Aspects of Flood Risk

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Some severe recent flood disasters

Philippines, Typhoon Haiyan, Nov 2013
Overall losses: US$ 10bn
Insured losses: US$ 700m
Deaths: >6,000
Dest./dam. bldgs: 1,200,000

Thailand, Storm surge, Sep-Oct 2011
Overall losses: US$ 43bn
Insured losses: US$ 10bn
• largest river flood loss ever worldwide

Uttarakhand/India, June 2013
Tens of thousands of pilgrims were forced to stay in the cold mountains for days with 3,500 cprted

Southern Germany, May-June 2016
Overall losses: ???
Insured losses: ???
Deaths: 11

Increase in number of events

Flood disasters

Inland flood losses 1980 – 2015

(only events with inflation-adjusted loss >US$ 50m are shown)

Increase in losses

Flood disasters

Inland flood losses 1980 – 2015

(only events with inflation-adjusted loss >US$ 50m are shown)
Inland flood losses 1980 – 2015 (only events with inflation-adjusted loss >US$ 50m are shown)

Does the flood risk increase?

What is risk?

Risk → Natural disaster

Human = value, exposure, vulnerable

What is risk?

Hazard

Risk → Natural disaster

Natural disaster
Risk = Hazard • Values at Risk • Vulnerability

natural event

cannot be influenced (except by climate change)

Flood risk reduction

\[ R = H \cdot E \cdot V \]

are man-made and can be influenced

Changes in environmental conditions

Upper Rhine Valley prior to 1800

Upper Rhine Valley today
Changes in landuse

Chao Phraya/Thailand
7 flooded industrial parks
1. Bangkadi
2. Nawanakom
3. Bang Pa-In
4. Wang Noi
5. Hi Tech
6. Rojana
7. Saha Rattana Nakom

Development on flood plains

Thailand 2011
Increase in value concentrations
Shanghai 1990

Increase in value concentrations
Shanghai 2010

Population development
Florida

Urbanisation
Jakarta

Source: Deutsches Zentrum für Luft- und Raumfahrt
Values inside of buildings
(Example basement)

High vulnerability

Climate change

Projected impacts on 100-year flood

Past

Today

Climate change

Increase in extremes: frequency and intensity

Source: IPCC AR5 WG2 Ch.3 Permanent Resources, Fig. 3.8

Multi-model median return period (years) in the 2080s for the 20th-century 100-year flood

17/06/2016
Hurricane Katrina Aug. 28, 2005

Climate variability
Characteristic precipitation changes during El Niño

- Increased rainfall and flooding in Indonesia/Philippines

Flood control – prevention – protection

Reduce the risk

Consequence: values in protected areas may increase immensely.

Climate variability
Characteristic precipitation changes during La Niña

- Reduced rainfall and flooding in Indonesia/Philippines
Types of flood
(un-official classification, not comprehensive)

1. Coastal floods (sea-borne)
2. Lake floods
3. River floods (fluvial floods)
4. Flash floods (pluvial, offplain)
5. Mountain floods
6. Groundwater/waterlogging floods
7. Backup floods
8. „Break“ floods
9. Subsidence-caused floods

Types, causes and impacts of floods

Coastal floods

Storm surge

Main cause: wind
Rain is not a factor!
Forecast/warning possible
Extreme loss potential:
„Katrina“, „Sandy“, „Haiyan“, Bangladesh, Netherlands/UK 1953, Hamburg 1962, etc.

River floods (fluvial floods)

Flooding process:
• Flooding originates from the river channel.
• Areas adjacent to the river are affected first.
  ➔ Flood zoning

Generated by:
• (Long-lasting) Rainfall with high amount over a large area
• Infiltration capacity is exceeded.
• Flood wave builds up.
Types, causes and impacts of floods
River floods (fluvial floods)

Impact:
• Long lasting flood stage
• Floodplains are high-value areas
  ⇒ high loss potential

Good news:
• Early warning is possible
• Flood control/protection/prevention is possible (e.g. dikes, reservoirs).
• These measures always pay off in the long run!

Types, causes and impacts of floods
Flash floods (pluvial floods, offplain floods)

• Intense rainfall (mm/time)

Bad news:
• May happen anywhere
• Early warning/defence measures not possible
Types, causes and impacts of floods

Mountain floods

Debris flow

- Mixture of sediment and water (30-70% of solids)
- High velocity
- Extremely destructive

Risk from river floods

Along rivers, flood control measures are concentrated, forecast and early warning are usually possible.

The risk for low and medium return periods (up to about 100 years) will decrease despite increasing values and climate change.

The risk from extreme events will increase, because the effectiveness of flood protection is limited.

A generally valid trend statement about the overall risk is not possible.

Risk from flash flood/off-plain flood

General (structural) protection against flash flood is not feasible.

Early warning is only possible in a qualitative way.
Preventive measures are easy for new buildings, but expensive and difficult in upgrading.

More, more valuable and more vulnerable exposure is created.
Climate change will lead to more frequent and more intense events.

The risk from flash floods will increase.
Flood insurance

General problems

- Large loss potential
- Linear rather than area impacts
- High variation of exposure within short distance
- High influence of local factors
- Flood control structures (e.g. dikes) make floods rare, but have almost no effect during extreme events
- Loss of awareness and feeling of security (“People think they know it better”)
- Adverse selection

Flood insurance

Adverse selection

**Principle of the insurance**

\[
\text{sum of premiums from all clients} = \text{sum of payments to the affected clients} \\
(\text{+ yields}) (\text{+ administrative costs + profits})
\]

Adverse selection

**A** Only those, who subjectively feel threatened by a flood, have interest in insurance cover; a large portion of them is in fact exposed to a high risk and experiences losses more or less regularly.

**B** The others feel safe and do not want to get insured.

If the portfolio mainly consists of members of group A, the spatial and temporal risk compensation is not guaranteed anymore.

Flood insurance

Approaches to a solution

- Information about individual exposure
- Definition of zones according to exposure level (country-wide for all areas)
- Adequately structured insurance contracts including deductibles
- Insurance package including coverage for other natural hazards (geographical spread of risk)
- Encouragement of measures for individual loss reduction
- Raising and maintaining risk awareness on all levels, from government to individuals
**Facts**

- Floods can happen practically anywhere.
- People and values concentrate in hazardous areas (on flood plains and coast).
- Flood protection is on a high level at many places, but cannot provide absolute security.
- Losses have reached new dimensions.

**Expectations**

- Development policy and land-use regulations do often not work well, we cannot stop the land-use change and concentration processes in the short term.
- Climate change is happening and will make the situation worse. Most we can do is to slow it down.
- Flood risk reduction must include adaptation.

**Solutions**

- Flood risk can be reduced by proper risk management.
- Technical measures (including non-structural) are crucial and irreplaceable. New techniques may be of great help.
- The residual risk must be put on the shoulders of all groups of a civil society (the government, the people concerned, and the insurance industry), and shared.
- Risk awareness must be created and maintained.

**Conclusion:** Insurance business will get tougher.

*Thank you.*
Managing Flood Risk
- Lessons and suggestions from Japan -

Kenzo Hiroki
Sherpa to the UN- World Bank High Level Panel on Water

Why is Japan so keen on Flood Management?
Concentration of assets and population in flood plain

<table>
<thead>
<tr>
<th></th>
<th>Flood (alluvial) plain</th>
<th>Other areas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assets</strong></td>
<td>75 (7.5 trillion USD)</td>
<td>25</td>
</tr>
<tr>
<td><strong>Population</strong></td>
<td>51 (65 million people)</td>
<td>49</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td>10 (37,000㎢)</td>
<td>90</td>
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</tbody>
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Cover Rates of Assets/Population in Flood Areas

- **Japan**
  - Assets: 約75%
  - Population: 約60%

- **U.K.**
  - Assets: 約9%
  - Population: 約10%

- **USA**
  - Assets: 約10%
  - Population: 約8%
If Typhoon Kathleen (1947) hit again and break dikes of Tone River, 2.3 million people can be under flood water.

Image of inundation of loop route No.7 (Katsushika City)

Flood water depth:
- 5.0m or more
- 2.0m or more
- 1.0m or more
- 0.5m or more
- Less than 0.5m

Inundation area (km²): 530
Population at inundation area (persons): 2,300,000

Spread of flooding through subway tunnels:
- Underground shopping areas and buildings' underground can be inundated by flood water through subway tunnels
- The inundation will be more rapid and deep

Inundated area in case of the right dike of Arakawa River broken:

- No pump operation
- Conditions of Water-stop Board is 1m high from gateway floor
- No in & out flow from ventilation shaft
Why is Japan so keen on Flood Management?

Because it is, through history, a matter of state survival

What we have achieved; and
What we have not
in national efforts of flood risk reduction
Annual investment for flood protection

Gross National Product (GWP)

Investment in flood prevention - Hand in hand with GDP -

GDP (10 billion USD)

Investment in flood prevention:

- Geological & Coastal Disaster Prevention: 2.5%
- Irrigation & Fishery: 11%
- Others: 1%

Total Value: 8 Trillion USD

- Road: 32.3%
- Port: 3.9%
- Airport: 0.5%
- Railway: 2.1%
- Garbage disposal: 1.9%
- Public Housing: 6.0%
- Sewage: 10.4%

National Infrastructure Stock

- Flood Prevention: 8.3% (700 billion USD)
- Schools & Research Facilities: 9.2%
- Urban Parks: 1.3%
- Water Supply: 5.7%
- Sports facilities: 2.2%
Steady investment led to decrease in disaster loss

Investment in flood prevention and flood economic loss in past 100 years

Investment in flood prevention (billion USD) vs. Rate of flood economic loss by per-capita income (%)

Investment in flood prevention:
- 0 (1900)
- 0.7 (1920)
- 4 (1940)
- 20 (1960)
- 30 (1980)
- 40 (2000)

Rate of flood economic loss:
- 0 (1900)
- 5 (1920)
- 10 (1940)
- 15 (1960)
- 20 (1980)
- 40 (2000)

Year:
- 1900
- 1920
- 1940
- 1960
- 1980
- 2000

Prevention pays off

Every one dollar spent for flood prevention creates 8 dollars of loss reduction

Case of the Shonai River, Nagoya City

Loss Reduction of 5.5 Billion USD

Investment of 0.7 Billion USD
What we have not achieved

Annual Human and Economic Loss by Flooding in Japan

- Death Toll
- Economic Loss
- Year
Death Toll

10,000

1,000

100

10

1

Economic Loss
Million USD

Human loss has been drastically reduced while economic loss still remains high

Catch me if you can
-Flood risk increases though flood area decreases -
Increasing extreme hydrological events

Frequency of heavy rain has increased by 50-100% in recent 20 years

Paradigm Shift in Flood Disaster Risk Reduction - to achieve what we have not -
Concept of Disaster Risk Reduction

Probability of Disaster

Damage/Loss

100%

50%

Disaster Risk

1/100 1/50 1/30 1/10 1/5 Probability of Disaster

Prevention (Dykes, Reservoirs, Diversions, etc.)
Concept of Disaster Risk Reduction

Probability of Disaster

<table>
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<tr>
<th>Damage/Loss</th>
<th>100%</th>
<th>50%</th>
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<td>1/100</td>
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<tr>
<td>1/5</td>
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Preparedness/ Resilience
(Flood Defense Brigades, Evacuation, Water proof buildings, Change of Crops…)

Prevention
(Dykes, Reservoirs, Diversions, etc.)

Risk Transfer
(Insurance, Compensation…)

Probability of Disaster
Paradigm shift in Flood DRR

- **100%**
  - Probability of Disaster
  - Damage/Loss
  - **1/100**
  - 1/100
  - 1/50
  - 1/30
  - 1/10
  - 1/5

- **50%**
  - Effective Prevention
  - Accelerating Preparedness/Resilience Actions
    - ( Awareness Raising, Flood-resilient Urban Planning, Water proof buildings...)
  - Promoting Transfer & Self-Help
    - (Insurance, hazard maps,...)

- **1/100** to **1/5**
  - Probability of Disaster

Turning paradigm shift into reality
Metropolitan Underground Flood Diversion Scheme

Connecting lowland rivers by vertical shafts (70m in depth) and underground tunnel (Φ11m × 6 km)
Divert and store flood water for later discharge

Super Levee by PPP

- Super embankments have mounding in more extensive urban areas than existing embankments. The advantages of super embankments are:
  1) no collapse at floods,
  2) no collapse against inundation, and
  3) earthquake-resistant.
- River bank land development is strictly restricted pursuant to the River Law. However, the whole slopes at the back of super embankments are designated as the special areas, for which land development is deregulated.
Developing retarding basins for flood management and ecosystem conservation

Ara River Retarding Basin #1
- Location: Saitama City & Toda City, Saitama Pref. (28.8 – 37.2 km from estuary of Arakawa river)
- Operation started: Year 2003
- Area of Reservoir: 560 ha
- Total Capacity for Flood Control: 39 mil. m$^3$
- Valid Capacity: 10.6 mil. m$^3$
- Control volume: 850 m$^3$/sec

Flood Protection Measures for Subways
1) Flood Protection Panels
2) Entrance Locks
3) Tunnel Locks
4) Automatic Ventilation Locks

* These pictures were taken from underground in the air vent, looking up to the ground surface.
Preventing urban flood by storing rain water in community

permeable tile pavement  rainwater storage in community

Provision of flood warning/information by mobile phone

Contents
- Precipitation by hyetograph
- Precipitation by radar rain gages
- Water level etc.

Information provided on the internet

Information provided to mobile phones
The assumed flood water depth is indicated using a tape.

Hazard Map on Street

Integrated Flood Management through River Basin Management Plan

Conservation of natural land
River basin measures
Damage alleviation measures

Embankment control
Maintenance of urbanization control areas
Permeable pavement

Disaster-prevention reservoirs
Facilities for rainwater storage and infiltration
Rainwater tanks

River improvement
River measures
Seepage pits

Multipurpose retarding basin
Rainwater storage and infiltration facilities for each house
Waterproof buildings

Construction of dams
Construction of drainage pump station
Establishment of evacuation warning systems

Rainwater storage in parks
Underground river
Lessons learned

- Disaster management (prevention & preparedness) requires decades of unfailing commitment and implementation. Country needs to keep solid legal, administrative and financial foundation for years to achieve this.
- Disaster prevention pays off. The challenge is, however, to convince this to the people including leaders in “normal days” when disasters are not visible and imminent. Keeping institutional memories, inter alia, is the key for success.
- “Good preparedness” in society is easy to say but extremely difficult to maintain as human being forgets. Do not fall into the pit that “preparedness” is a (cheap) panacea to ensure safety. It also has limitation of effectiveness as prevention does.

Lessons learned (continued)

- Best mix of prevention, preparedness and transfer for disaster management depends on diverse geographical, social, and financial situation of countries and communities. Step-by-step improvement learning from past disasters is shortest cut towards better disaster management.
- Transfer such as insurance is a good way for individuals and organizations to avoid “financial catastrophe” after disasters. However, transfer, per se, does not reduce disaster risks, particularly from national perspectives. Examine geographical, social, and financial situation of country/community before deciding the best mix. Geographical situation is particularly important to decide best mix for flood management.
Check list for a government when investing in disaster management

- Beware that disaster management requires years of unfailing commitment and implementation

- **Legal foundation (i.e. a system of laws for disaster management) that enables long-term planning, financing and implementation**

- **Budgetary system resilient enough to allow for stand-by budget line for “rainy days”**

- **In-house group of financial, legal and technical officials with good governance that can turn money into actual safety against disasters.**

- **Public consensus that disaster investment pays off**

- **Leaders’ awareness that good disaster governance is foundation for national security and stability**

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Thank you
Chennai Floods
Causes and Way Forward

15 June 2016

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Sources of information

• Main source of information in the following
  – Indian Institute of Technology (Madras)
  – Care Earth (NGO, Chennai)
  – Government of Tamil Nadu agencies
**Chennai Water Drainage**

- **Area of Chennai city**: 426 sq.Km
- **Population**: 8 million
- **Major Water ways**: Adyar River, Coovum River, Kosasthalaiar River, Buckingham Canal, Captain Cotton Canal, Otteri Nullah, Virugambakkam Canal, Mambalam Canal
- **Storm Water Drain Network**: 7,351 drains for a distance of 1896 km (30% roads)
- **Annual average rainfall**: 958.5mm
- **Share of NE Monsoon**: 48%

*Image of Chennai city during flood, December 2015.*
Rainfall

- Nov 2015 wettest month ever 1113.80 mm of rainfall, beating the record of 1918 when Chennai received 1088.40 mm.
- Dec 1st, 2nd rainfall of 319.60 mm recorded was highest single day rainfall in Chennai history.
- Kanchipuram and Tiruvallur districts - suburbs of Chennai - registered nearly 500 mm rain.
- Hundreds of lakes and tanks dotting the Chennai metropolitan region filled up during November rains.
- Nearly all overflowed during heavy rain during early December.
- Heavy discharge of water into Chennai’s rivers – Adyar, Cooum and Kosasthalaiar – especially as due to release from Chembarambakkam, Redhills and Poondi reservoirs.

Interesting questions and controversy

- Could the Dec floods be prevented with better management of water reservoirs?
- Was water release (or not release) cause of floods?
- Note: Chennai always has heavy rain for short periods
- Intense rain every 10 years (El Nino?)
- Intensity has increased
Chennai
Rainfall Intensity-Duration-Frequency

Intensity (mm/hr)

Duration (hrs)

T=2yr
T=5yr
T=10yr
T=25yr
T=50yr
T=100yr
Numgambakkam
Chembarambakkam
Dec.1, 2015

Chembarambakkam reservoir release

Reach “Reach-2” Results for Run “Run 1”

Flow (c m s)

0 100 200 300 400 500 600 700 800 900

26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11
Nov 2015 Dec 2015

Run Run 1 Element Reach-2 Result: Outflow
Run Run 1 Element Reach-2 Result: Combined Flow
Flooding vs water logging

- Flooding in December could not have been prevented
  - Reservoir release only small piece in entire scheme that lead to Chennai flooding
- Water logging of November can be minimized with efficient, well designed, well maintained storm drainage system
  - With restored water bodies, etc.
Causes of water logging and floods

Causes and types of urban flooding

1. Lack of drainage infrastructure
2. Backup due to elevated downstream water levels
3. Flooding in low-lying areas
4. Inundation caused by high river water levels
5. Blockage of the drainage system

Source: Urban Stormwater Management in Developing Countries, 2005
Water bodies

- Most water bodies in Chennai region encroached
  - Increases flood volume and flow magnitude
  - Compromised inlet and outlet
  - Some tanks/lakes totally disappeared
  - Balancing between lakes, reverse flow engineering etc. non existent

- Dumping of garbage
  - City has no scientific, sustainable processing

Encroachment and destruction of water bodies

Image: Birgitte Helwigh

Source: Urban Stormwater Management in Developing Countries, 2005
Storm water drains

- Insufficient coverage with storm water drains
- Lack Proper connectivity
  - Linkage to major canals and waterways
- Insufficient capacity
  - Original design intensity of 31.39 mm/h
    - 1hr storm duration and 2yr return period
    - Seems very less based on the IDF curve
      - Should have been > 50 mm/h

Data, plans – out of sync

- Outdated engineering and planning
  - Data (hydrology, road geometry, etc) not integrated
  - Roads become barriers to water flow
    - Like other encroachments like walls, buildings, etc.

- City planners unable to sync micro drain plans with macro reality and drains
  - New plot development uncoordinated with plans
Development in low lying areas

- Development also happening in low lying areas, paddy fields etc.
  - Master Plan out of sync with reality
  - No reverse engineering of canals etc. to match these developments
  - Water still flows into the low areas!

Insurance point of view

Prevention and reduction of loss
Pre and post runoff

- Runoff rate "post-development" without controls
- Runoff rate "post-development" with detention basin flood control
- Runoff rate "pre-development"
For Example

- In city Master Plan
- Hydrology and macro plans assume this water flow.
- Connecting exiting drains, water bodies.

But current property design

- Build wall
- Raise ground elevation with debris
- Quickly get rid of the water
- No coordination between macros and micro plans
- Weak development controls
Need modern Development Control Rules

- Private development needs sophisticated engineering
- Allow natural water flow
  - To avoid water logging upstream
- But retain pre-development volumes
  - To prevent overloading of drains
  - To prevent property damage

Source control
Green roof

Source control
Permeable surface

Site control
Detention basins

Source control/conveyance
Swales

Prevention/
Source control
Water butts

Source control
Permeable surface

Source control/conveyance
Underdrained swales

Regional control
Retention pond
Insurance Markets

- Insurance markets must play complementary role
  - Insurance linked to quality of design and plans of property.
  - Like fire damage and prevention system in buildings
  - Development should consider historic data
    • Architect/engineer should prove resilience of design

City, regional solutions
Solutions

• Regional macro and micros storm water
  – Flood plain modeling and mapping
  – Integration of road network with drains
    • Strict controls on re-asphalting of roads
    • Stop road height increase
  – Design drains for higher intensity (50 mm/hr)
  – Stringent maintenance
  – Implement balancing and reversal engineering

• Remove encroachments on water bodies
  – Restore connectivity drains

Solutions

• Modern development control rules
  – Property development controls
  – Prevent excess rain water discharge after development (compare pre and post dev)

• Adopt sustainable solid waste management
  – Prevent garbage and sewage in storm drains
Disaster Management System

• Current Disaster Management System weak
  – Coordination among agencies weak
• Adopt modeling and prediction
  – Rainfall, water logging, flooding models
• Implement infra and services for disaster mgt

• Robust response systems
  – Include social media to respond to disaster
  – Huge scope for using citizen help to complement govt efforts

Thank You

Chennai City Connect Foundation
www://chennaicityconnect.com