Managing Flood Risks Through Grey and Green Infrastructure – Emerging Trends and Perspectives

Climate Change Seminar @ AIT
10 February 2020

Mukand S. Babel
Professor, Water Engineering and Management (WEM)
Chair, Climate Change Asia (CCA)
Asian Institute of Technology (AIT), Thailand
Contents

• How to Mitigate Flood Risk?
• Grey Infrastructure
• Green Infrastructure
• Hybrid (Grey-Green) Infrastructures
• Case Studies
• Perspective
How To Mitigate Flood Risk?
By understanding the components of flood risk!

Flood Risk = Hazard X Exposure X Vulnerability

Hazard
Flood situation for a selected return period with spatial information on flood extent, depth, duration, and flow velocities

Exposure
Exposure of people and assets to floods

Vulnerability
Susceptibility of the elements at risk to suffer from flood damage
Integrating human behavior dynamics into flood disaster risk assessment

(iii) Disaster risk reduction

Protection, spatial planning, forecasting and evacuation → Government

Insurance and risk mapping → Business

Flood proofing, buying insurance, and deciding whether to buy a property in flood zone → Households

(ii) Examples of factors influencing behaviour and perception in DRR

Economic such as income and equity

Social such as age and literacy rate

Geographic Scale and distance to flood zone

Culture such as heritage and language

Information Media and data availability

Risk information or flood events

(i) Risk assessment

Hazard (events and flood extent, depth, and so on)

Exposure (people and assets)

Vulnerability (damage function)

Risk (Expected annual damage)


Multisectoral approach
Grey infrastructure

the human-engineered solutions that often involve concrete and steel
Traditional (Grey) Infrastructure Solutions

Water supply regulation

- Dams
- Groundwater pumps
- Distribution system
Traditional (Grey) Infrastructure Solutions

Water quality regulation

Water purification

Water treatment plant

Erosion control

Reinforcement of slopes
Traditional (Grey) Infrastructure Solutions

Water quality regulation

Water temperature control

Dams

Biological control

Water treatment plant
Traditional (Grey) Infrastructure Solutions

Moderation of extreme events

Riverine flood control

Urban storm water runoff

Coastal flood protection

Dams

Storm water drains

Sea Walls
Green Infrastructure

an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clear air and water, provide wide variety of benefits to people and wildlife
**NATURAL CAPITAL:** The planetary resources (e.g., plants, animals, air, water, soils, minerals) that sustain life and well-being. Natural capital underpins clean air, water and energy security, shelter, medicine, and more. Natural capital concepts are increasingly applied in national and corporate accounting to keep track of society’s dependence and impact on these vital resources.

**NATURE-BASED SOLUTIONS:** An umbrella term referring to actions that protect, manage, and restore natural capital in ways that address societal challenges effectively and adaptively. These include structural and nonstructural actions, ranging from ecosystem restoration to integrated resource management, green infrastructure, and more.

**GREEN INFRASTRUCTURE:** A subset of nature-based solutions that intentionally and strategically preserves, enhances, or restores elements of a natural system to help produce higher-quality, more resilient, and lower-cost infrastructure services. Infrastructure service providers can integrate green infrastructure into built systems.
Ecosystem Services

**Products obtained from ecosystems**
- Water supply
- Food production
- Raw materials
- Medicinal resources

**Regulating Services**
- Temperature control
- Carbon sequestration and storage
- Moderation of extreme events
- Water purification
- Erosion control including shoreline
- Pollination
- Biological control

**Provisioning Services**

**Cultural Services**
- Spiritual experience
- Recreation
- Aesthetic and cultural values
- Tourism

**Habitat or Supporting Services**
- Maintenance of genetic diversity
- Habitat of species

**Highlight the importance of ecosystems to provide habitat**

Non-material benefits that people obtain from ecosystems
<table>
<thead>
<tr>
<th>Water management issue (Primary service to be provided)</th>
<th>Green Infrastructure solution</th>
<th>Location</th>
<th>Corresponding Grey Infrastructure solution (at the primary service level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderation of extreme events (floods)</td>
<td>Re/afforestation and forest conservation</td>
<td>Watershed</td>
<td>Dams and levees</td>
</tr>
<tr>
<td></td>
<td>Riparian buffers</td>
<td>Floodplain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reconnecting rivers to floodplains</td>
<td>Urban</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wetlands restoration/conservation</td>
<td>Coastal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Constructing wetlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Establishing flood bypasses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Green Infrastructure Solutions for Flood

<table>
<thead>
<tr>
<th>Water management issue (Primary service to be provided)</th>
<th>Green Infrastructure solution</th>
<th>Location</th>
<th>Corresponding Grey Infrastructure solution (at the primary service level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderation of extreme events (floods)</td>
<td>Green roofs</td>
<td>Floodplain</td>
<td>Urban</td>
</tr>
<tr>
<td>Urban storm water runoff</td>
<td>Green spaces (bio-retention and infiltration)</td>
<td>Watershed</td>
<td>Floodplain</td>
</tr>
<tr>
<td>Water harvesting*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeable pavements*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal flood (storm) control</td>
<td>Protecting/restoring mangroves, coastal marshes and dunes</td>
<td>Watershed</td>
<td>Floodplain</td>
</tr>
<tr>
<td>Protecting/restoring reefs (coral/oyster)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Consists of “grey” elements
**Example: Green Spaces**

- Refer to areas of land **partly or completely** covered with **grass, trees** or other types of **vegetation**,  
  - creating basis for **bio-retention** and **infiltration-related** practices
- These are **suitable** for **urban areas**,  
  - as they help to deal with storm water runoff in the presence of large areas of impervious surfaces
**Example:** Green Spaces

<table>
<thead>
<tr>
<th>Water Management Benefits</th>
<th>Co-benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Flood mitigation (urban storm water runoff control)</td>
<td>• Biodiversity benefits</td>
</tr>
<tr>
<td>• Water purification</td>
<td>• Aesthetic value</td>
</tr>
<tr>
<td>• Water supply regulation</td>
<td>• Improved air quality</td>
</tr>
<tr>
<td>(improved groundwater recharge)</td>
<td>• Energy savings for water treatment</td>
</tr>
<tr>
<td>• Temperature control (shading of water ways)</td>
<td>• Carbon sequestration</td>
</tr>
<tr>
<td></td>
<td>• Reduced urban heat island effect</td>
</tr>
<tr>
<td></td>
<td>• Reduced noise pollution</td>
</tr>
</tbody>
</table>
Green infrastructure: Examples

- Rainwater collection in plantar box then channeled into rain garden
- Irrigation from disconnected downspout
- Green roof
- Vegetative swale
- Pervious pavement sidewalk
- Retention pond

(USEPA)
Benefits of Green Infrastructure

- Holistic approach to utilize the provision of ecosystem services to provide
  - primary WM benefits
  - secondary co-benefits like provision of food, recreation and erosion control using a more holistic approach
- Significant cost savings in operation
- Help to reduce the pressures on existing water infrastructures
  - and avoids large investments in new or expansions in grey infrastructure
- Value and function of the green infrastructure can increase over time
  - for both primary and co-benefits
- Play an important role in the wider strategies for climate change adaptation and mitigation
- Contributes to biodiversity conservation and
  - help to protect species through creating new habitats
Challenges of Green Infrastructure

• **Measuring return** on investment, risk management, and effectiveness

• Absence of regulation and resistance within regulatory bodies

• A largely untested concept, faces scientific uncertainty, socio-political uncertainty/acceptance, and decision-making uncertainty

• Lack of capacities in design and unfamiliarity in maintenance requirements and costs
Grey vs. Green

- Conventional practices such as WTP, dams and levees and the expansion of sewage networks
- **Offer immediate and high visibility impacts**
- Large carbon footprints due to long-term energy use
- Capital intensive to build, operate, maintain and replace
- Shift amplified risks to other locations
- Lead to declines in the quality and quantity of water supply

- Utilize the provision of ecosystem services for **primary WM benefits and secondary co-benefits**
- At the heart of Ecosystem-based Adaptation
- Carbon sequestration
- Lower carbon footprint
- Ecologically sustainable
- Recreation opportunities
- Better public health
Hybrid (Grey-Green) Infrastructures
Case Study: Ho Chi Minh City, Vietnam

Modeling results suggested green roof the best alternative, followed by pervious pavement, urban green space and rainwater harvesting. SUDS could mitigate run-off volume. Pollutant removal and Aesthetics enhancement.
Case Study: Ayutthaya, Thailand

Water management issues

Legend
Elevations (m)
- 5.1 - 6.0
- 6.0 - 6.9
- 6.9 - 7.8
- 7.8 - 8.7
- 8.7 - 9.6

Historical Sites
Ring Road - Dyke
Gates and pumping stations

0 310 620 1,240 1,860 2,480 Meters
1D model set up

River Center Line

River Cross Sections
Case Study: Ayutthaya, Thailand

2D model set up

DTM:
- LIDAR Image
- Grid Resolution = 10m x 10m
Case Study: Ayutthaya, Thailand

Measures: Green and Grey

- Increasing Detention Pond Area
- Reviving Ancient Canals
- Increasing Pumping Capacity
- Increasing Dike Height
Case Study: Ayutthaya, Thailand

**Green measures:** Blue and green corridors, multifunctional ponds, porous pavements, multifunctional landscape, etc.

**Grey measures:** Dike, pumping stations, drainage canals and pipes.
Perspective: Hybrid Infrastructure

‘Hybrid’ solutions have the best potential
### How Grey and Green Infrastructure can work together?

<table>
<thead>
<tr>
<th>Service</th>
<th>Gray Infrastructure Components</th>
<th>Examples of Green Infrastructure Components and Their Function</th>
</tr>
</thead>
</table>
| **Water supply and sanitation** | Reservoirs, treatment plants, pipe network | **Watersheds:** Improve source water quality and thereby reduce treatment requirements  
**Wetlands:** Filter wastewater effluent and thereby reduce wastewater treatment requirements |
| **Hydropower**                   | Reservoirs and power plants    | **Watersheds:** Reduce sediment inflows and extend life of reservoirs and power plants |
| **Coastal flood protection**     | Embankments, groynes, sluice gates | **Mangrove forests:** Decrease wave energy and storm surges and thereby reduce embankment requirements |
| **Urban flood management**       | Storm drains, pumps, outfalls  | **Urban flood retention areas:** Store stormwater and thereby reduce drain and pump requirements |
| **River flood management**       | Embankments, sluice gates, pump stations | **River floodplains:** Store flood waters and thereby reduce embankment requirements |
| **Agricultural irrigation and drainage** | Barrages/dams, irrigation and drainage canals | **Agricultural soils:** Increase soil water storage capacity and reduce irrigation requirements |
Thank you very much

msbabel@ait.ac.th
msbabel@gmail.com