub) tropical coasts. Mangroves have a multiple function for coastal protection: increasing sedimentation, reducing erosion, reducing the energy of high waves and reducing wind speed. |
| Mound, refuge area | Elevated area in a flood-prone location. |
| Natural or artificial reef | See Detached breakwater. |
| Removal of obstacles | Measure along the river or in the floodplain to reduce the hydraulic resistance. |
| River levees | Natural elevations along rivers, mostly consisting of sandy soils which may act as natural flood defense. |
| Room for the River | A strategy to reduce water levels by decreasing the hydraulic resistance in the river bed and its floodplain. It includes a variety of measures, such as lowering the floodplain and widening it by realigning embankments. |
| Salt marshes | Growth in the supra-tidal area of temperate climate zones. Salt marshes have a multiple function for coastal protection. They can increase sedimentation, reduce erosion and reduce the energy of waves. |
| Sand nourishment | Mechanical placement of sand in the coastal zone to advance the shoreline or to maintain the volume of sand in the littoral system. |
| Sea grass beds | Sea grasses are able to reduce erosion of sub-tidal areas and promote sedimentation. |
| Seawall | Often concrete or stone wall along the coast. |
| Separate sewerage system | System by which rainwater will not be drained in mixed sewerage (rainwater and waste water), but separately and directly on open water bodies. |
| Shellfish reef / bed | Habitat of large numbers of bivalves, e.g., oysters and mussels which reduce erosion of intertidal areas and promote sedimentation. |
| Storm surge barrier | Structures which are activated only during a flood. Examples are the Oosterschelde barrier in Southwestern Delta and Maeslant Barrier in Rotterdam harbor (remains open for navigational purposes). |
| Submersible dike | Dike that can withstand water overflowing without breaching. |
| Sustainable urban drainage systems (SUDS) | An approach to reduce urban flooding due to storm water and to improve water quality. Contains many different measures, such as Green roofs, infiltration swales, re-vegetation etc. |
| Super levee (Super dike) | High and wide levee or dike combining flood protection with use functions (such as roads, buildings and parks) |
| Temporary water storage in buildings | Storage of water in underground garages, cellars etc. |
| Urban wadis | A depression in the surface, which is not paved, to retain water and provide infiltration possibilities. In dry spells, it does not retain water. |
| Waterplaza | A paved square, which can be flooded in stages. In dry spells the square is dry; in heavy precipitation it can retain water, until the drainage capacity is restored. |
| Wetlands | Generic term for areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas or marine water the depth of which at low tide does not exceed six meters (Ramsar Convention). Wetlands may function as buffer zones between upstream and downstream regions, which may reduce peak-flow levels and increase low-flow levels. |

### *Scale Levels*

The understanding of flood risks is influenced greatly by the multi-scale nature of biophysical and human systems and the interactions between them across scales. Normally, disasters occur at the local level, for instance, at deltas or along floodplains. In order to understand the hazard level at a specific location, the larger geographic context must be considered. The rainfall pattern for a watershed determines the flood risk of a downstream community. In designing flood risk reduction measures, a source-pathway-receptor framework can be used (Samuels *et al.*, 2009). The hazard sources include the hydrological or hydraulic boundary conditions that may provoke a flood. The pathways are the channels through which the flood waters flow, including breaching processes of man-made and natural protection systems. The receptors refer to the people and their assets that may be impacted by the flood. This thinking framework enables understanding and managing the flood risk in a holistic way. To understand and reduce the flood hazard at source usually requires knowledge and interventions at the largest scale level of a river basin or catchment or regional sea. Hazard reduction along the pathway requires understanding and actions at a smaller scale level (e.g., a lowland river or delta). The actual receptors are local villages, urban areas and coastal zones, where local actions to increase resilience are often more efficient in reducing flood risks. For urban flood risk management, more detailed scale levels, such as neighborhood and building levels, may be used for planning and action.

In selecting appropriate measures for reducing flood risks, the processes and ecosystems at each of these scale levels must be taken into account. Failure to do so often results in underperformance of those measures. Many Green Water Defense measures are localized and have substantial impacts when applied over the entire river basin or coast. They modify the environment within the capillaries of the water system and, although their impact may be small on that level, exert a significant influence on the whole hydrological cycle. An example is the green roof practice, a small scale measure which works best when implemented for as many buildings/houses as possible.

## A Menu Type List of Green Water Defense Measures

Obviously, not all measures are applicable everywhere under all conditions. The applicability of GWD measures depends on the type of flood hazard and on the scale of operation and the type of process[7]. For this reason, a menu of measures has been prepared for easy reference, based on (a) flood type; (b) mechanism or process and (c) spatial layer (See Table 2.2). It is clear from this menu that knowledge of both the process and the applicable measure are necessary for effective flood management results. For instance, making room for water is an effective means of lowering high waters in river systems, but of far less use in coastal and estuarine environments. In the latter situation, the amount of water pushed up from the sea is almost infinite, any extra room for water is rapidly filled and water levels continue to rise. Hence, the buffer areas between coast and land do not function in the same way as those between river and land. Such areas along the coast contribute to wave energy reduction and sedimentation for coastline stabilization.

[7] Also the socio-cultural context is important in selecting measures, since people may have different perceptions of floods and respond differently (Hoekstra, 1988). This is not included in this menu.

**Table 2.2: A Menu of GWD Measures Based on Flood Type and Process**

| Flood Type | Mechanism | Spatial Layer | Examples of GWD Measures |
|---|---|---|---|
| **Coastal** | Wave energy dissipation | Occupation Layer | Managed realignment |
| | | Infrastructure Layer | Detached breakwater |
| | | Base Layer | Mangrove; natural or artificial reef; saltmarshes; shellfish reef or bed |
| | Flood defense | Infrastructure Layer | Dike/submersible dike/super levee; Seawall; storm surge barrier |
| | | Base Layer | Dune; natural levee |
| | Coastline stabilization | Occupation Layer | Managed realignment |
| | | Infrastructure Layer | Groynes |
| | | Base Layer | Mangrove; natural artificial reef; saltmarshes; sand nourishment; seagrass beds; shellfish reef or bed |
| | Zoning | Occupation Layer | Setback lines |
| | Early warning and evacuation | Occupation Layer | Real-time flood forecasting systems; evacuation procedures; storm shelters and refuges |
| **Pluvial** | Local retention | Occupation Layer | Water plaza; temporary water storage in buildings/garages |
| | | Base Layer | Green roofs; green space/parks; urban wadis |
| | Infiltration | Infrastructure Layer | Infiltration infrastructure; permeable pavement |
| | | Base Layer | green space/parks; urban wadis |
| | Drainage | Infrastructure Layer | Separate sewage system; pumps |
| | Flood defense | Infrastructure Layer | Guays and walls; temporary construction |
| | Impact mitigation | Occupation Layer | Flood proofing |
| | Evacuation | Occupation Layer | Evacuation procedures; refuge areas |
| **Fluvial** | Upstream water retention | Occupation Layer | Flood retention areas |
| | | Base Layer | Wetlands; watershed management |
| | Room for the river | Occupation Layer | By-pass/dike replacement; flood retention areas |
| | | Infrastructure Layer | Lowering of groynes; removal of obstacles in river and floodplain; river dredging |
| | | Base Layer | Lowering of floodplain |
| | Flood defense | Infrastructure Layer | Dike/submersible dike/super levee |
| | | Base Layer | Natural levees |
| | Early warning and evacuation | Occupation Layer | Real time flood forecasting systems; evacuation procedures; refuge areas |

## CHAPTER 3

# Selected Best Practice Case Studies

To illustrate the evolution of the green water defense concept over time and how the emerging best practices (again with focus on delta and coastal regions) are applied in the real world, this chapter presents cases from four countries, including the Netherlands, Singapore, Japan and the United States, as examples. This list is not exclusive as there may well be other good practices of green water defense in other parts of the world.

### The Case of the Netherlands

#### *KEY ISSUES AND CHALLENGES*

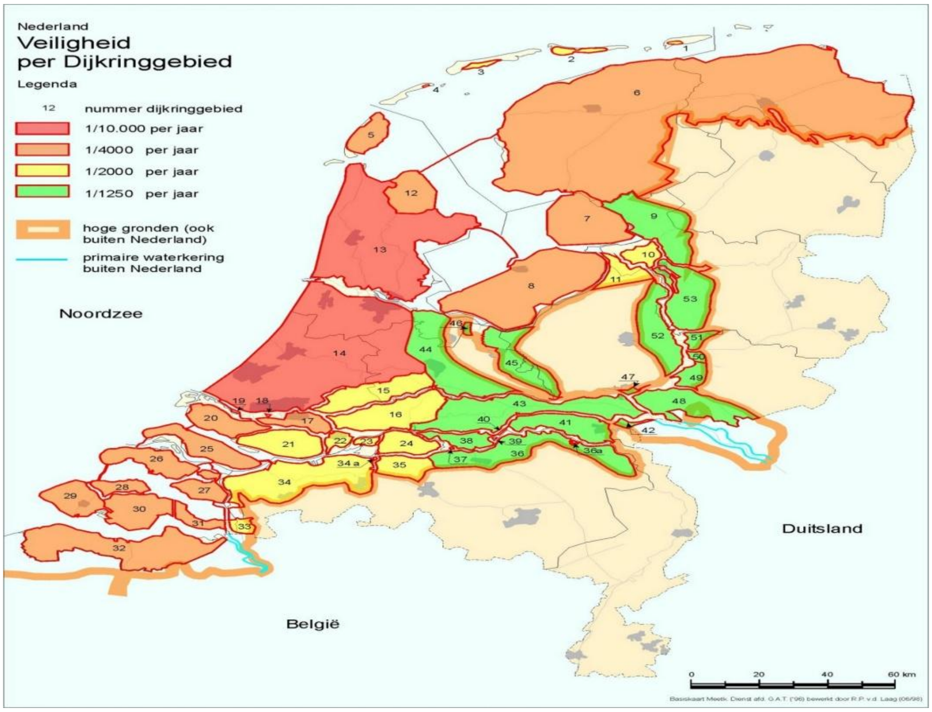
Located in northwest Europe along the North Sea, the Netherlands comprises a series of deltas from four major rivers — the Rhine, Meuse, Scheldt, and Ems. About two-thirds of the country's 34,000 km$^2$ of land is prone to flooding and more than 25% of the country is below mean sea level. Many of the low-lying parts of the Netherlands along the main rivers and coastal areas are protected by dikes and embankments, which together form the so-called 'dike rings' (See Figure 3.1).

The Netherlands is one of the most densely-populated countries in the world with 489 people per km$^2$ of land and a high density of urban development, leading to high flood risk within these low lying lands, as demonstrated by the frequent flood disasters before 1960s. Climate change is expected to increase the frequency and severity of flooding in the Netherlands. The increased uncertainty requires that the current infrastructure (e.g., dikes) be reinforced to meet safety standards. At the same time, there is an urgent need to rethink the overall strategy and approach to flood risk management, including adaptation to climate change impacts.

#### *OVERALL STRATEGY AND APPROACH*

In the Netherlands a gradual shift in water management approach occurred from an *optimization* paradigm to an *adaptation* paradigm over a time period between the 1970s and around the year 2000. Such a paradigm shift in overall thinking resulted from a range of social and cultural developments which challenged the conventional technocratic thinking in water management. The belief in the human ability to control the water system by massive infrastructures eventually gave way to a stock of adaptation measures for higher climate resilience. Under the latter approach, rivers and water systems are perceived as dynamic, complex and inherently uncertain. Consequently, water managers must continuously adapt the water systems and anticipate the future (Van der Brugge, 2009).

**Figure 3.1: Constructed Dike Rings in the Netherlands**




Source: Deltares, 2009

The overall approach of the Netherlands can be summarized as: (a) to 'live with nature (water)' and to adapt to (climate) change as guiding principles and overarching strategy, representing a shifting focus from 'hard' solutions (infrastructures) to a balanced 'soft' (natural/green) and 'hard' solutions, as indicated in Figure 3.2; (b) to involve stakeholders in the process of strategy formulation, planning, investment decision making and implementation; (c) to design targeted programs for reducing flood risks at different spatial levels, e.g., Delta Program, Room for the River and Waterplan (Rotterdam) and (d) to mobilize professional institutions to innovate and search for 'green'/natural and sustainable solutions to flood risk reduction and adaption, e.g., 'Building with Nature' for coastal protection.

The Dutch government is currently implementing the Delta Program for climate change adaptation in flood risk management. The Program consists of measures designed based on a water system approach, taking into account the linkages between the different water systems (rivers, lakes, estuaries and coastal zone) and water chain (demand and supply). In the Delta Program, much attention is given to innovative and integrated solutions, such as natural solutions that use 'soft' materials like sand, clay and vegetation to reduce the load on the defense system. Also, where applicable, deployment of foreshore elements, such as (salt) marshes, sand flats, sand bars and tidal areas, is foreseen. An important common feature of these natural solutions is the use of natural processes and sedimentation, as well as the development of vegetation. In addition, natural coastal defenses are better equipped to cope with changes in the system, such as rising sea levels.

The Dutch government strategy and overall approach to flood risk management are illustrated through selected examples of innovative practices and measures in the following sections.

**Figure 3.2: 'Soft' versus 'Hard' Solutions for Flood Risk Management in the Netherlands**


Source: Marchand *et al.*, 2012

### *'Room for the River' Program as an Example of 'Live with Nature'*

Studies in recent years indicate that climate change could lead to a 30% increase in flood discharges in the Rhine River. Instead of raising the levees, the government decided to give more room to the river, substantially lowering flood levels and sustaining a more attractive environment. The government officially adopted the 'Room for the River' strategy/program to achieve the required safety level for the river systems. It became the guiding principle for climate change adaptation along the major rivers.

The 'Room for the River' program consists of 39 different projects, located along all the main branches of the river Rhine. The first program implementation started in 2007 and is expected to be completed by 2015. Figure 3.3 highlights all the project locations of the program.

The main goal of this program is to maintain the safety of the land against flooding from the river for higher river discharges expected in the near future. Currently, the river embankments are able to withstand flood waters up to 15,000 $m^3/s$, a condition which occurs approximately once in every 1,250 years. The design discharge of the Rhine is expected to increase to 16,000$m^3/s$ in the year 2100. Without additional measures, this would mean higher water levels. The 'Room for the River' program consists of a range of innovative measures that will reduce the water levels and maintain the current flood protection level (1/1250 year).

**Figure 3.3: Map Showing the Project Locations of the Room for the River Program**


Source: Marchand et al., 2012

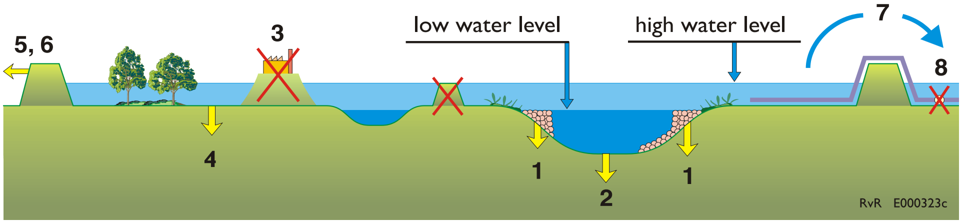
In addition to flood protection, the program also contributes to improving the spatial quality, amenity and nature values of the river landscape by: (a) increasing the landscape diversity between river branches; (b) strengthening the openness of the river with its characteristic waterfronts; (c) conserving and developing the scenic, ecological, geological, cultural and historic values; (d) improving the environmental quality and (e) promoting the use of the main navigation waterways.

The 'Room for the River' program consists of 8 basic types of measures to reduce the water levels in the floodplain (See Figure 3.4):

1. Lowering groynes: At high water levels groynes can hinder the river flow; lowering the groynes increases the discharge capacity;
2. Deepening low flow channel: Excavating the surface layer of the river bed increases the wetted area within the river channel, thereby increasing its flow capacity;
3. Removing obstacles: Modifying or removing obstacles in the river floodplain creates more room and thus reduces the hydraulic resistance;
4. Lowering floodplains: Excavating the floodplain lowers the water level during high river discharges;
5. Relocating dikes: Displacing the dike landwards increases the width of the floodplain;
6. Setting back dikes on a large scale: By relocating the riverside dike, a previously reclaimed floodplain area can be restored so water can flood the area during high tides;

7. Designating detention reservoirs: Assigning additional place for temporary water storage in exceptional times can alleviate flood conditions; and
8. Reducing lateral inflow: Preventing local water runoff reduces water levels.

**Figure 3.4: River Floodplain Cross-section Showing Measure Types under the Program**




1 - lowering of groynes
2 - deepening low flow channel
3 - removing hydraulic obstacles
4 - lowering flood plains
5 - locally setting back dikes
6 - setting back dikes on a large scale
7 - detention reservoir
8 - reduction lateral inflow

Source: Marchand *et al.*, 2012

**Implementation and stakeholder participation.** The Program required several years of studies, planning and deliberations prior to implementation. It began with a number of studies and research activities which concluded that the traditional way of flood protection (larger dikes) would transfer flood risk to downstream areas and would affect the beautiful river landscape. The studies also concluded that the urban expansion into the floodplain would require more fundamental interventions and the rivers would need to discharge much higher water flows due to climate change impact. The studies identified several locations where extra room can be created and, in the year 2007, the Dutch government approved the 'Room for the River' program that included 39 locations to undertake different measures.

Since such a large scale program is of national interest, the national government decided on the policy to give more room to the rivers. A Planning Key Decision (PKB) was formulated, that outlined the locations and types of measures. However, implementation of each of the 39 projects had to involve local governments (municipalities) and stakeholders. Many parties have interests because they own land along the river, have properties there or use the floodplain for recreation. These people live in the affected areas and should be satisfied with the new situation.

Local governments worked closely with the residents at each project location. All the stakeholders endeavored to find an appropriate way to achieve the required objective of the program. The type of measures, their exact locations and implementation were open for discussion. This participative planning process provided satisfactory solutions for all parties.

Information and knowledge sharing played a crucial role in the process. Both national and regional authorities, municipalities and individual citizens proposed around 700 local measures that could help reduce the water levels. Each of these measures would have secondary impacts and different costs. A *Planning Kit (a simple decision support tool)* was specially developed to handle such huge amount of information, and proved to be effective in supporting joint planning with stakeholders. Users can add measures to the existing situation of a river area in an intuitive manner, directly relating to their normal perception. They can for instance lower a dam or remove an obstacle. The tool visualizes the results of such interventions also in an intuitive way, e.g., showing the effects on natural quality and water levels. In this way, stakeholders jointly evaluate different strategies for adaptation.

In total, 17 different governmental agencies are involved in the program: two ministries, one central executing agency (Rijkswaterstaat), four provinces, six water boards and four municipalities. The 'Room for the River' Program Directorate is responsible for the implementation of the program and acts as the link between the national government and the region. It verifies that the plans are compatible with the 'Room for the River' policy, monitors the cohesion between the measures being taken, facilitates the process and promotes exchanges of expertise and experience among the 39 projects. The following sections provide two examples of the Green Water Defense measures and stakeholder involvement process under the 'Room for the River' program.

***a. 'Natural' dike design for Noordwaard polder.*** To prevent extreme high water levels at the city of Gorinchem, downstream in the Rhine Delta, the dike of the Noordwaard polder was set back to create more room for the river. This so-called 'depoldering' of the Noordwaard would allow water to flow freely over 468 hectares of floodplain again. As a side-effect, the renewed tidal influence will reshape the area in a more natural way.

Although some residents initially opposed the plan and proposed an alternative solution, the majority of the 'Bandijk society' was in favor, provided that a speedy implementation and sufficient damage compensation would be guaranteed. The alternative solution was rejected by the decision-maker, as it would not provide sufficient safety in the long term, and would require a second major intervention in due course. Within the Noordwaard, a small area with houses and a historic building ("Fort Steurgat") will have to be protected from floodwater. Instead of building a conventional dike, the stakeholders chose a lower dike with wave reducing willow-plantations in front.

The strip of willow trees will be 2 km long and 100 meter wide and will cause a wave reduction up to 80%. As a result, the dike can be lower and the environmental quality improved at the same time. Despite the higher maintenance costs, the overall cost of this design is much lower. The willow-forest will cost around 318 euro/m, whereas raising and armoring the dike would cost around 1,800 euro/m (De Bel *et al.*, 2011).

***b. People and nature synergy for protecting Overdiepse polder residents.*** In times of high water levels, a tributary of the river Rhine (Bergsche Maas) threatens the cities and villages along the river. Lowering the old dike will reduce flood risk by allowing the Overdiepse polder to store more water. Consequently the high water level in the river will be lowered by approximately 27 cm. It is expected that once in every 25 years the Overdiepse polder will flood, and a new dike needs to be built to protect the hinterland.

Initially, the residents of the Overdiepse polder strongly rejected the plan, because they would lose their farmhouses. To resolve the issue, the local government worked with the community to develop a new project plan. This plan supports the residents to construct their farmhouses on dwelling mounds ('terpen') so that they can live safely, cultivate crops and raise cattle. The project also has many benefits for nature, including nature-friendly zones to be developed along the river. Another benefit is the Westplas, a water storage pond under construction. These unique nature-friendly areas will attract new plants and animals.

This project represents a good example of collaboration and synergy among different stakeholders to work out the details of a project plan prepared by the government. This new approach to protecting the country from flood risk emphasizes not only working with nature but also working with the community.

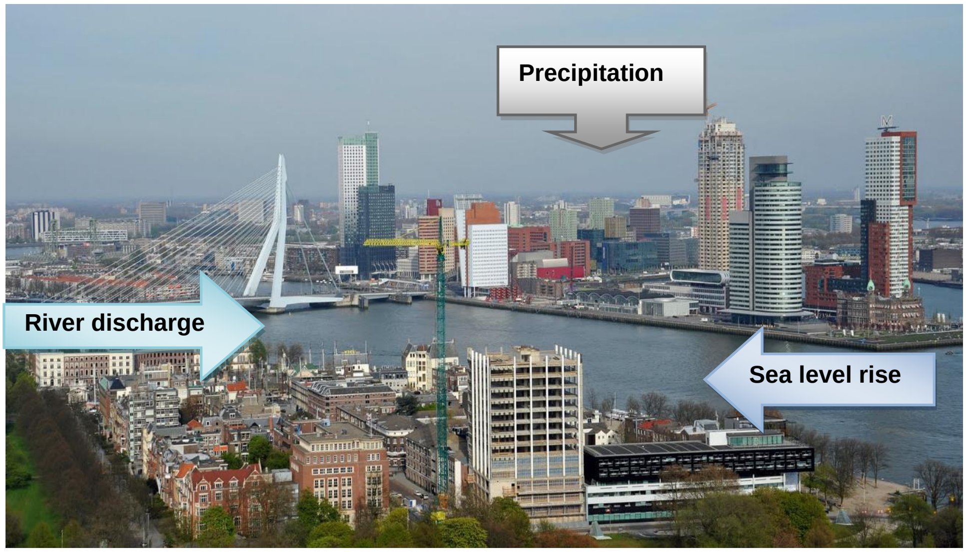
***c. Cost effectiveness analysis of 'Room for the River' projects.*** The total budget for the program was estimated at about 2.3 billion euro and was financed by the Dutch Government. At the start of the program a cost-effectiveness analysis (CEA) was performed by the national economic planning bureau (Ebregt *et al.*, 2005). A methodology was developed for evaluating measures and packages with more than one effect at the same time. Increase in safety, and increase in areas with higher spatial and recreational quality were set as objectives in this CEA. For each objective separate unit cost was defined. By adding up these unit costs for a specific project and comparing this with the actual total project costs, insight was gained on the cost effectiveness of the project. If the project costs were lower than the sum of the unit costs, the project was considered 'cheap' (cost effective). For example, the Noordwaard project (see previous section) scored 'cheap' in the CEA and was considered a cost-effective investment with both significant effects on safety and on compensating loss of nature elsewhere.

The CEA report has been an important source of information for the formulation of the decision to implement the Room for the River program. However, the most important determining factors for the 'Room for the River' projects remain flood safety, sustainability, spatial quality and regional support (Schultz van Haegen, 2006).

### *Flood Adaptation in Urban Areas – Waterplan of Rotterdam City*

The harbor city of Rotterdam with a population of 600,000 is an important economic center of the Netherlands. Situated in the low-lying Rhine river delta, it must cope with many water related challenges. Floods threaten this city from at least three different directions: from the river Rhine, from the North Sea and from local heavy precipitation (See Figure 3.5). Constructing the Maesland Barrier (in 1997) solved much of the water safety problem from the sea. However, the problems associated with heavy rainfall still linger in this city. The storm drainage capacity is inadequate for heavy downpours. It is estimated that the city needs an extra storage capacity of 500,000 to 600,000 $m^3$ to effectively cope with a 1-in-100-year rainfall event. This is the equivalent of 50 to 60 hectares of land with 1 m water level. In such a high density urban area this space is simply not available, so alternative solutions must be found to ensure that this 'water task' can be accomplished. Rotterdam municipality and the three water boards of Hollandse Delta, Delfland, Schieland and Krimpenerwaard joined forces to face this challenge together. As such, a targeted program, Rotterdam Waterplan2 was initiated to integrate the efforts from the government and private sectors in enhancing the flood defense of the city.

**Figure 3.5: Flood Threats in Rotterdam, the Netherlands**




Source: Marchand *et al.*, 2012

The Waterplan2, which integrates water management planning with urban development, consists of three types of projects: projects to improve safety, projects to cope with the quantity (or storage) of water and projects to improve the quality of the water. The program was designed with following principles and features:

- Protection of natural water systems in urban development, through building a 'river city', which emphasizes the multiple functions of rivers to achieve optimum management results;
- Reduction of storm water runoff and peak flows by using local detention and retention areas and pervious roads, water parks and canals, water plaza, underground reservoirs, parking garage, etc.;
- Protection of water quality and ecosystem by increasing filtration and retention through permeable pavement, greening along the river, green roofs, wetlands, water gardens and plantation box, etc. Such measures also contribute to reducing peak runoff; and
- Upgrade of drainage infrastructure to improve storm drainage capacity and amenity of urban areas through such measures as separation of sewage system and drainage system.

The following are some examples of the completed projects under Waterplan2 Program:

***a. Multi-functional parking garages.*** This is a good example of multifunctional solution to flood and related issues. An underground parking garage at the Museumpark (See Figure 3.6) stores 10,000 $m^3$ of water when needed during heavy rainfall. After the rain is over, the stored water is discharged into the drainage system of the city. The garage, completed in 2010, has a total number of 1,150 parking spaces. It contributes significantly to the reduction of local flooding from rain storms.

**Figure 3.6: Water Storage in a Parking Garage**

Source: Marchand *et al.*, 2012

***b. Transport junction redevelopment.*** In the late 1960s a junction between highway A13 and A20 was constructed at the entrance of Rotterdam city. As part of the city's Waterplan2, additional water storage under the junction is to be created under the plan for upgrading the waterways. During the construction of the traffic junction many waterways in the district were filled with soil, resulting in flow obstruction, poor water quality and a monotone ecosystem.

The re-development plan includes the construction of a water pool with natural banks under the junction (See Figure 3.7). The pool has a surface of 6,000 $m^2$ and creates an extra storage capacity of 2,520 $m^3$ for flood water detention and biodiversity. Adjacent to the central pond will be a water plaza, to generate an additional storage capacity of 960 $m^3$ and decorated with sculptures to increase the attractiveness of the entrance to the city. The redevelopment activities started in 2010 and are expected to be completed in 2013. The estimated costs are around 1.5 million Euro, of which the water board covers fifty percent.

**Figure 3.7. Design of Kleinpolderplein Reconstruction**

Source: Marchand et al., 2012

**Figure 3.8. Green Roofs in Rotterdam**

Source: waterplan.rotterdam.nl

***c. Green roofs.*** Since 2008, around 50,000 m² of green roofs have been created in Rotterdam (See Figure 3.8), of which around 35,000 m² were financed by a subsidy of 30 Euro/m² from the municipality and water board. From 2011 onward, the Waterplan 2 sets a target of increasing 40,000 m² of green roofs per year. The municipality and water boards will do their share by greening the roofs of their offices. Private house owners will be encouraged to do the same through subsidy and other forms of support. Green roofs retard runoff, reduce the peak flows, and also bring important amenity values to the city.

***d. Separated sewerage system.*** Sewage pipes that are over fifty years old in the city need upgrading. Under the WaterPlan2, separated sewerage systems are installed where technically and financially possible. One system is for the wastewater coming from the residents, the other system is for the rainwater coming from the roofs and the streets (See Figure 3.9). Separating these two systems greatly reduces the risk of spillover of untreated sewage water into the surface water during heavy rainfall. This practice saves operating costs of sewage treatment, and also makes it easier to manage storm water efficiently.

**Figure 3.9: Old Sewerage System (Left) and Separated Sewerage System (Right)**

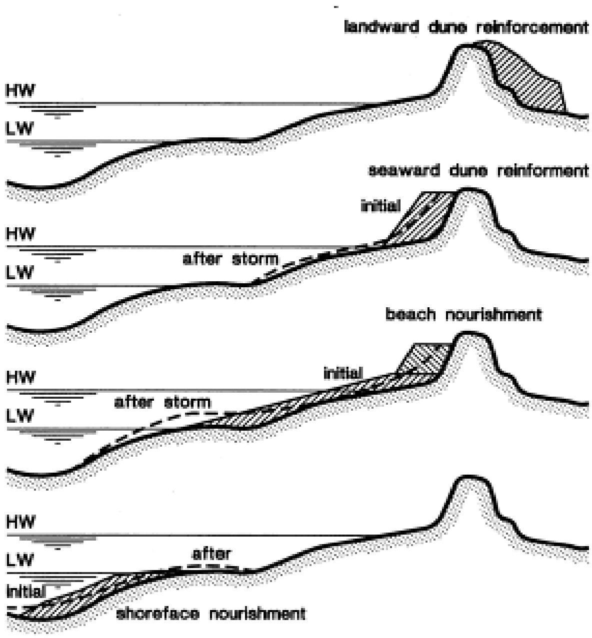
Source: Marchand et al., 2012

*'Building with Nature' for Green Coastal Defense*

Since 1990, the Dutch government has been implementing a new policy on coastline management, called 'Dynamic Preservation' and based on sand nourishment as the preferred method for protection. Only when this measure is not possible are alternatives of hard engineering structures, such as groynes, breakwaters and sea walls selected. This policy has resulted in a reliable, environmentally sound, sustainable and natural coastal defense system, consisting of dunes and beaches along the majority of the Dutch coastline (Marchand *et al.*, 2012). The following sections describe briefly how two innovative measures, sand nourishment and sand engine, work as examples of 'Building with Nature'.

***a. Sand nourishment****.* Sand nourishment is the mechanical placement of sand in the coastal zone to advance the shoreline or to maintain the volume of sand in the littoral system. It is a soft protective and remedial measure that leaves the coast in a more natural state and preserves its recreational value. The method is relatively inexpensive if the borrow area is not too far away (<10 km) and the sediment is placed at the seaward flank of the outer bar where the navigational depth is sufficient for hopper dredgers (Van Rijn, 2010). Usually sand nourishments are grouped into three types: beach, shore face and dune nourishments (See Figure 3.10).

**Figure 3.10: Types of Sand Nourishments**




Source: Marchand *et al.*, 2012

The majority of the Dutch coastline consists of sandy beaches and dunes, which are subject to erosion and accretion. When there is too much erosion, the coast will retreat and may result in flooding of the land behind the dunes. In fact, the dunes form a natural flood protection for large areas that lie below sea level. Fortunately, at most places the dunes are sufficiently high and wide to withstand the wave action during a storm. The system is quite resilient in the sense that it can (partly) replenish the sand lost. During a subsequent calmer period after a storm part of the sediment may return to the coast through onshore directed wave and wind-driven transport, usually resulting in accretion in the beach zone. However, long shore currents may also move the sediment further away from the original location (Marchand *et al.*, 2012).

The idea of sand nourishments is to enhance the natural resilience of the sandy coast, by adding sand in the system where too much sediment has been eroded due to long shore transports. After careful studies and monitoring, the Dutch government decided in 1990 to maintain the coastline position and prevent structural retreat through sand nourishments. Every year up to 12 million cubic meters of sand is used for this purpose (Marchand *et al.*, 2012).

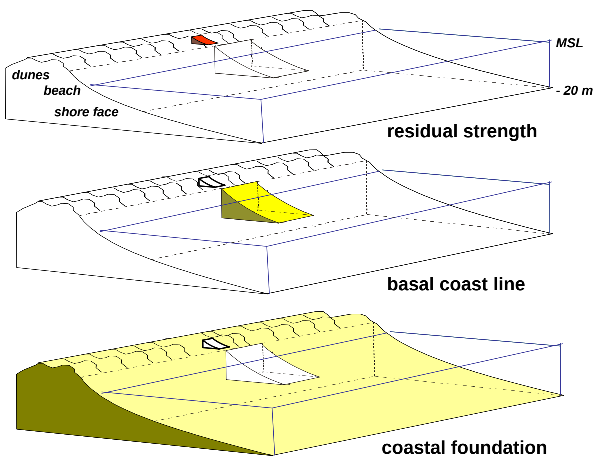
Using the coastline position of 1990 (the 'basal coastline' BCL) as benchmark, every year the government agency Rijkswaterstaat (RWS) evaluates whether the actual coastline meets the standards and, if not, decides on a nourishment. If a beach does not meet the standard, RWS will issue a tender for contractors (Marchand, 2010). The work is mostly executed between April and November in view of the sea and weather conditions.

Considering that morphological developments at larger scales (e.g., sand losses at larger depth and long term developments such as sea level rise) had been neglected, the Dutch Government decided in 1995 on an extended large-scale approach: additional compensation of sand losses at deeper water. Therefore, the policy defined the preservation and improvement of the coastal foundation: the area between dunes and the –20 m depth contour (Marchand, 2010).

With this additional objective the Dutch coastal policy now includes management objectives at three different scales (see Figure 3.11): (a) to guarantee residual dune strength; (b) to maintain coastline position of 1990 (basal coast-line); and (c) to preserve and improve coastal foundation (Marchand, 2010)**.** The rationale for distinguishing between different management scales is that the large scale provides boundary conditions for the smaller scales. The minimum requirement of the dune strength creates boundary conditions for safety against flooding in any place at any time. The maintenance of the Basal Coast Line (BCL) creates boundary conditions for the assurance of the dune rest strength over a period of 10 years and alongshore distances of 10s to 100s of kilometers. The preservation of the coastal foundation in turn creates boundary conditions for maintenance of the BCL over decades to centuries and over alongshore distances of tens to hundreds of kilometers (Mulder *et al.*, 2011).

The sand nourishments support multiple functions: flood protection, prevention of structural erosion, a wide beach and adaptation to sea level rise. This results in a cost effective maintenance of stable coastal zone with many opportunities for a healthy ecosystem as well as for recreation and tourism (Marchand *et al.*, 2012).

**Figure 3.11: Definition Sketch of three Different Management Objectives**




*Dune residual strength (days – meters); Basal Coast Line (years – kilometers) and Coastal foundation (decades to centuries – 10s to 100s of kilometers)*

Source: Mulder *et al.*, 2011

***b. Sand Engine.*** The 'Sand Engine' concept was initiated as a more sustainable way to replenish the Dutch coast. The idea is to apply an extra amount of sand that will be redistributed by nature itself, thus stimulating natural dynamics of the coast, nurturing a buffer zone for future sea level rise and enlarging the coastal intertidal zone with benefits for nature and recreation (Marchand *et al.*, 2012). This method tends to be more cost efficient as it serves more functions than just safety.

The Sand Engine is a unique example of building and working with nature. By depositing a vast volume of sand in a single operation, repeated disturbances of the vulnerable seabed can be avoided. Under the traditional nourishment approach, both the dredging at the sand extraction zones and the beach nourishments disturb the ecosystem every 5 years approximately. By using the Sand Engine the disturbance interval increases from 5 to 20 years, the ecosystem gets the opportunity to recover in a longer time period (Marchand *et al*., 2012).

Between March and October 2011, Rijkswaterstaat and the Province of South Holland created the Sand Engine (See Figure 3.12 and Figure 3.13), a hook-shaped peninsula. It extends 1 km into the sea and is 2 km wide where it joins the shore. Dredgers picked up the sand ten kilometers off the coast and took it to the designated area. There will also be two offshore replenishment locations alongside the peninsula, completed in March 2012. The total costs are €70 million of which the national government contributes €58 million and the Province of South Holland provides €12 million. The Sand Engine is expected to relieve replenishment efforts for the coming 20 years. The Sand Engine offers a new opportunity to use natural processes to replenish the beaches (Marchand *et al.*, 2012).

**Figure 3.12: Construction of the Sand Engine**

Source: Marchand *et al.*, 2012

The Sand Engine will be open for recreational purposes after construction. The peninsula was opened to visitors in the latter half of 2011. Visitors are able to dwell over the enormous sand shoal or go up the watchtower to savor the views. Even the seals have found their way to the Sand Engine. After a few years, visitors will be able to explore the new nature, which will be allowed to develop freely on the Sand Engine (Zandmotor 2011).

**Figure 3.13: The Sand Engine Close to Completion**

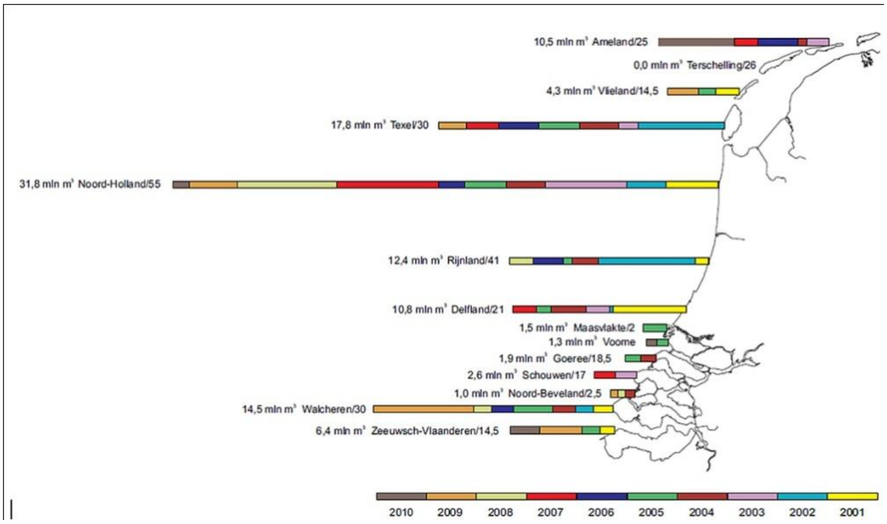
Source: Marchand et al., 2012

### *RESULTS*

By embracing the 'Live with Nature (Water)' as the new strategy for achieving long-term flood safety, and vigorously implementing well-conceived targeted programs with innovation, the Netherlands has made itself as a world leader in adaptive flood risk management, particularly in costal defense and urban flood management. The following represents some results from successful implementation of the new flood defense strategy and programs in the Netherlands:

- Although much of the benefits from implementing the new strategy and targeted programs are yet to be quantified, the most prevailing fact is that there has not been a single flood disaster in the country over the last 50 years. Furthermore, a recent evaluation of the Delta Program revealed that green flood defense can lead to substantial savings in the order of tens of millions of Euros (Fiselier *et. al.*, 2011). This is on top of the enormous flood risk reduction benefit and other co-benefits from the program investments;
- The projects completed under the 'Room for the River' program successfully maintained the high flood protection level of 1/1250 years in the project areas. Such benefits involve avoidance of tens of millions of Euros of flood damages and loss of human lives;
- Rotterdam, with its vision of creating a '(river) water city', has achieved its interim targets of climate proof and resilience through the Waterplan program. One measurement of these achievements is that the city is achieving initial success in maintaining high level protection against 1-in-100-year rainstorms, by adopting such innovative adaptation measures as multifunctional facilities and green infrastructures;

**Figure 3.14: Graph Showing the Dutch Coastline and Sand Used for Nourishment**




Source: Rijkswaterstaat, 2011

- The practice of 'Building with Nature' and the consistent pursuit of innovative solutions for coastal defense have yielded very plausible results (See Figure 3.14). Sand nourishment projects completed have helped reduce beach erosion and prevented retreat of the long coastline. The coastal areas also see an increasing application of the Sand Engine to protect the coastal area in a more natural and sustainable way. Sand nourishment has also served to enhance the coastal ecosystems.
- Through the Delta Program, the government provides academic and professional institutions with adequate funding for innovative research and knowledge creation in the field of delta flood risk management. As a result, different alliances and networks within the country and internationally help information sharing and exchange of good practices in adaptive delta defense benefiting delta regions and professional communities around the globe.

### LESSONS LEARNED

The initial success of the Netherlands in adaptive flood risk management provides important insights and valuable lessons to other countries with high vulnerability to floods of various types. These key lessons of experience are highlighted as follows:

- ***The 'Live with Nature' strategy emerged with the paradigm shift in management approach from sectoral and technocratic to integrated and interactive management, proved to be an effective and sustainable strategy*** in securing a low lying country such as the Netherlands with increasing flood threat and climate uncertainty;

- ***Successful implementation of adaptive flood defense strategy and programs requires involvement of stakeholders in the entire process through an appropriate multi-stakeholder governance mechanism*** as illustrated in the 'Room for the River' project examples. Stakeholder involvement serves to increase their commitment and support to flood defense interventions such as 'Room for the River' projects and enhance sustainability of related investments;
- ***Well designed target programs with dedicated organization and financing are effective ways to achieve specific targets of flood risk reduction and protection.*** Such programs include the Delta Program, 'Room for the River', etc. are implemented with very clear objectives and well-defined targets, and with dedicated organization and resources;
- ***Continued economic development and urbanization accompanied by climate change increase flood risk and call for constant search of innovative solutions to flood defense.*** It is important that the government and operational management entities maintain close collaboration with the academic institutions, and that sufficient funding be provided for research and development activities;
- ***The 'Build with nature' as a green defense practice has a very promising prospect despite the fact that its application is still in the early stage and the cost efficiency is to be further improved.*** It emphasizes making best use of natural process/forces and the services of ecosystems, and it can provide a variety of co-benefits (e.g. protection, ecological services, recreation and tourism) with long-lasting effect and low externalities;
- ***The 'Room for the River' program provides a host of different interventions to increase discharge capacity and lower water levels (and flood risks) in the floodplains of major rivers.*** In spite of the challenges of implementing such a program in a well developed area with high population density, solutions satisfactory to all parties concerned achieved the program objective of reducing water levels (or flood risks) at high discharges. This was achieved through intensive information sharing and consultations with stakeholders including local communities, water boards and private entities and participatory planning with the aid of easy-to-understand decision support tools (DSS); and
- ***The 'Water City' concept, characterized by forward looking spatial planning (integrating land – water – ecological environmental management) and water sensitive design (e.g., multifunctional facilities and green infrastructures), successfully linked flood risk management with urban development.*** Such spatial management approach opens opportunities for sustainable solutions to urban flood issues, which are compatible to development needs and therefore relatively easy to gain supports in implementation.

## Total Water Management in Singapore

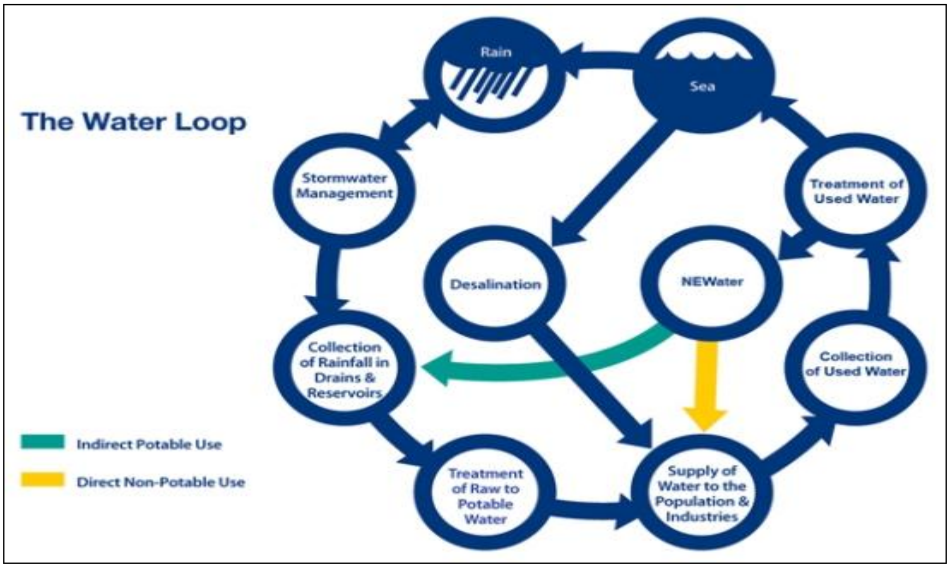
### *KEY ISSUES AND CHALLENGES*

Singapore, a tropical island nation, receives abundant rainfall of about 2,400mm annually that unevenly distributed temporally. Two-thirds of the island in low-lying areas often suffers from wide-spread flooding (PUB, 2011). The projected climate trends show increased uncertainty in frequency and intensity of heavy rainfall events, making the city more vulnerable to floods. An effective storm drainage system is therefore critical. In the past, conventional approaches were used to enlarge and line most natural waterways with concrete, including the Kallang River and Sungei Sembawang, to increase their conveyance capacity and reduce bank erosion. While concrete waterways are able to discharge higher flow, they also increase downstream peak flows and cannot provide a habitat to support healthy aquatic ecosystems along the rivers. At the same time, Singapore experienced seasonal water shortages, which calls for a more integrated approach to inter-linked water issues.

### OVERALL STRATEGY AND APPROACH

To address the flooding and other related water issues and improve the living environment of its people, Singapore envisioned becoming a 'City of Garden and Water' and developed a strategy of total water management. This strategy relies on precise control and management of the entire water cycle and different forms of water, to achieve the objectives of flood risk reduction and improve water environment and year-round availability (See Figure 3.15).

**Figure 3.15: Total Water Management in Singapore: The Water Loop**




Source: PUB, 2011

This approach involves precise assessment of water movement, from rainfall to water storage to runoff generation in order to determine the storage and infiltration capacity required to absorb the flood water from various sources. Such assessment and management of the water movement underpins the selection and implementation of a range of 'green' technologies and multifunctional infrastructures to reduce the flood hazards. Many of the green infrastructures such as constructed wetlands also serve to treat the storm water, store up water for dry seasons and improve the landscape. Further, a monitoring network for the drainage system evaluates system performance and issues early flood warnings to the general public.

The overall strategy and approach of Singapore for urban flood risk management are reflected in the Active, Beautiful, Clean Waters Program (or ABC Waters Program), described in the next section.

### KEY MANAGEMENT MEASURES UNDER THE ABC WATERS PROGRAM

The ABC Waters Program was launched in 2006 by Singapore's Public Utility Board (PUB) as the key program to implement the vision of 'City of Garden and Water'. It is a strategic initiative to improve the quality of water and life by harnessing the full potential of the water and managing its movement through the water cycle. By integrating the drains, canals and reservoirs with the surrounding environment in a holistic and eco-friendly manner, the ABC Waters Program aims to create beautiful and clean streams, rivers, and lakes with 'postcard-pretty' community spaces for all to enjoy (PUB, 2011). The major elements of the Program include the following:

- *An ABC Waters Master Plan.* Developed in 2007, the master plan guides the overall implementation of projects to transform the city's drains, rivers and reservoirs into vibrant, picturesque and clean flowing streams and lakes that are well integrated with the environment (PUB, 2011);
- *Promotion of the ABC Waters Concept*. The ABC Waters Concept encapsulates Singapore's idea of harnessing the full potential of waters and integrating them into the environment and lifestyles. The rationale is to use natural systems to retain and treat storm water on site before it flows into the waterways and reservoirs. At the same time, they enhance biodiversity and the living environment (PUB, 2011);
- *People-Public-Private (3P) Partnership Approach*. PUB works closely with the community to adopt and take ownership of the water bodies. For example, it encourages schools to develop educational learning trails for the various ABC Waters projects so that students can learn and better appreciate the value of waters. Private companies and grassroots organizations organize and participate in activities at the ABC Waters sites (PUB, 2011); and
- *Inter-agency collaboration.* The ABC Waters design principles are also recognized and adopted by other sector agencies such as the Building & Construction Authority (BCA). For example, the BCA Green Mark Scheme is a benchmark scheme which incorporates internationally recognized best practices in building environment design and performance (PUB, 2011). Two of the most important criteria in evaluating the building performance are water efficiency, and green features and innovations adopted such as green roof, balcony plantation, etc.

The ABC Waters Program embraces a range of 'green' technologies for different functional levels of the water cycle. At the catchment management level, green rooftop, sky garden or terrace, green balcony, planter box, ground level greenery within open space and vertical greenery around the buildings are widely adopted in the city (See

Figure 3.16). At the treatment level, representative technologies used include vegetated swales, bio-retention swales and basins, cleansing biotopes and constructed wetlands. At the conveyance and storage level, greening waterways and bioengineering stabilization techniques are utilized (PUB, 2011). Below are two examples of incorporating 'ABC' Waters Concept into the project design and implementation to achieve multiple benefits.

**Figure 3.16: Balconies and Rooftops Fully Utilized in Public and Private Developments**

Source: PUB, 2009

***Kallang River-Bishan Park.*** The national water agency (PUB), in close collaboration with the National Parks Board, designed the Kallang River-Bishan Park with a holistic sustainable approach in mind, integrating the park with the river. A key feature is the conversion of the concrete canal into a naturalized river with bio-engineered river banks using a variety of plants and bedding materials. As a pilot project, integrating the river with the park made the waterway more accessible to the public, while creating more spaces for the public to enjoy. The naturalized river meanders through the park and brings park visitors closer to the water. The river was designed based on a floodplain concept whereby during dry seasons, the river flow will be confined to a narrow stream in the middle of the river. The gently sloped river banks will form part of the park features, and park visitors are able to walk along the water front. In the event of a storm, the water level in the river will rise and the area adjacent to the river will become a flood plain to contain the rainwater (PUB, 2009).

In addition, the new Bishan Park will be home to diverse wildlife. Ponds with soft and gentle slopes connect with the river. Furthermore, a water playground is part of the redevelopment, allowing children to have fun with water and appreciate its quality and value. Through these interactions with water, the park provides the public with different services and fosters a sense of communal ownership and appreciation of the water resources (PUB, 2009).

***Sengkang Floating Wetland for stormwater filtration.*** In the northeastern part of Singapore lie the Punngol Reservoir and Sengkang Floating Wetland (See Figure 3.17). The pond and constructed wetland are part of the Sengkang Riverside Park, used for recreational purposes such as water sports and walking in a scenic environment. The water reservoir also acts as flood storage during heavy rainfall. Excessive rainfall collected in the pond is eventually released through its outlets within two or three days. The artificially created floating wetland is the largest man-made floating wetland in Singapore (PUB, 2009). It has a surface area of approximately 2500 $m^2$.

**Figure 3.17: The Senkang Floating Wetland in Singapore**

Source: PUB, 2009

The constructed wetland treats storm water and natural sewage. The coarse particles in the water are filtered in two sedimentation basins. If the volume of water flowing in is larger than the basin capacity, the water will be redirected through a bypass into the pond to prevent damage to the wetland. After the sedimentation process, water flows slowly into the macrophyte zone. Macrophytes are plants (e.g. reeds and cattails) that thrive in marshlands and absorb nutrients and release oxygen through photosynthesis (PUB, 2009).

The constructed wetland also provides a new habitat for fish and birds and strengthens the local ecosystem and increases biodiversity. The roots of the plants cleanse the water and absorb pollutants from the reservoir, improving the water quality in the Punggol reservoir. The wetland is home to approximately 18 species of plants which were selected according to their cleansing and aesthetic properties. The wetland can be reached through a boardwalk, connecting Anchorvale Community Club to the Sengkang

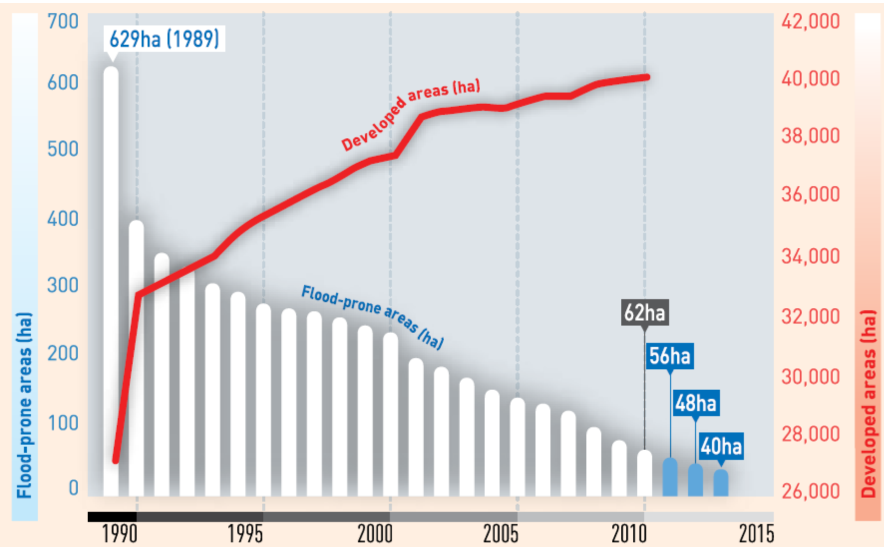
Riverside Park (PUB, 2009). Parts of the wetland have been adopted by local schools for maintenance, helping connect the community with nature and water.

### RESULTS

As a result of dedicated efforts in implementing a total water management strategy and the well conceived ABC Waters Program, Singapore is well protected against floods. Some of the achievements are summarized as follows:

- After decades of continued endeavors in improving water and land use management, the flood-prone areas in Singapore have decreased substantially from 629 ha in 1989 to 56 ha in 2011 (See Figure 3.18) (PUB, 2011);

**Figure 3.18: Changes in Singapore's Flood Prone Area**




Source: PUB, 2011

- Guided by the vision of developing a vibrant 'City of Gardens and Water', the ABC Waters program is making great progress. Eleven projects are completed by the end of 2010, with over 100 projects earmarked in the next 15-20 years (PUB, 2011). Such concrete and targeted efforts in management investments have substantially improved the drainage system capacity and flood security in Singapore;
- Through the 3P (People, Public, Private) Partnership program, public awareness of flood risk and the need for adaptive management, as well as their appreciation of and support to the management programs have increased, leading to changes in people's behaviors in caring for water and the natural environment; and
- Innovatively designed water management infrastructure such as Marina Barrage reservoir (See Figure 3.19) is making considerable contributions to reduction in

flood risks in the low-lying areas of the city with other co-benefits. For example, the Barrage has also become a well-known landmark and lifestyle attraction of Singapore. Similarly, the floating wetlands are producing multiple benefits in flood risk management, water environment and shortage alleviation, and landscaping.

**Figure 3.19: Multifunctional Use of Marina Barrage Reservoir in Singapore**

Source: PUB, 2009

LESSONS LEARNED

Singapore faces the challenges of both water scarcity and flooding. Its water management has progressed towards integrated water resources management for sustainable water use and flood risk reduction. Some of the lessons learned from the Singapore case are as follows:

- ***A total water management strategy leads to an integrated solution to multiple inter-connected water issues with satisfactory results.*** This can be achieved by precise management and control of water in different forms as a portfolio, for multiple co-benefits;
- ***A well designed target program, featured with green and adaptive measures and multifunctional infrastructures and implemented with dedicated institutions and funding, proves to be effective in addressing urban flood issues under changing climate***;
- ***Flood risk management programs benefit a great deal from involvement of the stakeholders,*** and from enlisting their support throughout the project cycle. The 3Ps (People, Public, Private) partnership in implementing the ABC Waters program provides a good example; and

- ***Restoring nature in a water system can be cost effective because of its multiple benefits and long lasting effect*** as shown in the cases of Sengkang floating wetlands and Kallang River-Bishan Park.

## Comprehensive Flood Risk Management in Japan

### *KEY ISSUES AND CHALLENGES*

The topography of Japan consists of a chain of spinal mountains running through the central part of the country and a number of alluvial plains situated between the mountain ranges which branch out to the coastline (Sato T., 2006). Although the total area of floodplains accounts for only 10% of the national land, 75% of the total assets and 51% of the total population of Japan are clustered on those floodplains. Floods with heavy losses, caused by overflowing river and tidal effect, have been common phenomena in Japan's development history. Rivers in the mountainous areas are short and steep, and time interval between initial rain fall and occurrence of flood is therefore also short. Therefore, the flood emergency response, including evacuation of residents, is very difficult (OECD, 2006). With changing climate, the precipitation pattern tends to become more concentrated temporally and extreme flood events more common. From the sea side, the impacts of climate change such as sea level rise, make flood drainage harder and flood events more damaging.

Conventional flood management, or flood control as more commonly known in Japan, relies mainly on increasing river discharge and flood storage capacities through channel improvement and construction of flood control facilities such as dams and retarding basins. Over the past decades, with continued economic growth and industrialization, there has been a progressive conversion of large quantity of farmland and forest land into urban development uses (commercial, public and residential uses), leading to various problems related to flood risk management. The essential water retention and retarding capacities of river basins have declined, resulting in shorter runoff concentration time and increase in the flood peak discharge. The urbanization and change in demographic conditions such as population density increase the scale of flood risks as well (Alphen J. V., *et. al.,* 2011). As managing the flood risk through conventional measures has become more difficult, the need for a more comprehensive approach to flood management which integrates with the regional development has been recognized.

### *OVERALL STRATEGY AND APPROACH*

To meet the increasing challenges of river flooding, as evidenced in the 2000 Tokai flood disaster in metropolitan Nagoya, the government of Japan adopted *a 'comprehensive flood control' strategy*. The comprehensive strategy combines structural and non-structural measures to achieve more sustainable results. The measures range from flood control facilitations, such as river improvement, construction of dikes and storm water drainage works, basin management measures like essential storage reservoirs and catchment management interventions, infiltration facilities at public parks and rainwater storage in residential areas, to soft measures such as flood hazard mapping and publicizing to raise awareness and guide land use planning and emergency response, establishment of flood warning system and flood response (or 'flood fighting') system, and land use management measures including retention of urbanization regulation areas, preservation and restoration of green areas, and subsidy for flood resilient houses.

The above diversified measures undertaken in Japan can be categorized into several types of interventions: flood hazard assessment, (floodplain) land use planning and regulation, flood prevention and protection, adaptation to changing climate and flood warning and emergency responses. The following section provides actual examples of each type.

### *KEY MANAGEMENT MEASURES*

Responsibilities for flood management at the national level rest mainly with the Ministry of Land, Infrastructure and Transport (MLIT), with several bureaus, each mandated with certain aspects of flood management. Under a common umbrella planning framework, each bureau creates and implements specialized management plans in coordination with other bureaus and related agencies and in accordance with the applicable laws and regulations. The laws include the River Law, the City Planning Law, the Buildings Standards Law, the Land Use Fundamental Law, the Natural Land Use Planning Law, etc. They are supplemented with respective ordinances and guidelines that provide detailed rules for applications (OECD, 2009). Guided by this comprehensive legal framework and management plans, various management measures targeting at major elements of flood risk management are designed and implemented. Some examples of the key management measures are discussed below:

***Investing in advanced management information and tools for flood forecasting and preparedness.*** In most parts of Japan, a flood defense system is already in place. However, the increasing intensity of torrential rain as a result of climate change has generated concern over an increase in flood scale and the resulting decline in flood safety level. As such, it is necessary to review the original designs of the flood control facilities to see whether there is a need to compensate for increased and more uncertain precipitation. To this end, intensive researches have been financed on climate change impacts upon the floods and methods to estimate the scale of flood control facilities required to accommodate climate change impacts (MLIT, 2008). These studies provided critical insight information and tools to illustrate the impact of climate change on hydrological cycle and the practical implications for the general public. Important information and tools produced include annual maximum daily precipitation maps, and maps showing variations of flood peak runoff in major rivers and variations of the corresponding flood return periods for each river system.

In addition, the national government invested in installing a number of specialized radars (X-band MP radar) in three metropolitan areas. Now it is possible to make detailed and real-time observations of localized and short bursts of rainfall which could not be detected by conventional radars (Alphen J. V., *et. al.*, 2011). It is anticipated that the new radars will improve the accuracy of prediction over rising river levels and flood hazards due to intensive rainfall.

Further, building on the advanced monitoring technologies and management information system, comprehensive Decision Support Systems (DSS) have been developed and widely used in Japan for flood forecasting and early warning, and for prompt and accurate responses to local changes in precipitation and high tides to significantly bring down the flood risk. Last but not the least, the Japanese government developed detailed flood hazard maps for urban areas with high exposure to flood risk. Such flood hazard maps are available in most of the cities in Japan (See Figure 3.20 for an example). They help raise public awareness of flood risks, and are essential tools for proper spatial panning of land use and urban development.

**Figure 3.20: Illustrative Flood Hazard Map for Japan's ISE City**


Source: www. icharm.pwri.go.jp

***Adaptive management for sustainable flood risk reduction.*** In view of the country's high exposure to floods, Japan has worked to build a robust physical flood defense system. For decades, investments have been focused on construction of protective engineering works, such as dikes, dams and control basins, for river improvements and for runoff control to counterbalance the increasing flood risks. Benefits of these structural measures are obvious with major decreases in flood damages and disaster recovery costs. However, strong evidence in the country and internationally have shown that the structural measures have limitations in providing effective flood defense and tend to transfer the flood risks to the downstream areas and elsewhere, increasing the flood vulnerability of communities with lower level of protection (OECD, 2006). In recognition of the above and in consideration of the needs for adapting to evident climate change and variability in the country, the government has begun to adjust its management approach and focus towards more cost-effective non-structural measures and better integration of the flood defense needs with urban development and natural environment improvement. The following examples illustrate Japan's reorientation in management strategy and practices.

- **Vigorously promoting non-structural measures.** Building on its strength in information and spatial technologies, the government has stepped up its efforts in supporting a wide range of cost effective non-structural measures, including flood hazard mapping and publication, flood forecasting and warning system, optimal operation of flood control and protection facilities, capacity building for flood fighting, upgrading building codes and subsidy program for climate-resilient buildings, development of disaster action plans, etc. Insurance programs are also encouraged as good risk sharing mechanism. These measures supplement the well-built infrastructure network to form a comprehensive flood risk management system in different basins and municipalities;
- **Increasing storm water storage, infiltration and runoff control.** To mitigate the impact of rapid urbanization and land conversion for urban development, management measures to reduce rainstorm runoff and increase water infiltration are encouraged through government regulations such as city construction codes, and subsidy programs (e.g., subsidies for individual households to improve their rainwater storage and drainage systems). Examples of specific management measures include creating additional water storage and infiltration facilities at public parks, schools and in newly developed residential areas. Construction of these facilities is closely coordinated with urban development (land use) planning and sewage system construction. These measures have demonstrated very positive effects on flood risk management for urban areas with small and medium sized rivers (OECD, 2006);
- **Greening of urban rivers.** Greening of urban rivers through natural river bank restoration and river-side forest development, etc., is a new development in urban flood management investments. Such interventions contribute to flood protection through river bank stabilization and wave reduction (in the case of river bank restoration); at the same time, they help improve the river ecosystems. Furthermore, efforts have been made to create more attractive waterside environment by planting greenery on dikes and constructing walking paths, for combined benefits of landscaping, recreation and living environment improvement; and
- **Building multi-functional flood management facilities**. One noteworthy feature of flood management measures in Japan is the wide use of multi-functional facilities such as retarding basins, underground floodways and super levees, etc. As an example, super levees (See Figure 3.21), built as part of the overall urban renewal with their high design standard, provide superior earthquake resistance and flood control capability. They also bring other benefits, e.g., the elevated lands can be used for evacuation at times of disasters.

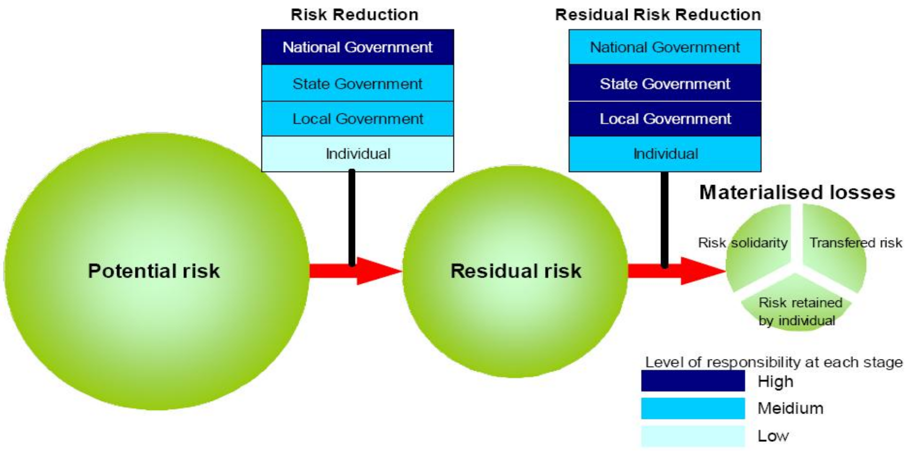
**Figure 3.21: Super Levees (Top) and Function Illustration (Bottom) in Japan**


Source: www.seacityresearchnet.com

***Emergency response and risk sharing mechanism.*** In Japan, flood emergency responses are well organized and very effective with clear division of responsibilities and collaboration arrangements. Operational responsibilities for emergency response rest mainly on municipalities, usually the most relevant level of government for taking emergency actions. Inter-municipal agreements on emergency response and disaster management enhance response capacity at the local level. In the event of major floods, the national government authorities provide general support and guidance to the local governments, to ensure necessary co-operation and co-ordination and to provide additional resources required to manage the emergency (Alphen J. V., *et. al.*, 2011). Once a flood event occurs, an emergency team at the national government level gathers at the Crisis Management Center to assess the available information and analyze the disaster situation. The Cabinet Office is also involved in assuring effective co-ordination of disaster reduction activities. The Cabinet Secretariat provides situation awareness and incident information to the Cabinet, based on the data collected around the clock by the Cabinet Information Collection Center.

The costs of flood disasters are shared by concerned individuals and entities, the government and the insurance industry in Japan, similar to the risk-sharing arrangement shown in Figure 3.22. In accordance with the Disaster Relief Act, local public bodies are required to set aside specific budgets as disaster relief funds, which are managed by the designated agencies. Flood insurance is optional and bundled with fire insurance, with relatively high penetration rates of approximately 49% for dwellings, and 35% for household property (Alphen J. V., *et. al.*, 2011). It is common practice in Japan that individuals concerned bear a significant part of the economic loss from disasters.

**Figure 3.22: Common Flood Risk Sharing Mechanism**




Source: WMO & GWP, 2009

### RESULTS

With a comprehensive management approach and various adaptation measures introduced over the years, Japan has made impressive progress in mitigating flood risk and reducing flood losses, as indicated in the following:

- As a result of implementing the comprehensive management strategy and effective response and recovery practices, flood risks in terms of flood losses appear to be generally decreasing over time, despite the continued economic growth and effects of climate variability. The alluvial lowlands are much less vulnerable to flooding, and the ratio of flood damage to the national GDP has fallen substantially over the years;
- The advanced flood forecasting and early warning systems established in different river basins, supplemented by awareness raising and information sharing, have enabled high level of flood preparedness and prompt response. This has contributed to the improved effectiveness of emergency evacuation of people affected by flood disasters, and to the subsequent reduction in flood disaster casualties in recent decades;
- As part of the endeavors to implementing its climate change adaptation strategy, the government of Japan increased the investments towards building green infrastructures to create additional rainwater storage and increase water infiltration into underground in the urban areas. Such measures have greatly reduced the flood load on the storm drainage system and the river systems, and lower the flooding risks from rainstorms; and
- Dedicated efforts of the municipalities in maintaining and upgrading of the flood defense infrastructure systems are successful, enabling them to progressively strengthen their capacity of handling heavy rainfall and resulting floods. For

example, the Tokyo metropolitan is able to successfully cope with rainfall up to 50 millimeters per hour through implementing the well-designed embankment and river works maintenance program.

### LESSONS LEARNED

Many lessons can be learned from Japan's long history of flood management and solid approaches; the following are examples from limited literature review:

- Establishing a comprehensive regulatory framework with special laws, ordinances and regulations forms a strong legal basis for effective flood risk management. ***An effective legal framework enables the integration of flood prevention and risk reduction into the urban planning process to minimize flood losses due to new development;***
- Equipped with necessary management information and decision support tools, ***a well functional flood management organization with clear responsibilities, chain of command and collaboration mechanisms played a critical role in successfully preventing and managing flood disasters*** in the recent history of Japan. Decentralized institutional arrangements, where the municipalities take primary responsibilities in flood risk management, have enabled the government to act quickly and efficiently at the time of flood emergency. In addition, local government officials proactively pursue enforcement of related regulations in development decisions;
- ***Adoption of a comprehensive flood risk management approach*** characterized by a balanced mix of essential structural measures (robust infrastructure network) with carefully selected non-structural measures (hazard mapping, land zoning, flood forecasting and emergency preparedness), ***puts the country in a very strong position to manage the flood and related risks in a dynamic manner, and adapt to the changing climate and operating environment***;
- ***Advances in technologies for monitoring, decision support analysis and forecasting equip Japan well in scientific decision making, and enhancing the entire management process of flood awareness, preparedness, mitigation, response and recovery***;
- ***Continued public awareness-raising, flood hazard information sharing (e.g., by publicizing hazard maps) and flood warnings have prepared Japan to deal with flood disasters*** (similar to earthquakes and other natural disasters). These measures are essential for effectively involving different stakeholders including the communities and private sector, and enlisting their support throughout the management cycle. They also serve to help increase the vigilance and resilience of the communities and general public;
- ***Multi-functional facilities (e.g., super levees, water parks, green infrastructures, etc.) are cost-effective innovations for flood defense in cities with limited land space for building large flood control infrastructures.*** The underground floodway in Tokyo is a good example; it solves the problem of lack of space to create additional flood discharge capacity to protect the mega city against flash floods, with other co-benefits; and

- ***The practice of sharing flood risks among government, individuals and private sector, through insurance programs and disaster recovery financing from public flood relief funds, etc, is working well*** in Japan to ensure quick post-disaster recovery and reducing flood losses.

## Selected Practices of Adaptive Flood Risk Management in the United States

### *KEY ISSUES AND CHALLENGES*

Extensive hydro-meteorological records demonstrate that climate, in terms of temperature, seasonal and spatial distribution of precipitation, is changing with varying effects on different regions, of which the delta regions are affected the most. With the general trend of increasing climate variability characterized by more concentrated precipitation, especially in the coastal areas, the chances of more frequent and severe floods are much higher (Brekke *et. al.*, 2009). As such, the United States faces the following challenges related to flood risks: (a) many communities in the urban and rural areas on the floodplains are vulnerable to flooding; (b) aging flood management infrastructure is reducing their reliability in flood hazard reduction; (c) new developments with changes in land use are likely to impact run-offs and increase flood risk; (d) climate change and variability may alter rainfall patterns and flow regimes, and lead to increased storm surge and sea level rise; (e) federal and local flood risk management policies are not always consistent and (f) there is a need to further raising community awareness of flood risks and to enhance emergency management plans.

### *OVERALL STRATEGY AND APPROACH*

In the United States, the responsibility for managing flood risks is shared among the federal, state and local governments, communities and the private sector. While it is difficult to fully capture the strategies and management practices in different regions of such a big country, the general approach to flood risk management involves integrated planning and management, green adaptation, flood risk-sharing, emergency preparedness and disaster responses. With such an approach, flood risk assessment under different climate change scenarios informs investment decision making and policy development. Floodplain management sees improvement in integrating flood risk management with local development and land use planning. Coastal flood defense in the US is now guided by the principle of green adaptation through wetlands restoration and better utilization of ecological services. Insurance program plays a vital role in assisting enforcement of zoning and land use regulations. This integrated and adaptive approach is being implemented through a series of national and regional programs launched in recent years, such as the National Flood Risk Management Program, the FloodSAFE Program in California Delta, Wetland Restoration Program in Louisiana, National (Emergency) Response Framework and National Disaster Recovery Framework and the National Flood Insurance Program. Some of these programs are discussed in the next section.

### SELECTED PROGRAMS AND KEY MANAGEMENT MEASURES

#### National Flood Risk Management Program

In May 2006, the federal government launched the *National Flood Risk Management Program*, and the US Army Corps of Engineers (USACE) took the lead. Its mission was to provide support to integrating and synchronizing flood risk management interventions, internally within the USACE system and with the counterparts including the Department of Homeland Security, Federal Emergency Management Agency (FEMA), other related federal agencies, state organizations and regional and local agencies. The specific objectives of the Program include: (a) providing current and accurate floodplain information to the public and decision makers; (b) identifying and assessing flood hazards posed by aging flood control infrastructures; (c) improving public awareness and understanding of flood hazards and risks; (d) integrating flood hazard and damage reduction programs across federal, state, and local agencies and (e) increasing capabilities to collaboratively deliver and sustain flood hazard mitigation and flood damage reduction services. This program was implemented along with other related initiatives, some of which are described below.

***Floodplain management program.*** Under this program, the federal government agency (USACE) provides information, technical assistance and planning guidance to states and local communities to help address floodplain management issues. The focus areas of the program are floodplain development management, flood hazard and damage reduction on the floodplain, and coastal protection at the estuaries. Specific measures include: (a) risk-informed land use planning, flood monitoring and early warning, and emergency response; (b) construction and optimized operation of essential reservoirs and dikes for flood protection and (c) restoration and enhancement of natural wetlands and other ecosystems to enhance their flood retention and wave protection capacities (USACE, 2009). The floodplain management program is supported by improvement of policy and regulations on various aspects of flood risk management. Through this program, the federal government responds to state and local requests for flood management information, technical assistance with risk assessment and management planning, which has contributed to the flood risk mitigation and damage reduction throughout the country.

***Dam and levee safety program.*** As an important step in enhancing the management of major federal assets of over 600 large dams and levees operated by the USACE nationwide, a risk-informed dam and levee systems safety program is being implemented. The Program, launched in 2006 with the National Flood Risk Management Program, follows a portfolio risk management process. It ensures that all these dams and levee systems continue to function as designed with adequate operation and maintenance arrangements (USACE, 2011). The Program covers activities to classify, assess, communicate and manage the safety risks to extend the life of these flood risk management systems. In addition, the key concepts, approach and supporting tools of this safety program are made available to other dam and levee owners and operators. They are also made available to the state and local governments that are responsible for monitoring the performance and safety of dams and levees (Alphen J. V., *et. al*., 2011).

*FloodSAFE California Program in California Delta*

The Sacramento – San Joaquin Delta is the heart of California's water systems, an 837,594-acre area where the Sacramento and San Joaquin Rivers join before entering the San Francisco Bay (Fredenburg, J., *et. al.*, 2012). This region has a vast system of islands, marshes, and farming communities. The freshwater from the rivers combine with the saltwater from the Pacific Ocean, creating the West Coast's largest estuary. Composed of 57 levee island tracts and 700 miles of sloughs and winding channels, the Delta is an impressive and intricate water system. It is faced with enormous challenges in coping with the increasing flood threats from changes in demographic conditions and land uses as well as climate change (DWR, California, 2009).

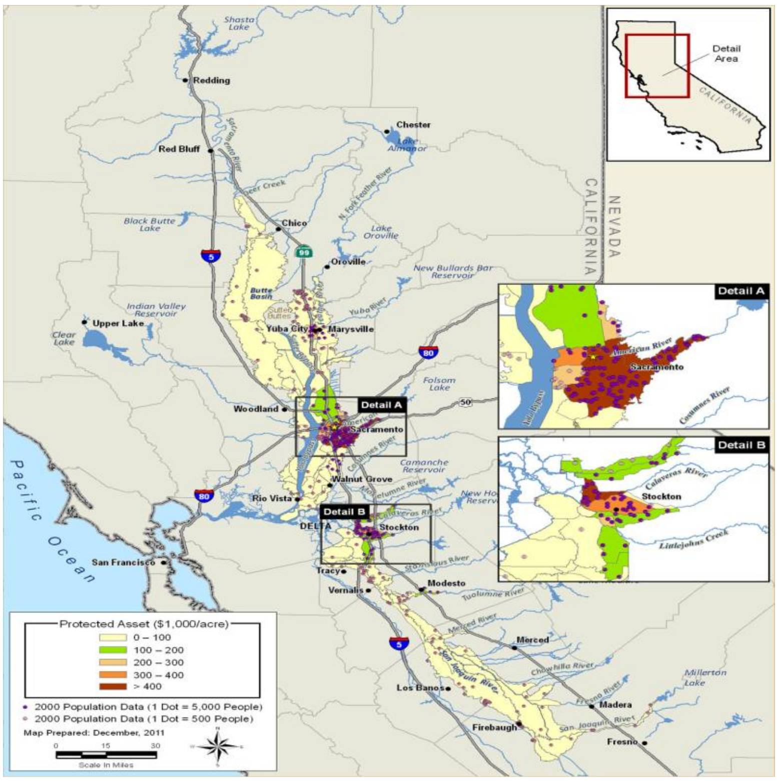
As part of the efforts to meet these challenges, the California Department of Water Resources (DWR) is implementing a multifaceted initiative called *FloodSAFE California* to improve integrated flood management throughout California, with a particular emphasis on better managing the State-federal flood protection systems in the California Delta. The vision of the FloodSAFE program is 'a sustainable integrated flood management and emergency response system throughout California that improves public safety, protects and enhances environmental and cultural resources, and supports economic growth by reducing the probability of destructive floods, promoting beneficial floodplain processes, and lowering the damages caused by flooding' (DWR, California, 2011). Some of key components of the Program are as follows:

- *State Management Planning*. The DWR, in close cooperation with the Central Valley Flood Protection Board (CVFPB) and the USACE, is required to describe and document all aspects of the existing State-federal flood protection systems, assess current performance of the systems, and evaluate alternatives to improve system-wide flood management. These documents are published in the Central Valley Flood Protection Plan (CVFPP);
- *Local Level Management Planning.* Local land use planning agencies in the Sacramento-San Joaquin Valley are required to revise their general plans and zoning ordinances to consider flood risks based on updated information including that provided in the CVFPP. Local agencies must prepare detailed flood risk management plans and define flood emergency response and recovery procedures. Approving development in the areas of moderate flood risks requires provision of specified flood protection measures;
- *Risk Mapping and Notification*. This involves mapping the areas susceptible to flooding in the Central Valley, and the areas protected by the State-federal flood protection systems. The program is required to notify landowners in those areas about the flood risks they face, and offer information on how land owners can better manage their risks;
- *California Building Standards Code*. The DWR, in consultation with the CVFPB, the Division of the State Architect, and the Office of the State Fire Marshal, must propose for adoption and approval by the California Building Standards Commission, updated requirements to the California Building Standards Code for new construction in areas protected by facilities of the CVFPP that are subject to deep flooding in a 1-in-200-year flood event; and

- *Levee Status Reporting.* Local agencies responsible for operation and maintenance of State-federal flood protection system levees must submit annual reports to DWR describing levee status and work done to keep levees functioning as designed. The DWR must provide annual reports to the CVFPB describing the levee status, work being done to inspect and maintain the systems, and any planned repairs or improvements.

FloodSAFE projects are being managed as a discrete program following a uniform approach. Several FloodSAFE projects have been completed in the Central Valley. Although the benefits of these interventions are yet to be quantified, it is safe to say that through the implementation of the FloodSAFE program, the flood risk for a large population and enormous amount of assets and related services is being reduced significantly (DWR, California, 2011), as indicated in Figure 3.23.

**Figure 3.23. Population and Assets Protected by the FloodSAFE Program**




Source: California DWR, 2011

### *Wetland Restoration Program in Louisiana*

Louisiana has over 4 million acres of wetlands, representing 40% of the country's total. These wetlands are among the world's most diverse and productive ecosystems. The wetlands (a) support and protect a multi-billion dollar oil and gas industry; (b) provide nursery grounds for fish and shellfish for much of the country's seafood; (c) protect over 400 million tons of waterborne commerce annually; (d) provide winter habitats for about one-half of the Mississippi wild bird population and (e) serve as a buffer for hurricanes and storms.

The wetlands of Louisiana are disappearing at a high rate: every 38 minutes, a football field sized parcel of Louisiana's wetlands is taken over by water. Across the region, communities are being threatened, jobs are being lost and habitats are vanishing. The loss of Louisiana’s coastal wetlands is one of the most serious environmental problems facing the country today. The wetland loss is the result of cumulative natural and human-induced effects, which include hydrological alteration due to oil and gas developments, levee and canal construction, land subsidence, salt water intrusion and storms (Steyer and Llewellyn, 2000).

In an endeavor to offset land loss, several initiatives have been taken in the past decades. Since 1991, most projects have been supported by federal funds with matching state funds through the Coastal Wetlands, Planning, Protection, and Restoration Act (CWPPRA) passed in 1990 by the Congress. It was the first federally mandated restoration effort along Louisiana’s coast and the first program to provide a stable source of federal funds dedicated specifically to coastal restoration. The Act directed that a task force consisting of five federal agencies and the State of Louisiana develop a "comprehensive approach to restore and prevent the loss of coastal wetlands." CWPPRA has been the State of Louisiana's primary tool for responding to coastal wetland losses. It emphasizes intergovernmental cooperation. As of June 2010, there were 180 active CWPPRA projects, of which 85 had been completed, 12 under implementation, and 26 rejected or transferred to other programs. The remaining projects were in various stages of planning and design.

These projects are selected for contributing to the region-specific restoration objectives. The restoration techniques adopted under the projects include: freshwater and sediment diversions, outfall management, barrier island restoration, marsh creation through the use of dredged materials, hydrologic restoration, marsh management, vegetative planting, sediment and nutrient trapping, shoreline protection or combinations of these measures (Steyer and Llewellyn, 2000). The beneficial use of dredged materials under the CWPPRA Project BA-39 Mississippi River Sediment Delivery is a particularly noteworthy technique. Sediment from the Mississippi River dredging is used to rebuild wetlands at a new location. A dredger near the levee pumps sediments into the fragile wetlands, to rebuild marshes that had turned into open water, and to create new wetlands (See Figure 3.24).

### *National Flood Insurance Program*

The Flood Insurance and Mitigation Administration (FIMA), a branch of the Federal Emergency Management Agency (FEMA), manages the National Flood Insurance Program (NFIP). Close to 20,000 communities across the United States and its territories participate voluntarily in the NFIP leading to major reduction in flood losses. The NFIP benefits from adopting and enforcing the floodplain management ordinances for flood damage reduction. In return, the NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in these communities (FEMA, 2008).

In addition to supporting flood insurance, the NFIP identifies and maps flood hazards of the nation's floodplains. Flood hazard mapping creates broad-based awareness of the flood hazards and provides the information needed for floodplain management planning and programming, and for decisions on flood insurance.

As a result of the NFIP implementation, flood damage is reported to have been reduced by nearly $1 billion a year. This was achieved mainly through enabling the communities to meet floodplain management requirements and property owners to purchase flood insurance. Also buildings constructed in compliance with NFIP building standards suffered approximately 80 percent less damage annually than those that were not (WMO and GWP, 2009).

**Figure 3.24: Mississippi Wetlands Restoration Project**

Source: www.lacoast.gov

### *RESULTS*

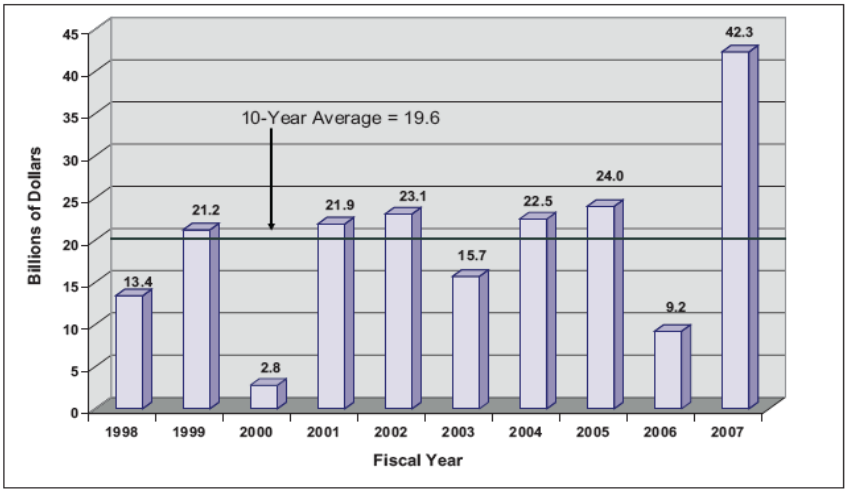
The implementation of US government's adaptive flood management strategy has led to very positive results. The following represents a brief summary of the initial achievements of the programs described above.

- The implementation of the Dam and Levee Safety Program across the country has prevented enormous losses of lives and assets. The program has managed to prevent estimated flood losses of $19.6 billion in different river basins and coastal areas (USACE, 2009) (See Figure 3.25);
- The FloodSAFE program has made great progress in ensuring effective flood risk management in California Delta. The Program is expected to provide 1-in-200-year flood protection to the entire urban areas in the Sacramento – San Joaquin

Valley by December 31, 2025 when the Program interventions are fully implemented (DWR, California, 2011);

- The successful implementation of the NFIP has benefited approximately 5.6 million households and businesses across the country for a total of $1.25 trillion in exposure. The NFIP was self-supporting from 1986 until 2005 as policy premiums and fees covered all expenses and claim payments, until 2005 when the NFIP incurred approximately $17 billion in flood claims caused by Hurricanes Katrina, Rita, and Wilma (Rawle O. K. ,2011); and
- Under the CWPPRA, a large number of projects have been implemented over the last 17 years to restore and protect over 120,000 acres of coastal wetlands, about three percent of the Louisiana coast. As a result, the coast of Louisiana is now protected from Category 5 Hurricanes, a higher protection standard than against Hurricane Katrina (Category 3) (Armando C., Douglas J. M., 2009).

**Figure 3.25: Flood Damage Prevented in US for the Past Decade (1998~2007)**




Source: USACE, 2011.

### LESSONS LEARNED

A number of lessons can be drawn on the emerging best practices in the US flood defense approach. These are briefly described below:

- ***Effective flood risk management calls for successful alignment of the interests of different levels of governments and relevant agencies, the communities and private sectors.*** It helps enhance the commitment of stakeholders and promotes a sense of risk-sharing and joint financing responsibility, which contribute to sustainability of risk management investments;
- ***A comprehensive flood risk management plan requires an appropriate mix of structural and non-structural measures addressing different elements of flood risks: hazard, exposure and vulnerability.*** These measures range from flood

hazard mapping and notification (for awareness raising), land use zoning, integration of flood risk management into local development plans, to upgrading of building standards, policy and regulation development, and to technical assistance to local agencies in management planning, implementation and O&M, and ensuring timely construction and safe operation of an essential flood protection system including dams and levees;

- ***Green adaptation through such measures as wetlands restoration yields high returns to investments,*** especially for coastal areas subject to storm surge impact and land erosion. These measures produce many long-lasting co-benefits through nurturing healthy interactions between the ecosystem and human activities in land and water uses; and
- ***A government supported insurance program enables sharing of the flood risks and financial burdens of management investments between the government and beneficiary communities.*** It is also a powerful instrument and incentive in helping enforce land use and floodplain development regulations. This is because the premium of insurance policy can serve as a restricting factor for decisions on land development.

## Key GWD Measures from Best Practice Case Studies

The following is a brief summary of the emerging best practice measures of GWD from the selected case studies:

- 'Live with Nature (Flood)' proved to be an effective and sustainable strategy and should be promoted as an overarching guiding principle for low-lying countries and regions in managing their flood risks and adapting to climate change;
- Adoption of a comprehensive flood risk management approach characterized by a balanced mix of eco-friendly structural measures and carefully selected non-structural measures puts a country or a region in a very strong position in managing the flood and related risks in a dynamic manner, and in response to the changing climate and operating environment. These measures should address different aspects of flood risk: hazard, exposure and vulnerability;
- A total water management strategy can lead to an integrated solution to multiple inter-connected water issues with satisfactory results;
- Successful implementation of flood defense strategy and management programs requires involvement of stakeholders in the entire process through an appropriate institutional arrangement. It requires alignment of the interests (benefits and risk-sharing) of different levels of governments and relevant agencies, the communities and private sectors;
- A good legal framework create an enabling environment for the integration of flood prevention and risk reduction into the urban planning process to minimize flood risk escalation due to new development;
- A well functional flood management organization with clear responsibility division, line of command and collaboration mechanism plays a critical role in successful flood disaster management as demonstrated in Japan;

- Well designed target programs, such as the 'Room for the River' program in the Netherlands, with dedicated organization and financing are efficient ways to achieve specific objectives and targets of flood risk reduction and management;
- 'Building with Nature' as a green flood defense practice, utilizing ecological service and other natural forces and processes for flood protection in coastal and delta areas, has a very promising prospect despite the fact that its application is still in the early stage and the cost efficiency can be further improved;
- Green adaptation through such measures as wetlands restoration like the case of Louisiana, yields high returns to investments, especially for coastal areas subject to storm surge impact and land erosion;
- A 'Room for the River' program for riverine flood management can provide a host of different interventions to increase discharge capacity and lower water levels (and flood risks) in the floodplains of rivers;
- The 'Water City' concept, characterized by forward looking spatial planning (integrating land – water – ecological environment management) and water sensitive design (e.g. multifunctional facilities and green infrastructures), can be very catalytic in successfully promoting integration of flood risk management with urban development;
- Advances in technologies for information collection, monitoring, decision support analysis, flood forecasting and warning, should be best utilized to improve scientific decision making, and enhance the entire process of flood awareness, preparedness, mitigation, response and recovery;
- Multi-functional facilities such as super levees, water parks and green infrastructures are cost-effective measures of green flood defense in flood-prone cities with limited land space for development;
- Changing climate and spatial environment (economic growth, urbanization and population expansion) increase flood risk and call for constant search and close collaborations of government entities and professional organizations to find innovative solutions to sustainable flood defense;
- Continued public awareness-raising, flood hazard information sharing (e.g., by publicizing hazard maps) and flood warning are crucial to ensure high level of alert, preparedness and response for dealing with flood disasters; and
- The practice of sharing flood risks among governments, individuals and private sector, through insurance programs and disaster recovery financing from public flood relief funds, etc, proved to be a powerful mechanism for helping enforce land use and floodplain development regulations.

## General Conclusions

This report has explained the GWD approach and a three spatial layer concept framework, and has illustrated various types of GWD practices and measures. GWD does not focus exclusively on one type of solution, it addresses flood defense in a more holistic and natural way. Instead of focusing only on infrastructure solutions, it emphasizes the interactions between different uses of land and water, the infrastructure network and the natural conditions. Furthermore, it seeks to integrate flood risk management with related development activities to achieve multiple benefits. Based on the case studies, some general conclusions can be drawn as follows:

*(a)* *Green Water Defense represents a major paradigm shift in management strategy and approach, and requires flexibility and dynamic interactions in applications;*
*(b)* *It is more adaptive, and emphasizes the use of natural forces and processes, and non-structural measures for long-term sustainability;*
*(c)* *Green Water Defense advocates stakeholder involvement and cross-sector collaboration;*
*(d)* *It is a risk-based approach and seeks to integrate flood defense with development and land use planning and management;*
*(e)* *Green Water Defense approach often provides multiple co-benefits, and is normally more cost-efficient; and*
(f) *It is rooted in tradition and needs to be supported with good local knowledge and modern management tools.*

In applying with the key lessons of GWD best practices, it is important to pay particular attention to the essential elements of the GWD approach: (a) understanding the system and the flood risks; (b) raising public awareness and engage stakeholders in design and implementation; (c) adopting the principle of 'live with nature (floods)'; (d) integrating flood risk management with development planning; (e) assessing and prioritizing investment options based on cost effectiveness; (f) designing and implementing targeted programs with dedicated organizations and resources and (g) innovating towards optimal solutions.

CHAPTER 4

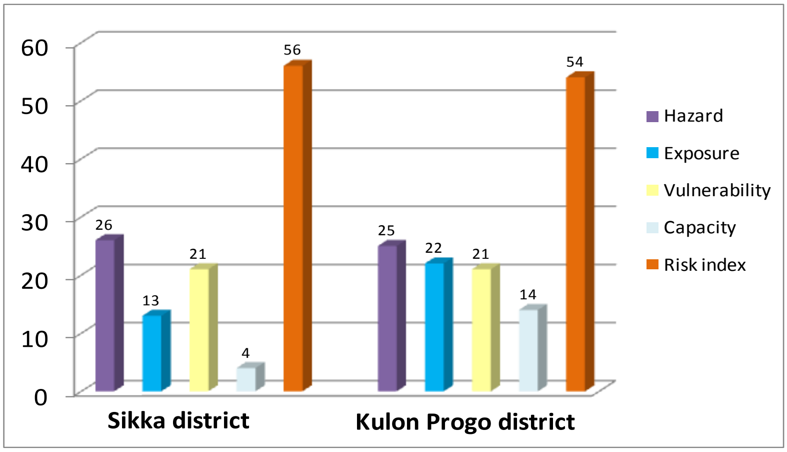
# Towards a Roadmap for Green Flood Defense in East Asia

## General Process for Applying GWD Approach

In recognizing the fact that the applications of GWD approach in terms of selecting the key measures are very location specific, the following is intended to provide a general guide for the overall process for GWD application in flood risk management.

***(a) Understanding the water system and flood risks***: Flood risk management starts with understanding the target water system, whether it is a river basin (or catchment), an urban system or a coastal zone, and the associated risks. For this purpose, the flood management information (knowledge) system needs to be in place, which concerns the hydrological, meteorological, socio-economic and demographic information, the natural environment (eco-system) and built environment. For quick assessment and particularly where important information is missing, the spatial technologies such as satellite and remote sensing can be very valuable in filling in the data gaps.

**Figure 4.1: Disaster Risk Index Comparison**




Source: Bollin and Hidajat, 2006

After flood sources and hazard scale, level of exposure (people, services and assets) and their vulnerability, etc. are identified based on field survey and data analysis, flood hazard (or risk) maps can be developed. A composite risk index combining the key elements of risk (hazard, exposure and vulnerability), such as the one shown in Figure 4.1 for evaluating disaster risk level in Indonesia, may also be used to measure flood risk level. These maps can be used to raise public awareness, and to guide development (land use) planning and emergency response;

**(b)** ***Defining shared vision and objectives through stakeholder involvement:*** To align the interests of the government, communities concerned and ecological system preservation, it is critical to formulate a shared vision and objectives of flood risk management through stakeholder involvement, in light of the more broad development goals. For example, a city may want to become climate-resilient with deign protection level against flood (or rainstorm storm) of 1-in-200-year return period. The shared vision and management objectives will serve to influence the related policies for land and water use management, and investment funding. The vision should be in line with the overall principle of 'live with and adapt to floods' and the objectives set realistically depending on the hazard level and socio-economic development conditions in the target areas;

***(c) Master planning - configuring an integrated flood risk management system:*** An integrated flood risk management system (IFRMS) reflects the paradigm shift from protection to adaptation in overall management strategy, and from flow control to risk-based approach. The system design gives priority to utilization of the natural system and process, and cost-effective non-structural measures, on top of the very essential infrastructure. Furthermore, the system promotes the practice of total water management, namely, managing water in different forms: rainfall, surface runoff, water in water bodies, groundwater and wastewater. The key elements of an effective flood risk management system should include the following as a minimum:

- An integrated cross-sector management organization setup with dedicated staff and resources, and stakeholder involvement mechanism for decision making;
- A good flood management information system with functional data-collection system (e.g., hydro-met monitoring network) and shared database (preferably GIS database), and a decision support system (DSS);
- Flood management infrastructure network compatible with the local conditions (including dikes, reservoirs, river works, sluice gates, detention areas and storm drainage depending on the circumstances);
- Catchment management and flood adaptation measures such as land use zoning, soil conservation and building codes;
- A flood forecasting and early warning system, particularly for areas affected by river floods;
- An effective flood emergency preparedness and response system; and
- Risk-sharing and investment funding mechanisms, such as flood insurance (commercial and/or government-supported), public private partnership in flood risk reduction investments, flood protection charge or tax on beneficiary communities and entities, and special flood management funds established by government.

***(d) Investment planning and programming.*** As a critical part of the decision process for flood management, investment planning involves option identification, assessment and prioritization, leading to investment programs for different time horizons. A portfolio of applicable green water defense measures can be developed to address flood hazard, exposure and vulnerability issues. These measures should build on the strengths, where applicable, of the existing defense system. A number of different investment options can be formulated on that basis, to achieve the intended management objectives. The next step is to prioritize the options according to cost-effectiveness, following one of the main GWD concepts – 'buying down risk'. The results of the selected options can be turned into investment programs through more detailed technical analysis. In order to ensure robust decision making in option assessment, prioritization and selection, the use of a decision support system (DSS) is highly recommended to look into different development and climate scenarios and weigh the tradeoffs as part of the participatory decision making process. As the best practice cases have shown, targeted programs such as the Delta Program in the Netherlands and ABC Program in Singapore produce long lasting results on the ground. Depending on the level of the risks, near and longer term investment programs with dedicated resources and organizations can be designed to achieve intended objectives. In the same token, resources and efforts can be dedicated towards piloting or demonstrating some of the innovative GWD measures for future replication and scaling up;

***(e) Designing management measures to achieve optimal results and sustainability***. The GWD design should keep in view the inter-linkages between different parts of an integrated management system and its long-term sustainability. In designing the major structural measures (infrastructure), care should be taken to ensure they are water sensitive and compatible with the natural environment, and that they provide multiple-benefits as much as possible. The non-structural measures such as flood forecasting, need to be designed to capture potential co-benefits (e.g. flood forecasting serves to reduce flood impacts and to help optimizing reservoir operation for multiple benefits as well);

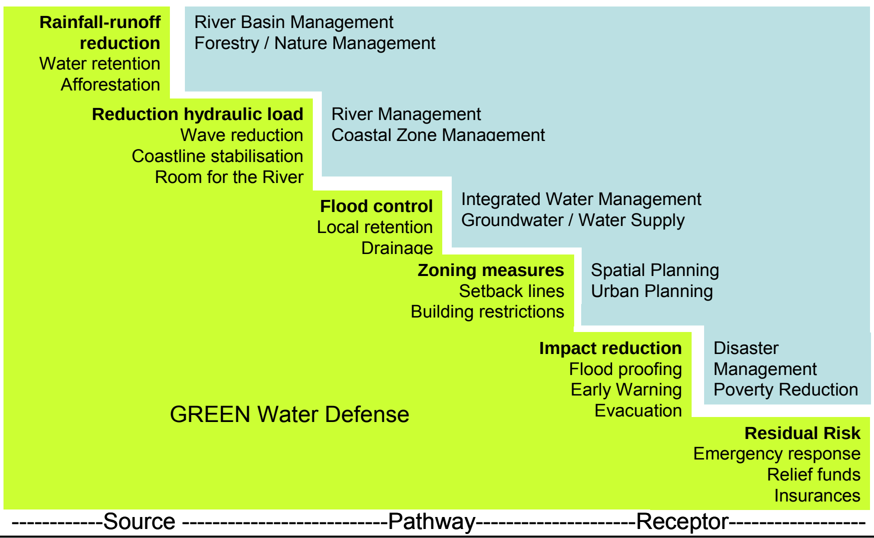
***(f) Institutional development and capacity-building.*** The institutional development should aim to establish an integrated organizational arrangement which involves stakeholders with effective information sharing, communication, coordination and decision-making mechanisms, and a functional regulatory system. The capacity building should target the decision makers, the operational staff and communities with particular attention to strategic planning and decision making, hazard reduction operation, adaptation and responses respectively. On-the-job training through projects has proved to be a most effective way of capacity-building; and

***(g) Emergency preparedness and response system***. The importance of a fully operational emergency preparedness and response system cannot be over emphasized. The system includes a well-conceived emergency preparedness plan covering such key elements as warning, communication and evacuation facilities and arrangements. It needs to be highly participatory and used in close coordination with the forecasting system, covering both natural flood events and other flood disasters such as dam failures or dike breaches.

### Focus of GWD Approach Applications

Floods can happen at different spatial scales (e.g., different river reaches, coastal zone or in an urban system). To facilitate the thinking process for formulating a GWD strategy and identifying broad types of management measures, one can follow a Source-Pathway-Receptor cascade approach (See Figure 4.2). Moving from source towards the receptor of flood risks (hazards), the focus of GWD measures (shown on the left side of the cascade) shifts from rainfall runoff (for fluvial and pluvial floods) and hydraulic load reduction, to flood control to zoning and impact reduction measures, and to measures for managing residual risk.

**Figure 4.2: A Cascade of Green Water Defense Measures**




Source: Marchand et al., 2012

Taking flash and river floods for example, the reduction in rainfall runoff could prevent high discharges downstream and subsequent flood risks. For that purpose, water retention and afforestation to increase infiltration can be considered. 'Room for the River' is an effective strategy for lowering the high water levels and hydraulic load, thereby reducing the chance of levee overtopping or river bank breach. Basic infrastructures such as essential dikes and drainage systems are usually needed for flood control purposes, and can be done very differently under GWD approach. When it comes to impact reduction measures, land use zoning, building codes, flood forecasting and early warning should be given high priority. Finally, one should recognize that flood risk cannot be completely eliminated. Measures such as emergency preparedness and response, risk-sharing mechanism like flood insurance, and post-disaster recovery are necessary to cope with the residual risk and reduce the losses of those affected by the floods.

The cascade can also visualize the corresponding policy dimensions (shown on the right side of the cascade) of GWD measures at different scale levels. Flood risk management cannot be implemented independently, it is crucial to integrate flood risk management with related development policies, regulations and activities to achieve intended results.

In summary, floods can happen at different scales (basin-wide or localized) from different sources. Local conditions of the spatial layers are not the same either. Therefore, in formulating the management strategy and selecting GWD measures, the decision on the focus areas ought to be based upon the flood types (causes), e.g., riverine (fluvial), pluvial or coastal, with full consideration of the local natural and socio-economic conditions:

- For management of riverine or fluvial floods, special attention should be given to floodplain (land use) and river management, watershed management, flood management information system, flood forecasting and early warning, flood regulation and detention, and emergency responses;
- For managing coastal or delta floods, the focus needs to be placed on spatial planning, making best use of natural defense and ecological services (such as mangroves and wetlands), groundwater management, flood adaptation and local protection, and emergency preparedness; and
- In dealing with pluvial or urban floods, such management measures as integration of flood risk management with urban development (land use) planning and management, sustainable drainage system, building codes, green and multiple-functional infrastructures for total water management deserve particular consideration.

## CHAPTER 5

# Practical Applications of GWD Approach in East Asia

East Asia has extensive coastlines and many densely populated and enormously productive deltas such as Mekong Delta, Jakarta, Manila and Pearl River Delta, which are highly susceptible to river flooding, storm surge and sea level rise. Much progress has been achieved in the past decades in East Asia in improving flood management. However, a great deal more needs to be done to reduce substantially the flood damages and impacts from extreme weather events. With evident climate change and rapid changes in land use and demographic distributions, leading to increasing uncertainty in flood risks, a more integrated and sustainable approach is required. Green Water Defense seems to be a natural choice.

It is encouraging to note that some of the Green Water Defense practices are being applied in this region. Some are in initial stage of trial application while others, such as mangrove rehabilitation, have quite a long history of adoption. In this chapter, three different cases in East Asia: the Mekong River Delta in Vietnam, Jakarta City in Indonesia, and Jingdezhen City in China, will be discussed to demonstrate how the GWD approach and practices could potentially be applied. The first case is still largely a rural delta, the second is a highly urbanized metropolitan area, and the third an inland city.

## GWD Application in the Mekong River Delta (Vietnam Part)

### *Key Challenges and Drivers*

The Mekong delta is located in Cambodia and Southern Vietnam, where the Mekong River reaches the South China Sea. It extends for about 270km from its apex at Phnom Penh to the coast, with about 30% of the total area in Cambodia and remaining 70% in Vietnam. The width of the delta near the coast is around 350km while the coastline has a length about 600km. In Vietnam, the Mekong Delta is intensively developed for agriculture. It is one of the most productive and intensively cultivated areas in Asia. It produces considerable amount of rice, fish and fruit products. Some 22% (or 18 million) of Vietnamese population live in the Mekong Delta, and over 80% of the population live in rural areas. The climate at the delta is tropical. The average annual rainfall ranges from 1,500mm in the central and northwest region to 2,350mm in the south. There are distinct wet and dry seasons. Much of the water supply is from groundwater due to inadequacy of reliable piped water supply which is improving but still has a long way to go. Over-abstraction of groundwater, leading to salinization of water sources, is becoming a major concern.

Floods play an important role in the life of people living in the Mekong Delta. Each year floodwaters inundate up to 1.9 million ha of land and affect the lives of more than 2 million people. For example, in 2005, half a million $m^3$ of flood water inundated almost 50% of the delta. Normally, these floods are essential to food security and biodiversity, and people there have a tradition in living with the floods. However, extreme mainstream flood events can be destructive and cause enormous damages. Sea level rise is expected to result in large areas of permanent and more frequently inundated coastal plains. Also rise in sea level will increase salinity levels in the Delta rivers and the water network. Agricultural production will be affected by more frequent and longer periods of flooding as well as salinity intrusion. In fact, surface water salinity and acidification of sulphate rich clays are two constraining factors for agriculture at the delta.

The delta population is projected to increase from the present 17 million to around 30 million by 2050. This will fuel the urbanization trend, taking more land out of agricultural production. At the same time more people need to be provided with food and fresh water. Ongoing industrialization will also take up more space and increase the demand for water as well as the production of wastewater. Both trends call for proper spatial planning, efficient water supply, investments in water treatment and stringent enforcement of environmental legislation. The current water management system including its dense network of irrigation canals, levees, sluice gates and roads, is essentially based on the 1994 Mekong Delta Master Plan. An upgrading of the master plan is presently under discussion.

### *Recommended Way Forward*

Mekong river delta is a complex multi-functional water system subject to the influence of upstream development, local land/water development pressure and sea water intrusion. Managing the flood risks at the delta requires an integrated and adaptive approach. The upgrading of the management master plan for the delta can be a good opportunity to review the vision, development objectives and strategy for managing flood risks and related development issues, and explore ways to apply the GWD approach and best practices. The new master plan conceived in line with the overarching principle of 'live with floods' and built on the international and local experiences including the climate change adaptation initiative at HCMC, needs to address the following key aspects of flood risk management:

***(a) Rainfall-runoff reduction***: To mitigate the impact of upstream development, the government needs to continue working closely with the upper riparians through the Mekong River Commission and related mechanisms. Opportunities of optimized operations of upstream reservoirs and regulating storage facilities including Tonle Sap should be explored for multiple-win results. The donor funded regional water resources management and climate change adaptation programs can play a pivotal role in this respect. The flood management information system and flood forecasting and early warning system built with donors' support for the Lower Mekong River Basin should be best utilized for downstream impact reduction. Spatial technology such as earth observation can be used to develop models for flow monitoring and prediction, and risk assessment (See Figure 5.1 for an example of using satellite for flood monitoring in LMRB);

***(b) Hydraulic load reduction***: The delta covers 13 provinces and some emerging regional centers and major towns such as Can Tho. Their development planning should be closely coordinated through a multiple stakeholder (cross-sector) mechanism with the aid of a decision-support system, to ensure that the requirements of flood risk reduction are taken into account. Canals and rivers need to be regularly dredged in order to maintain their conveyance capacity at design level;

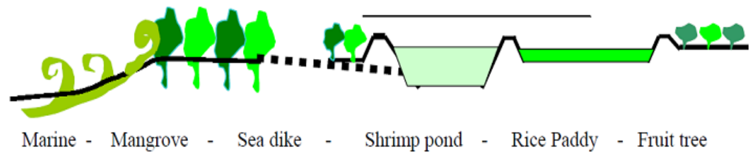
***(c) Flood control***: New flood control facilities and measures need to be conceived within an integrated water resources management framework, so that the flood risk and closely linked water service issues (e.g., water supply expansion, pollution abatement, and control over groundwater over-abstraction) can be addressed effectively together. There is significant scope for protection of sea dikes by mangroves, especially on the 28,000 ha of newly accreted land in the southern provinces. The infrastructure network of the complex delta water system needs to be operated more optimally and maintained appropriately to fulfill their intended functions in flood and water management. Building on the experiences of local transport sector, the use of Vetiver grass (*Vetiveria zizanioides*) to protect rural flood management infrastructure against erosion should be explored;

**Figure 5.1: A Satellite Image Showing the LMRB Flood of Oct. 18, 2011**


Source: NASA

***(d) Impact reduction through adaptation:*** Increasing urbanization and industrialization require different flood safety standards across the delta, a spatial (land use) plan based on flood hazard assessment and other necessary considerations should be developed to guide future development at the delta. Integrated mangrove-dike-shrimp-rice-fruit tree is a very innovative way of adapting agricultural practice to climate change and sea water intrusion (See Figure 5.2). Policy interventions and technical assistance are required to enable the local communities to replicate this good practice over large areas. Similarly, policy and regulation supports are needed to control new land reclamation activities, to encourage mangrove forest protection and restoration for coastal defense and biodiversity preservation, and to promote Melaleuca forests for improving acid sulphate soils; and

**Figure 5.2: Mangrove-Dike-Shrimp-Rice-Fruit Tree Model at MKD**




Source: T.V Truong *et al.*, 2001

***(e) Managing residual risk***: Efforts should be stepped up to improve flood emergency response, post-disaster recovery and risk management financing, to increase risk management capacity, and to explore risk-sharing mechanism such as government supported flood insurance.

### GWD Application in Indonesia

#### *Ongoing Applications*

As discussed earlier, the GWD is not an entirely new concept in the sense that some of the GWD measures have already been used in different parts of the world, including Indonesia. The following are two examples of GWD applications in Bali and Aceh regions of Indonesia respectively:

**Bali Beach Conservation Project**: Sanur and Nusa Dua Beach are two of the most famous tourist destinations in Bali. Severe beach erosion gradually ate away the white sandy beaches. Started in 1997, the Government of Indonesia with assistance from Japan undertook a beach rehabilitation project (See Figure 5.3). The project design adopted sand nourishment combined with engineering works, walkways and public facilities to restore the beaches at Bali and conserve the natural ecosystem and cultural values. By the end of the project, wide white sandy beaches have been restored along 14 km shoreline. Monitoring results showed that the number of visitors at Sanur and Nusa Dua Beach increased by 2.5 times and that of total hotel guests increased by 1.8 times compared to those before the project (Wijaya, 2009).

Figure 5.3: Bali Beach Conservation Project

Source: Wijaya, 2009

**Mangrove restoration in Aceh:** Mangrove restoration in Aceh under the Tsunami recovery program (See Figure 5.4) applied the concept and good practices of green coastal defense and 'Building with Nature'. Under the program, mangrove trees were planned to serve as natural and ecological barriers to storm surges to dissipate wave energy, reduce coastal land erosion and stabilize the costal lines and levees.

Figure 5.4: Mangrove Restoration in Banda Aceh, Indonesia after the Asian Tsunami

**Source: Marchand et al., 2012**

## GWD Application in Jakarta, Indonesia

*Key Challenges and Drivers*

Jakarta is located in the National Strategic Zone Jabotabekpunjur (See Figure 5.5), comprising Jakarta and several other cities: Bogor, Depok, Tangerang, Bekasi, Puncak and Cianjur. Based on the official registration, Jakarta has a population of about 9.6 million (2010), with an average density of about 14,500 people per km$^2$. The Jakarta Metropolitan area has become the center of economic activity in Indonesia. According to BPS data (2008), the highest per capita gross production of Indonesia is in Central Jakarta and amounts to IDR 200 million per year. The 13 short and steep rivers flowing through Jakarta respond very quickly to rainfall, and due to the high rainfall intensity, population density and percentage of impermeable land surface, large amount of run-off flow into the city at high velocity without infiltration during rainy seasons.

**Figure 5.5: Map of Jakarta and Surroundings**


Source: Google Map

Jakarta faces enormous challenges in managing floods from the rivers and sea side. Throughout the centuries the city has suffered from severe flooding. The 2007 flood (of 1-in-50-year probability) was one of the worst floods ever experienced in Jakarta. The flood extended over 70% of the metropolitan area with 30% of the area with water depth of over 1 meter. It costed 57 lives, displaced more than 422,300 people, with an estimated total damage to property and infrastructure of USD 695 million (World Bank, 2011). The city is considered at high risk to flood disasters because very few areas of the city are immune to recurrent floods, and the coastal areas are most vulnerable. Although the flood hazard is not a new phenomenon in Jakarta, with rapid urbanization and expansion (exponential population and asset increase), demographic change, ground subsidence and climate change (variability, storm surge and sea level rise), the risks have increased substantially over the past decades (World Bank, 2011). Many studies have been carried out and various plans prepared, there seems to be still short of clear path in addressing the issues in a systematic manner. Most of the studies seem to indicate that the key flood related challenges in Jakarta fall under the following categories: (a) space competition for development and flood management; (b) high exposure and vulnerability; (c) inadequate infrastructure for flood regulation, protection and drainage; and (d) increasing coastal erosion and sea level rise impact (against continued land subsidence). This provides good opportunities for applying the GWD approach and management measures.

### *Recommended Way Forward*

The flood management challenges in Jakarta are inter-linked and call for an integrated approach. In recognition of multiple facets of the issues and diverse interests of different stakeholders, it is important to have a shared vision, strategy and development objectives for near and long terms, building on the good work done by various parties. To this end, the first step can be updating the flood management master plan with stakeholder involvement, on the basis of related studies completed. Globally available spatial information should be utilized as much as possible where there are data gaps.

Considering that the flooding issues are combined results of basin, local (urban) and coastal factors and climate change impact, the master plan needs to address all the related key aspects of flood risk management:

(a) *Rainfall-runoff reduction:* through watershed management and soil conservation measures in the upper reaches of rivers, and in other parts of the catchment to control and reduce the (peak) runoff;

(b) *Flood storage and regulation*: through making best use of existing infrastructures and building essential new multifunctional infrastructures for flood storage and protection, and for storm water drainage, as well as improvement in maintenance and safety management of such critical assets;

(c) *Hydraulic load reduction*: through management measures of providing more rooms for rivers and green space in the basins; reducing ground pressure on alluvial soils in urban areas, etc.; and through restoration and better utilization of natural defenses (e.g. wetlands) to reduce wave actions and land erosion along the coast;

(d) *Flood impact reduction:* while the above three categories of measures are mainly for reducing flood hazards, management measures can be taken for reducing exposure and vulnerability of people, assets and services to lower flood impact (losses). These measures range from effective enforcement of land use regulations through participatory spatial planning and mainstreaming flood risk management into urban/coastal development management, integration of land reclamation with coastal defense to flood forecasting and early warning, building codes renewal and flood-proof measures, and integrated water management, etc; and

*(e) Managing residual risk:* through efforts focused on emergency response and post-disaster recovery, risk management capacity-building as well as introduction of risk-sharing mechanism such as government supported flood insurance.

The updated master plan should be integrated with the spatial plan and be used to guide urban development of the region. Priority investments can be decided upon following the general process recommended in the earlier sections. Some examples of GWD measures to address those challenges are presented in Table 5.1.

**Table 5.1 GWD Measures Recommended to Coping with Flood Challenges in Jakarta**

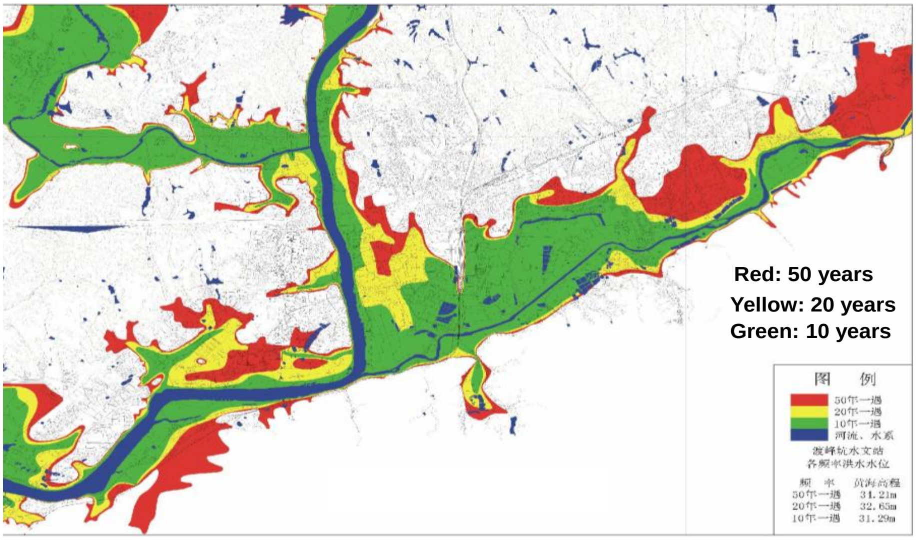
| Issues and Challenges | Types of Management Measures (Examples) |
|---|---|
| *Space competition for development and flood management* | Update the flood management master plan (in connection with finalization of the city's spatial plan) with clear vision, objectives/targets and strategy through stakeholder involvement |
| | Enforce strict control over land use conversion and encroachment into floodplains through policy interventions |
| | Invest in watershed/catchment management to reduce land erosion and sedimentation |
| | Consider building strong levees/dikes and other multi-functional defense works where space is limited and communities are very vulnerable |
| | Explore options of spatial development pattern (e.g., building more satellite towns/cities) to reduce the population density and encroachment into floodways |
| *High exposure and vulnerability* | Integrate flood risk management with urban/costal development planning & management (including transport network): establish multi-stakeholder participation mechanism for development plan preparation and review; develop shared flood management information system and decision-support system (DSS); prepare and publicize flood hazard maps, etc |
| | Develop/upgrade flood forecasting and early warning system, emergency preparedness and response plan (as part of disaster management plan) |
| | Implement 'total water management' including demand and supply-side management measures (e.g. water conservation financing, water tariff and effluent charge) to address issues of lack of local water storage, seasonal water shortage, groundwater over-abstraction, and water pollution), increase capacities of piped surface water supply and wastewater treatment, and establish water allocation and use permit system |
| | Upgrade building codes, and promote water-sensitive and climate-resilient designs in new urban development |
| | Establish flood management investment fund, and introduce appropriate flood insurance program |
| *Inadequate infrastructure for flood regulation, protection and drainage* | Selectively upgrade and scale-up priority infrastructures |
| | Safe and optimal operation of existing infrastructures through O&M improvement |
| | Investment in discharge channels and other drainage facilities (dredging, rehabilitation and expansion), and solid water management programs |
| *Coastal erosion and sea water rise threat* | Coastal wetlands/coral protection and restoration |
| | Regulations and control mechanism for land reclamation along the coast |
| | Consider using where appropriate technologies like 'sand nourishment' for coastal restoration and protection |

## GWD Application in Jingdezhen City, China

The World Bank was requested by the Chinese Government to support the construction of a proposed Wuxikou Flood Control Reservoir on the Changjiang River in Jiangxi province, to increase the flood protection of the ancient porcelain capital, Jingdezhen City.

This hilly city is prone to major flood hazards from the unregulated Changjiang River that flows through the city. It has been experiencing increasing flood losses in the past decades, e.g. the 1998 flood led to the city being under water for 94 hours affecting 27 million people and 95% of the urban areas, with a direct economic loss of 2.3 billion Yuan (See Figure 5.6 for the flood hazard map). There lacks in the city, of basic infrastructure to protect against annual river floods and local storms, despite the fact that a fairly effective flood emergency response system and a rudimentary flood forecasting system have been established over the years. An engineering oriented flood control master plan was developed over a decade ago based on a river basin development plan.

**Figure 5.6: Flood Hazard Map of Jingdezhen City**



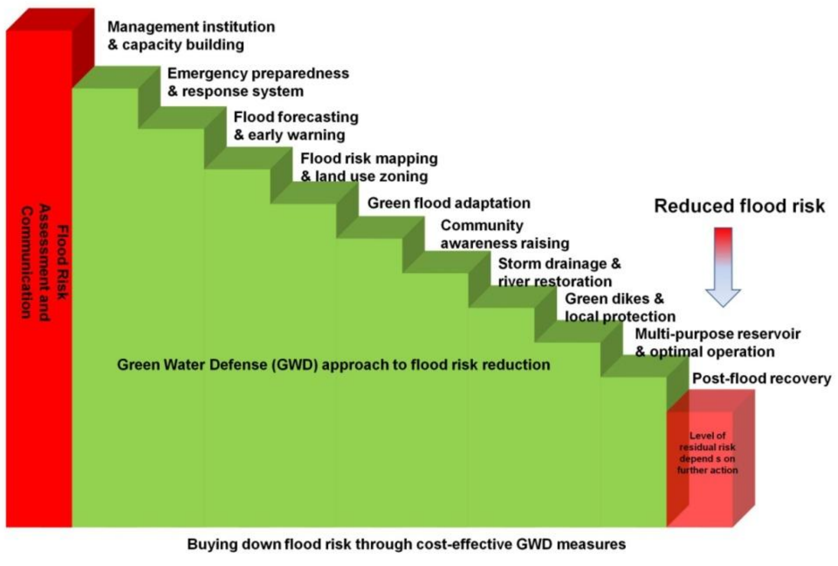

Source: The World Bank, 2012

Managing flood issues in Jingdezhen city calls for an integrated and risk-based approach. Therefore, in addition to the essential infrastructure – Wuxikou reservoir, the Bank project would also support introduction and improvement of cost-effective non-structural measures, to reduce the flood risk in the central urban area of Jingdezhen City. The Bank project conception and design followed a process described below (also See Table 5.2):

A. ***Understanding the flood risks and deciding on risk reduction strategy and targets.*** Risk mapping and assessment were undertaken as part of the project preparation studies. The results showed that the critical flood hazards came from the Changjiang river reach upstream of city. In light of the risk assessment results and related development plans of the government, it was decided that the strategic focus should be on reducing the scale of the flood hazard through flood regulation, namely, a storage reservoir on the river to complement the urban dike system, as there are not sufficiently large natural retention areas along the river. In consideration of the investment scale required, 1-in-50-year floods were set as the medium term flood safety target.

**B.** ***Indentifying options with balanced structural and non-structural measures.*** A long list of potential green water defense measures was developed to address the hazard, exposure and vulnerability aspects of flood risks for Jingdezhen City. The guiding principle followed in the analysis is to 'live with floods'. These measures were conceived by building on the strength of the existing flood management system, including unified flood commanding organization, water information system, flood forecasting and emergency response system. The initial list of structural measures cover flood storage, regulation and protection, drainage and river restoration. The non-structural measures have a much wide range, including flood risk management institution, master plan, hazard mapping and land use zoning, catchment management, flood resilience and adaption, emergency response, and capacity building. Different packages of appropriate structural and non-structural measures formed the investment options to achieve the project objectives.

**Figure 5.7: Buying-Down Flood Risks in Jingdezhen City through GWD Measures**




Source: Concept based on Manous 2011

**C.** ***Analyzing and prioritizing the options based on cost-effectiveness taking into account the environmental and social impact (externalities).*** Analysis of the investment options and measures was carried out based on the different planning and feasibility studies completed. The proposed investment options were examined according to their contributions to risk reduction, in relation to their costs, i.e. cost-effectiveness following the 'buying down risk' approach. In the case of structural measures, social (e.g., resettlement and land acquisition) and environmental impacts are important criteria in deciding on the detailed options (e.g., dam site, reservoir size and operating water levels). For the same reason, non-structural measures which are much less costly were given higher priority. The results of the prioritization are shown in Figure 5.7.

***D. Designing the selected measures to achieve optimal results and sustainability:*** The project design kept in view the inter-linkages between different parts of an integrated system and long-term sustainability. In designing the major structural interventions (e.g., Wuxikou dam), care was taken to ensure a robust design with consideration of the climate variability. Non-Structural measures, such as flood information management, flood forecasting and warning system as well as emergency response system, were designed keeping in mind the need for enhancing the operational performance of structural measures. With the aim of introducing the risk-based approach and strengthening the capacity for long-term flood risk management of the city, the following non-structural measures would be included in the final project design:

(a) *Formulation of a Flood Risk Management Master Plan:* This master plan will draw upon international good practices, introduce GWD approach, and address all aspects of flood risk management ranging from risk reduction at source to adaptation and resilience enhancement, and to flood emergency response and post-disaster recovery at the receptor end;

(b) *Development of a Flood Risk Management Decision Support System (DSS):* This would include development of a real-time flood forecasting and early warning system coupled with GIS database and network technologies, optimizing the flood control operation of the Wuxikou reservoir and flood control system, and introducing flood risk analysis and flood damage assessment;

(c) *Strengthening of Urban Flood Management Organization:* This would involve establishment of a municipal flood risk management center; strengthening the cross-sector coordination mechanism and capacity-building for flood management; and

(d) *Piloting Participatory Flood Emergency Response:* This would support community-based flood emergency response demonstration, public awareness raising and education for flood risk management.

***E. Implementation:*** The project is still under preparation and expected to be implemented from 2013 to 2017.

**Table 5.2: Wuxikou Flood Risk Management Project (WFRMP): Screening & Prioritizing GWD Measures through 'Buying down' Flood Risks**

| **Management Mechanisms and Tools** | | **Key Measures** | **Status/Plan** | **Gaps and Actions Needed** | **Cost-effectiveness & Priority Level** | **Interventions under WFMP** | **Remarks** |
|---|---|---|---|---|---|---|---|
| Flood Risk Management Institution | Flood management organization | Participatory Management organizations | Existing multi-stakeholder organizations are in general satisfactory | Inter-agency coordination is subjected to evaluation for IFRM. | Low cost and very high benefit, high priority | Existing organizations will be evaluated during project preparation and needed changes identified | Organizations Include policy and operational levels |
| | Flood risk management policy and regulations | Management Policy and Regulations | General management policy and detailed regulation (incl. financing mechanism) are in place | The policy and regulations need to be reviewed in light of the needs for IFRM. | Low cost and very high benefit, high priority | Existing policy and regulations will be reviewed during project preparation and necessary actions included under capacity-building activities of the Project. | |
| Flood Risk Management Strategy and Plan | Management information/ knowledge base | 1. Management information system (Hydromet, Asset management, socio-economic database of city);<br>2. Flood risk assessment and mapping | 1. Good Hydromet system in place; asset management system under development<br>2. Flood inundation maps exist. | 1. Inter-agency data sharing requires enhancement<br>2. Flood maps with inundation depth, duration &locations not available, and flood risk assess to be conducted. | Low cost and high benefit, high priority | 1. Data-sharing arrangements will be reviewed and needed actions taken;<br>2. Flood risk assessment & mapping will be included under the Project | Some rainfall stations in remote u/s areas, and flow stations on main tributaries to be added via government programs |
| | Strategy and Master Plan for FRM | 1. Long-term strategy;<br><br>2. A Master Plan for Medium Term | 1. No written management strategy;<br>2. A infrastructure oriented master plan exists and is being updated | 1. A clear strategy based on 'live and build with flood' principle is needed;<br>2. Existing Master Plan needs to be upgraded into an integrated FRM Master Plan | 1. FRM Strategy: low cost and high benefit, high priority<br>2. IFRM Master Plan upgrading: low cost and high benefit, high priority | 1. A FRM strategy for JDZ City will be reviewed and improved during Proj. Preparation;<br>2. A Master Plan for IFRM in JDZ City to be upgraded under the Project | The Master Planning TA will be linked to the DSS development for FRM under the Project |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Catchment Management | River watershed | Soil and water conservation | Very good vegetation coverage with little land erosion in river catchment | Wuxikou reservoir construction effect on local watershed needs to be managed carefully | Medium cost and high benefit, medium priority | No interventions is expected except environmental management plan | |
| | Urban watershed | Management practices to increase rainfall infiltration, reduce flood peak and land erosion | Urban development policies encourage greening of city landscape | Green and multiple function infrastructure needs to be promoted where appropriate | Medium cost and benefit, medium priority | Needs and measures for urban watershed management improvement will be reviewed under IFRM Master Plan | Jingdezhen is a hilly city with limited land area |
| Flood storage and regulation | River flood storage/regulation | 1. Wuxikou reservoir construction on Changjiang River;<br><br>2. Utilization of existing tributary reservoirs (small/medium sized) | 1. Wuxikou reservoir of 0.5BCM capacity in design stage;<br><br>2. Most tributary reservoir spillways are ungated. | 1. Wuxikou reservoir needed to raise protection level to 1-in-50-year flood;<br>2. Storage capacity of tributary reservoirs needs to be fully utilized for flood hazard reduction. | High cost and very high benefit, high priority due to its critical importance in flood risk reduction | The multipurpose Wuxikou reservoir will be financed by the project, with joint operation of tributary reservoirs; Environmental and social considerations are important factors in reservoir option assessment and design | Gate addition and dam heightening of tributary reservoirs to be included in medium-term Gov. programs to further increase protection level |
| | Flood Retention/ detention | Construction of retention and/or detention basins and ponds | A number of lakes and ponds exist in the urban areas | Full utilization of existing ponds and lakes needs to be reviewed | Cost could be very high with limited benefits owing to local topography, low priority | The FRM Master Plan will examine possibility of expanding retention and detention capacity | |
| Local Flood protection | Dikes and polders | Construction of river dikes along key river sections | Construction of river dikes to protect core urban areas will be completed before 2012 flood season | Flood protection level can reach 1-in- 20-year flood with these dikes (greening measures included) | Relatively high cost and high benefit, high priority due to its critical function | The dike system will be reviewed as part of the physical flood defense system during Master Plan upgrading | |
| Flood/storm water drainage | River restoration | River channel normalization and dredging | River channelized with bank protection in urban area; need for limited river dredging is investigated | The river sections to be dredged, with benefits and costs need to be identified, and included in longer term plan. | Medium cost and benefit expected, relatively low priority | River dredging will be evaluated under the Master Planning activity. | River dredging will be undertaken by government program in medium term |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Storm drainage system | New construction of storm drainage facilities and upgrading of existing ones | Existing sewer system to be separated to storm &sewer systems; 5 of planned 9 storm pump stations built | Effectiveness of the planned separate sewer systems and the pumping stations are to be evaluated quantitatively. | Medium costs and benefits, high priority | Effectiveness of separate storm drainage system and pumping stations will be evaluated as part of the IFRM Master Planning task | Construction and upgrading are fully financed by the municipal government |
| Flood Resilience, Adaptation & Emergency Response | Land use management | Land use planning and zoning based on flood risk | Land use plan does not fully reflect flood risks | No guidelines for land use planning and development considering flood risk | Long cost, high priority (for medium term) | Land use zoning is to be included under the Project | Recommend-ations for land use planning& development to be included in upgraded Master Plan |
| | Flood adaptation | Water-sensitive development and management practices and beneficiary behavior to better use ecological service and increase flood resilience | Building design considers flood proofing measures, important works (e.g. power plant) being located away from high risk zone | Potential of more natural flood risk reduction and adaptation measures (incl. eco-system enhancement and such market mech-anism as insurance) needs to be explored | Relative low and high benefit, relatively high priority | Further demand-side management measures will be considered under the updated Master Plan | Training on Green Water Defense approach to flood risk management will be provided |
| | Flood forecasting & early warning | Flood related Information gathering and transmission system | Real-time data transmission system is available (See above regarding hydromet system) | Existing hydromet system generally adequate for flood forecasting and early warning; additional rainfall stations in remote u/s areas, and flow stations on main tributaries needed | Relatively low cost and high benefit, high priority | Limited essential equipment may be financed under the Project | The planned construction will be financed by government through separate programs |
| | | Decision-support system (DSS) for flood forecasting and early warning | Existing flood forecasting is based on a rainfall-stage relationship and a conceptual rainfall-runoff model | Current approach is inappropriate after Wuxikou Reservoir is constructed. A new DSS for flood forecasting and early warning to be established with reliable | Relatively low cost and very high benefit, very high priority | An IFRM DSS (including database, GIS, optimal reservoir joint operation scheme, flood forecast and early warning, flood damage analysis and a DSS platform) is to be included under the | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | real-time data transmission and processing | | Project | |
| | capacity-building for flood risk management operations | Capacity building and training activities targeted at management and operation agencies | Regular training is provided, but mostly on engineering and general management aspects | Training and capacity-building for risk-based flood management and operation are lacking and much needed | Cost relatively low with high benefits, relatively high priority | Capacity building/training on IFRM for flood management agencies is part of the Project design | |
| | Emergency preparedness and response system | Emergency response organization and plan | An effective emergency response system in place and well functional | The existing system is generally effective, although Community tends to be reactive | Low cost and very high benefit, very high priority | A community-based flood response pilot is to be included under the Project to enhance community participation | EPP needs to incorporate risks associated with new dam & dikes |
| | Community awareness raising | Community awareness raising and education | Community awareness is relatively high due to frequent flood events | Much more can be done to enhance adaptation and emergency preparedness ( going beyond emergency response) | Very low cost and high benefit, relatively high priority | Community awareness raising and education are included under the Project | Community awareness and education can lead to better flood preparedness and more effective risk management |
| Post-flood recovery | Post-flood recovery system | 1. Damage/loss assessment;<br>2. Post-disaster recovery planning and implementation | The city has a functional post-flood recovery system as proven in recent years' floods | The existing recovery system is in general satisfactory; | Essentially; Cost and benefit depends on damage, medium priority | Training will be provided under the project for flood damage/loss assessment | |

**Flood Risk = SUM (Flood Hazard Probability x Consequence of Flood Events); Consequence of flood events is a function of exposure and vulnerability**

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