MEASURES FOR FLOOD MITIGATION

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ABSTRACT

India is highly vulnerable to floods with 12% of the land prone to floods. Flooding in the cities and the towns is a recent phenomenon caused by increasing incidence of heavy rainfall in a short period of time, indiscriminate encroachment of waterways, inadequate capacity of drains and lack of maintenance of the drainage infrastructure. Hence there is need to address the critical factors that accentuate flood risk and take necessary steps for flood prevention, preparedness and mitigation. The various measures which can be taken to minimize flood damage are briefly discussed in this paper.

Introduction

Disasters disrupt progress and destroy the hard-earned fruits of painstaking developmental efforts, often pushing nations in quest for progress, back by several decades. A disaster is a result from the combination of hazard, vulnerability and insufficient capacity or measures to reduce the potential chances of risk. A disaster happens when a hazard impacts on the vulnerable population and causes damage, causalities and disruption. Disaster Management includes disaster prevention, disaster preparedness or predisaster management, during-disaster management and post-disaster management.

India is highly vulnerable to floods and out of the total geographical area of 329 Mha, more than 40 Mha (12% of land) is flood prone. Floods are recurrent phenomenon, which cause huge loss of lives and damage to livelihood system, property, infrastructure and public utilities. It is a cause for concern that the flood related damages are showing an increasing trend. On an average every year, 75 lakh hectares of land is affected, 1600 lives are lost and the damage caused to crops, houses and public utilities is Rs. 1805 crores due to floods. The average annual flood damage during the last 10 years (1996-2005) was Rs. 4745 crore as compared to Rs. 1805 crore, the corresponding average for the last 53 years. This can be attributed to many reasons including rapid increase in population and urbanisation coupled with growing developmental and economic activities in the flood plains and global warming. Flooding in the cities and the towns is a recent phenomenon caused by increasing incidence of heavy rainfall in a short period of time, indiscriminate encroachment of waterways, inadequate capacity of drains and lack of maintenance of the drainage infrastructure. Hence there is need to address the critical factors that accentuate flood risk and take necessary steps for flood prevention, preparedness and mitigation. Flood management involves measures for flood prevention, preparedness and mitigation. Measures for flood mitigation are briefly discussed in this paper.

Floods – Causes and Effects

Inadequate capacity of the rivers to contain within their banks the high flows brought down from the upper catchment areas following heavy rainfall, leads to flooding. The tendency to occupy the flood plains has been a serious concern over the years. Because of the varying rainfall distribution, many a time, areas which are not traditionally prone to floods also experience severe inundation. Areas with poor drainage facilities get flooded by accumulation of water from heavy rainfall. Excess irrigation water applied to command areas and increase in ground water levels due to seepage from canals and irrigated fields also are factors that accentuate the problem of water-logging. The problem is exacerbated by factors such as silting of the riverbeds, reduction in the carrying capacity of river channels, erosion of beds and banks leading to changes in river courses, obstructions to flow due to landslides, synchronisation of floods in the main and tributary rivers and retardation due to tidal effects.

India can be broadly divided into the following four regions for a study of flood hazard[1].

- The Brahmaputra River Region consists of the rivers Brahmaputra and Barak and their tributaries, and covers the states of Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Tripura, Nagaland, Sikkim and the northern parts of West Bengal.

- The Ganga River Region has river Ganga with many tributaries, the important ones being Yamuna, Sone, Ghaghra, Raphti, Gandak, Burhi Gandak, Bagmati, Kamla Balan, Adhwara group of rivers, Kosi and the Mahananda. It covers the states of Uttarakhand, Uttar Pradesh, Jharkand, Bihar, south and central parts of West Bengal, Punjab, parts of Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and Delhi.

- The North-west River Region: The main rivers in this region are the Indus, Sutlej, Beas, Ravi, Chenab and Jhelum. These rivers are the tributaries of the Indus. They carry quite substantial discharges during the monsoon and also large volumes of sediment. They change their courses frequently and leave behind vast tracts of sandy waste. This region covers the states of Jammu and Kashmir, Punjab and parts of Himachal Pradesh, Haryana and Rajasthan. Compared to the Ganga and the Brahmaputra river regions, the flood problem is relatively less in this region.

- The Central India and Deccan Region: Important rivers in this region are the Narmada, Tapi, Mahanadi, Godavari, Krishna and Cauvery. These rivers have mostly well defined and stable courses. They have adequate capacities within the natural banks to carry the flood discharge except in the delta area. The lower reaches of the important rivers on the east coast have been embanked, thus largely eliminating the flood problem. However the embankments need to be raised and strengthened to latest standards to continue to provide protection against floods and erosion. This region covers the states of Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Orissa, Maharashtra, Gujarat and parts of Madhya Pradesh. The region does not have serious flood problem except that some of the rivers in Orissa State namely Mahanadi, Brahmini, Baitarni, and Subarnarekha are prone to floods every year. In addition the Andaman and Nicobar Islands and Lakshadweep have peculiar characteristics, which result in drainage congestion, flooding and erosion in coastal areas.

Flash Floods: Flash floods are characterised by very fast rise and recession of flow of small volume and high discharge, which causes high damages because of suddenness. This occurs in hilly and not too hilly regions and sloping lands where heavy rainfall and thunderstorms or cloudbursts are common. Depression and cyclonic storms in the coastal areas of Orissa, West Bengal, Andhra Pradesh, Karnataka, and Tamil Nadu also cause flash floods. Arunachal Pradesh, Assam, Orissa, Himachal Pradesh, Uttarakhand, the Western Ghats in Maharastra and Kerala are more vulnerable to flash floods caused by cloud bursts. Sudden release of waters from upstream reservoirs, breaches in landslide dams and embankments on the banks of the rivers leads to disastrous floods.

Damages Caused by Floods

Floods affect anything sited in flood plains (Fig.1) - Earth buildings or masonry with water-soluble mortar; Buildings with shallow foundations or weak resistance to lateral loads or impact; Basements or underground buildings; Utilities: sewerage, power, water supply; Machinery and electronics including industry and communications equipment; Food stocks; Cultural artifacts; Confined/penned livestock and agriculture; Fishing boats and other maritime industries.

Most floodwaters carry contaminants, such as sewage, hydrocarbons, silt, salt and other biological and chemical substances, which can affect the health of the occupants and the performance of the building. Buildings may require further cleaning or extended drying times following a flood leading to increased costs and delays in re-occupation.

Table 1 gives effect of floods in terms of loss of life in India over the years. More than the loss of life and damage to property, the sense of insecurity and fear in the minds of people living in the flood plains is a cause of great concern. The after effects of floods such as the agony of survivors, spread of epidemics, non availability of drinking water, essential commodities and medicines, loss of the dwellings etc. make floods the most feared among the natural disasters faced by mankind. Physical health may suffer if floodwater is contaminated or if the building is re-occupied before it is allowed to dry effectively. Stress caused by the disruption to lifestyle and livelihood both during and after a flood is probably one of the main consequences of a flood.

Fig.1 Flood in Chennai (2015)

Table 1 Death toll in major floods of India

Year	Number of people killed	Location
1961	2,000	North
1968	4,892	(1) Rajasthan, Gujarat (2) North-East, West Bengal, Assam
1971	1,023	North India
1978	3,800	North, Northeast
1980	1,600	Uttar Pradesh, Bihar, Gujarat, Kerala, Haryana
1989	1,591	Maharashtra, Andhra Pradesh, Gujarat
1994	2,001	Assam, Arunachal Pradesh, Jammu & Kashmir, Himachal, Punjab, Uttar Pradesh, Goa, Kerala, Gujarat
1995	1,479	Bihar, Haryana, Jammu & Kashmir, Punjab, Uttar Pradesh, West Bengal, Maharashtra
1997	1,442	Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Sikkim, Uttar Pradesh, West Bengal.
1998	1,811	Arunachal Pradesh, Assam, Bihar, Kerala, Meghalaya, Punjab, Sikkim, Uttar Pradesh, West Bengal.
2000	1,290	Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Kerala, Madhya Pradesh, Punjab, Uttar Pradesh, West Bengal.
2005	1094	Maharashtra
2008	527	Kosi , North Bihar
2009	300	Andhra Pradesh, Karnataka, Orissa, Kerala, Delhi, Maharashtra
2013	> 1000	12 out of 13 districts in Uttarakhand
2015	470	Tamil Nadu - Chennai, Tiruvallur, Kancheepuram and Cuddalore districts

Flood Preparedness Measures

Flood preparedness measures include the following aspects.

- Prevention of over-bank spilling.
- Improvement in drainage.
- Reservoir construction.

- Provisions for stabilization of flow conditions.
- Awareness on flood forecasts.
- Preparation of evacuation plan.
- Adherence to flood warnings.
- Listening to local radio station for information and following the advice and instructions. from State/District/Local administration.
- Erection of livestock shelters at a higher plane.
- Awareness on closest high ground and how to get there.
- Updating insurance.
- Land-use control planning.
- Construction of reservoirs, dams, dykes, alternate drainage sources.
- Construction of structures over stilts, and elevated flood levels.

The following activities are planned for minimizing flood and consequent losses.

Phase I - Identification and marking of flood prone areas on maps, preparation of close contour and flood vulnerability maps, formulating plans for expansion and modernisation of flood forecasting and warning systems, identification of priority flood protection and drainage improvement works, identification of reservoirs for review and modification of operation manuals and rule curves and undertaking special studies on problems of river erosion. The National Disaster Management Authority has developed vulnerability map of India for floods (Fig.2).

Phase II - Implementation of the schemes for expansion and modernisation of the flood forecasting and warning network, execution of flood protection and drainage improvement schemes, modification and adoption of revised reservoir operation manuals, enactment and enforcement of flood plain zoning regulations and planning and preparation of Detailed Project Reports (DPRs) for storage reservoirs and implementation of the schemes for real-time collection of hydrometeorological data on rivers in Nepal, Bhutan and China.

Phase III - Implementation of activities, which include construction of dams and catchment area treatment works in India as well as neighboring countries.

All floods can be assessed in terms of flood depth, speed of flow, frequency of occurrence and duration (however, not all of these data are always readily available). This information can then be used to evaluate the flood risk to people and property at a particular location. Flood risk is a combination of the probability of the flood occurring and the consequence of the flood on people, property and infrastructure.

Flood forecasting and routing simulation studies may be conducted to control flood. Past rainfall data can be used to calculate the antecedent precipitation index (API) which is a measure of the excess water. The ratio of the expected inflow into the reservoir for the next few days is calculated from the rainfall data from rain gauge stations and weather forecast. Based on the inflow of water information of reservoir levels and inflow, the computer simulation can suggest the procedure to be used for regulating release of water from the reservoirs. Computer model has been developed by Ramani for Gandhi Sagar dam[2].

Flood Mitigation Measures

The impact of floods can be considerably reduced by planning and implementation of measures to reduce the risks associated with floods and the process of planning for effective response to floods which still may occur. Main Mitigation Strategies include

- Land-use control and locations planning to avoid potential flood plain being the site of vulnerable elements,
- Engineering of structures in floodplain to withstand flood force, strong foundations, design for elevated floor levels and use of water–resistant materials and
- Seepage-resistant infrastructure.

In addition to the above, community participation is also important which includes the following aspects.

- Sedimentation clearance, dike construction.
- Awareness of flood plain.

- Farming practices to be flood-compatible.
- Awareness of deforestation.
- Living practices reflect awareness: storage and sleeping areas high off ground.
- Flood evacuation preparedness, boats and rescue equipment.

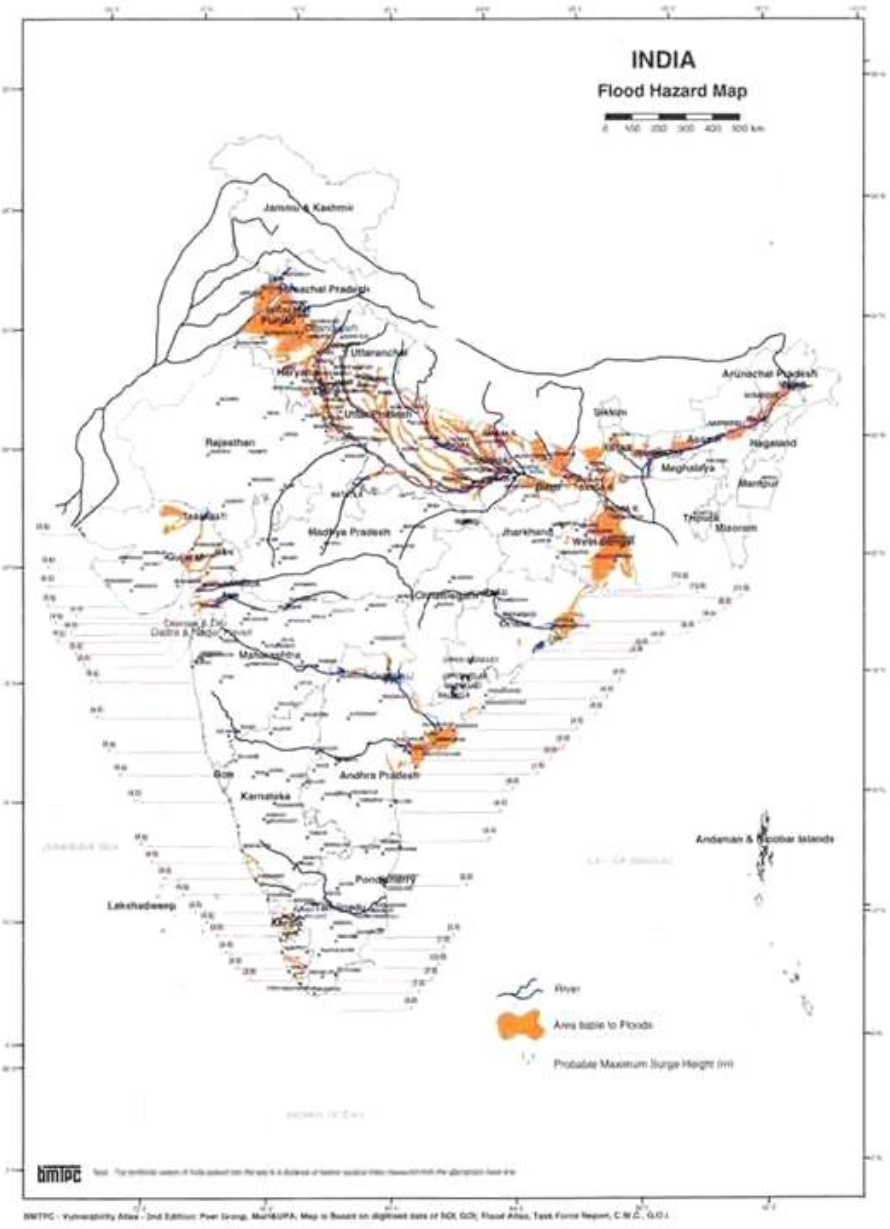

Fig.2 Flood hazard map of India

The hierarchy of design of buildings and sites is given below.

Flood avoidance: Constructing a building and its surrounds (at site level) in such a way to avoid it being flooded (e.g. by raising it above flood level, re-siting outside flood risk area etc). Avoidance measures include

- Not building in flood risk areas wherever possible.
- Raising ground or floor level or re-designing to a location outside the flood area, and provision of replacement storage.
- Local bunds can be designed to protect individual or groups of buildings from flooding. It is unlikely that these can be made fully watertight and pumps may be necessary to remove or re-direct any seepage water within the protected area. Bunds may be effective where the

predicted duration and depth of flooding is low. Advice should be sought from a Qualified Engineer/Professional to ensure the bunds can withstand predicted water pressures.

- Landscaping of a development site or building curtilage to direct or divert floodwater away from buildings can be effective particularly where the predicted duration of flooding is short i.e. Hours rather than days. Landscaping is an integral component of sustainable drainage systems. They can be designed to manage flood risk and water quality, and also environmentally acceptable to communities.
- Boundary walls and fencing could be designed with high water resistance materials and/or effective seals to minimise water penetration for low depth, short duration floods (but not for groundwater flooding).

***Flood Resistance*:** Constructing a building in such a way to prevent floodwater entering the building and damaging its fabric. Resistance measures are aimed at preventing floodwater ingress into a building; they are designed to minimise the impact of floodwaters directly affecting buildings and to give occupants more time to relocate ground floor contents. They will probably only be effective for short duration, low depth flooding i.e. less than 0.3m. They include the use of low permeability materials that reduce the rate of water ingress into a property.

***Flood Resilience*:** Constructing a building in such a way that although flood water may enter the building its impact is reduced (i.e. no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated).

***Flood repairable*:** Constructing a building in such a way that although flood water enters a building, elements that are damaged by flood water can be easily repaired or replaced. This is also a form of flood resilience.

Knowing the characteristics of a particular flood is essential when designing a building to be resilient or resistant to flooding as it enables selection of the most appropriate form of mitigation measures[3]. For example, groundwater flooding can be prolonged, and therefore appropriate basement (e.g. CIRIA[4], 1995) and floor construction design is critical. Living accommodation below ground level is not recommended for new build in flood risk areas. Some of the measures followed in U.K. are shown in Figs. 3 and 4.

Fig.3 The openings in the property wall and road on the new estate which is in a known area of flood risk, were specifically designed to convey flood flows away from the property and into temporary underground storage.

Fig.4 A swale used to deal with surface water drainage in a housing development in England.

It is possible to reduce the consequences of flooding to people and property by managing the flood risk. Flood risk should be managed in a hierarchical approach, by firstly considering developing outside flood risk areas (avoidance), secondly the use of resistance measures to prevent water from entering a building, through to use of resilient measures to reduce the impact of flood damage to a building.

The following guidelines may be useful while designing buildings in flood prone areas[5,6].

- Construction of buildings very near to the water bodies like lakes should be avoided.
- Structures shall not be built in:
  - Areas subject to flash flooding (floodwaters rise to 0.9m or more above banks in less than 2 hours).

    - Erosion-prone areas (determined by analyses) unless protected.
    - High velocity flow areas (faster than 3 m/sec) unless protected.
- Building should be founded on stable soil. Filled up and loose soil to be avoided for foundation.
- The effects of erosion and scour must be included in the calculation of actions on building foundations and other structures *in* flood hazard areas.
- The footing system design must account for instability and decrease in structural capacity associated with soil properties when wet, erosion and scour, liquefaction, and subsidence resulting from the flood actions, depending on the geotechnical characteristics of the site.
- The minimum depth of foundation is 1.5 m below natural ground level at places where there is risk of scouring due to storm surge. In other regions, it can be 1.2 m.
- The finished floor level of habitable rooms must be above the Floor Hazard Level (*FHL*). *FHL* is the flood level used to determine the height of floors in a building and represents the *defined flood level* (*DFL)* plus the *freeboard*.
- Materials used for structural purposes and located below the *FHL* must be capable of resisting damage, deterioration, corrosion or decay taking into account the likely time the material would be in contact with flood water and the likely time it would take for the material to subsequently dry out.
- Horizontal beam at plinth level or ground level should be provided. Minimum plinth height is 0.6 m.
- External walls should be designed for out of plane lateral pressures adequately by providing transverse walls or pilasters. It is necessary to reinforce the walls by means of horizontal RC bands and vertical tie members. Continuous lintel should be provided for partition walls.
- Minimum thickness of RC roof slab of M20 concrete is 100 mm. Flat RC roof is preferable to gable type roofs. This will help the occupants to go to the terrace when flood water enters the house.
- Openings should be located away from the corners by a clear distance equal to at least 1/4th of the height of the opening or 60 cm whichever is greater.
- Utilities and related equipment, other than an electrical meter for the building, must not be placed below the *FHL* unless they have been designed specifically to cope with flood water inundation.
- Electrical switches must be placed above the *FHL*.
- Ductwork, tanks, gas storage cylinders and the like must be placed above the *FHL* or designed, constructed, installed and anchored to resist all flood-related actions and other actions during the DFE(design Flood Event).

Conclusion

The various measures which can be taken to minimize flood damage are briefly discussed in this paper. Proper planning, implementation and monitoring will greatly help to prevent or reduce flood damage. Community involvement through education is also very important.

References

1. Management of floods, NDMA Guidelines, National Disaster Management Authority, India, January 2008.
2. Ramani S., How to store just enough water in Chembarambakkam reservoir, The Times of India Chennai, December 14, 2015.
3. Flood Resilient construction, Improving the flood performance of new buildings, Department of communities and local government, London, May 2007, www.communities.gov.uk
4. CIRIA (1995). Water-Resisting Basement Construction – A Guide. Report 139. Construction Industry Research and Information Association, U.K.
5. Construction of Buildings in Flood Hazard Areas, Australian Building Codes Board (ABCB), 2012.
6. Flood Resistant Design and Construction ASCE 24-05.
7. Ramachandra Murthy D.S., Principles of disaster management, SCITECH Publications (India) Pvt. Ltd., 2016, 26 pages.