Urban Flood Management

S. K. Mazumder
AICTE Emeritus Fellow and Professor of Civil Engineering
Delhi College of Engineering/Delhi Technological University
(DCE/DTU)

1.0 INTRODUCTION

Most of the civilizations in the world have come up by the side of rivers, since they are a source of water for municipal and industrial consumptions and also act as drainage channels for disposal of storm run-off and waste water. Floods occur when the inflow into a river exceeds its carrying capacity. Floods are area specific and hence the cause of floods must be investigated thoroughly before adopting flood protection measures – be it in rural or built up areas. Floods cause not only loss of life and properties; they also bring in their wake unimaginable sufferings for the people - especially those living within the flood plains. Urban flood management including flood protection and flood forecasting/ warning are of great importance to save lives and properties by adopting precautionary measures before the occurrence of floods.

In this paper some of these aspects are discussed with special emphasis on flooding of built up areas in India.

2.0 FLOOD DAMAGE

The Rashtriya Barh Ayog (RBA 1987) estimated that the total area liable to floods in India as 40 Mha. Subsequently, the extent of maximum area affected in a year by floods has been updated by XII Plan Working Group on Flood Management and Region Specific Issues as 49.815 Mha. As per data base maintained by CWC (1979), the highlights of flood damage during the period from 1953 to 2016 are given in Table 1.

Table-1 Flood Damage in India (1953-2017)

Item	Average Annual	Maximum (Year)
Area Affected (Million Hectare)	7.51	17.50 (1978)
Crop Area Affected (Million Hectare)	3.65	10.15 (1988)
Population Affected (Rupee crore)	3.29	7.045 (1978)
Human Lives Lost (Nos.)	1601	11,316 (1977)
Cattle Lost (Nos.)	92,828	6,18,248 (1979)
Houses Damaged (Nos.)	12,17,461	35,07,542 (1978)
Value of damage to crops (Rupee crore)	713.25	4,246.62 (2000)
Value of damage to house (Rupee crore)	279.86	1,307.89 (1995)
Value of damage to public utilities (Rupee crore)	825.45	5,604.46 (2001)
Value of damage to crops, houses & public utilities (Rupee crore)	1,818.56	8,864.54 (2000)

Apart from the tangible damages given above, floods result in unimaginable human miseries/ sufferings due to loss of their abodes and goods, lack of communication, water borne diseases, etc. Photos 1 and 2 illustrate the flood furies in Bihar and West Bengal after breach of flood embankments. The recent floods in Europe due to intense rainfall paralysed the life in many cities there. As a result of significant changes in weather patterns due to climatic changes, recent extreme

precipitation in different parts of the world far exceeded the design capacities of local protection infrastructures and systems – resulting in massive flooding, casualties, and economic losses. In mid-July. the German regions of Rhineland-Palatinate and North Rhine-Westphalia saw 148 litres of precipitation per square metre falling within a period of 48 hours with 154 mm of rain in 24 hours. That was 170 per cent higher than the previous record when usually that area received about 80 litres in the whole of July (Photo-3).

Floods due to cyclonic storms have been causing loss of life and properties in the coastal areas. Recently the Ratnagiri area in Maharashtra and the Sundarban areas in West Bengal. Some years ago Kedarnath town was washed out (Mazumder, 2014) resulting in instant death of about 3000 persons due to a Glacial Lake Outburst Flood (GLOF) in the Mandakini

Photo-1: Devastation in Bihar brought about by River Kosi due to Breach in Left Flood Embankment about 12 km upstream of the Kosi Barrage

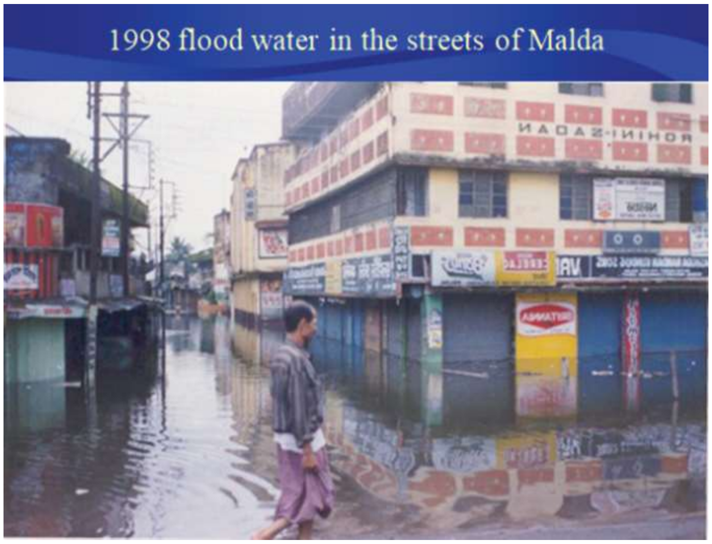

Photo-2: Flood in Malda Town due to Breach of Left Marginal Flood Embankment in River Ganga U/S of the Farakka Barrage

Photo-3: Showing flooding in Erftstadt Germany. Rhein-Erft District in July 2021

Photo-4: Washout of Kedarnath Town, Uttarakhand due to GLOF in Mandakini River in 2013

River in the year 2013 (Photo-4) .Chamoli Valley flood in the Rishiganga River in Uttarakhand (Mazumder, 2021) also caused loss of life and severe damages to hydro-power projects and roads in March 2021.

3.0 FLOOD INVESTIGATION

All floods are area specific. It is, therefore, extremely important to investigate the exact cause of the flood. The main causes of floods in India are:

(i) High intensity rainfall in a short duration

(ii) Poor or inadequate drainage/ channel capacity

(iii) Unplanned reservoir regulation

(iv) Aggradation and degradation of rivers, river meandering and river avulsion

(v) Failure of flood control structures, e.g., dams, barrages, flood embankments, etc.

(vi) Cyclonic storms in the Arabian Sea and the Bay of Bengal, and

(vii) Glacial Lake Outburst Flood (GLOF)/ Landslides/ Avalanches.

Any flood control measure without proper investigation of the cause of flood is likely to be ineffective and would be a wastage of resources apart from money.

4.0 FLOODS IN URBAN BUILT UP AREA

As already mentioned, most of the cities/ towns are built by the side of rivers/ streams principally for easy access to a water source and drainage of storm and waste waters. Intense and prolonged rainfall in the catchment area of these rivers/ streams often result in high run-off causing high flow and rise in flood level in the river/ stream. When the flood level exceeds the natural bank level, the flood waters spill over the bank and resulting in flood and consequent damage. Flood embankments are built on low level banks for protection of the cities/ towns against flood fury. Breach in the embankment is responsible for sudden and severe floods in the adjoining areas as illustrated in Photos 1 & 2. Embankments are also responsible for drainage congestion in urban areas unless properly designed gated sluices are provided to permit run-off generated in the urban catchment to drain into the river. The most affected are the poor people who live in the flood plain areas behind the embankment in the countryside.

Drainage congestion in cities/ towns occurs also due to inadequate or improper provision of the drainage system. The drainage network (mostly for flow by gravity) have to be designed such that their carrying / conveyance capacity is equal to or more than the inflow run-off at any point of the system at any point of time. Time of concentration and the corresponding rainfall intensity of design return period have to determined scientifically at all points wherever a change in section or a junction occurs since flow in drains are spatially varied. Any arbitrary method adopted to determine the design rainfall is one of the principal causes of flooding/ waterlogging in most of the urban drainage systems in India. The Guidelines for Urban Drainage (HEC-22; ASCE,92) prescribes use of rational formula (Q=0.028fPIc A) for determination of design flood discharge (Q) based on design rainfall intensity (Ic) in the catchment area (A) having run-off coefficient, P. The current practice being followed in finding design rainfall intensity is as per IRC:SP:50-2014. The design intensity being adopted in some of the metropolitan cities in India are given below:

Delhi: (i) Internal Drains: 1cusec/acre, (ii) Intercepting Drains: 0.75 cusec/acre, and
(iii) Main Drains: 0.5 cusec/acre

Mumbai: Critical intensity of rainfall: 50 mm/hour (Frequency of storms: 2times a year)

Chennai: Critical intensity of rainfall: 25mm/hour (corresponding to a duration of 1 hour with 1.25 year return period.

Rainfall intensity (Ic) corresponding to the Time of Concentration and Frequency/ Return Period should be found scientifically for computing the drainage discharge. Mazumder [2017(a)] outlined different methods of finding design rainfall intensity by Rational and other methods for computing design flood for drainage design in built up areas.

Another important aspect of drainage design is the hydraulic condition at all outfall points for mains, branches and tertiary drains. When the main drain joins a river/ stream, the drain flows freely only when the drain water level is higher than the flood level of the river/ stream. In a flat terrain, however, situation arises when the peak flood level is higher and the outfall may be submerged. Up to a given limit of submergence (also called submergence limit), drains may discharge freely. Once the submergence limit is exceeded, it is submerged flow when the co-efficient of discharge (Cd) in the flow formula (Q=Cd L H3/2 for weir type control) reduces as explained in IRC-SP-13 (2020) and Mazumder (1981). In the formula Q is flow rate, L is the effective length of weir, and H is the head above the crest. At 100% submergence, Cd is zero and hence Q=0 causing drainage congestion in the city area and water from the river would backflow into the city area. In such situations, drain water at outfall must be pumped into the river by construction of suitable sumps equipped with pumps.

5.0 URBAN FLOOD MANAGEMENT

Floods are natural phenomena except the situations which involve failure of the flood control structures or faulty regulation of reservoirs. Permanent immunity against floods is not techno-economically feasible. However, impacts of floods can be mitigated to a certain degree by adopting appropriate structural and non-structural measures as briefly discussed below. The loss of lives, property, goods, working hours and the financial as well as economic losses in the recent floods in Mumbai in Maharashtra and Sunderban areas in West Bengal could be far more than the cost of any permanent solution of flood control.

5.1 Structural Measures

Some of the structural measures of flood control are:

5.1.1 Construction of Reservoirs

Reservoirs built on rivers (e.g. Govindsagar, Hirakud, Narmada sagar, Nagarjun sagar, Panchet, etc.) help in absorption of flood and lowering of peak flood by temporarily storing water in the space between FRL and MRL(surcharge space).

In recent times it's the reservoirs that have become the cause of flooding the downstream areas because the reservoir water is let out with all gates opened. Better rainfall prediction and reservoir level monitoring and flood prediction would go a long way to minimise and even prevent such instances.

5.1.2 Detention basins/Check Dams

Dams cannot be constructed in the lower reach of a river in flood plains. However, Detention basins [Mays,2012& 1999; Mazumder,2017(b)] for temporary storage of storm water can be built at the tail end of an urban drainage system for absorption of run-off from city catchments such that the flood level of river remains unaltered before and after the development of the city as shown in Figure-1.

Besides controlling flood, such storages are useful in recharging ground water, pollution control, fish culture, recreation etc. Check dams in steep channels are found to be highly effective in reducing peak flood in urban areas.

5.1.3 Flood Embankments

As stated earlier, flood embankments are preventive measure of flood control. However, they are costly and need regular maintenance and constant vigil. Without dykes (embankments), Netherlands would be submerged, since most of it is below sea level.

5.1.4 River Improvement

All rivers especially in plains are found to meander and silt up thereby reducing the carrying capacity /conveyance of the rivers with time. River improvement works e.g. dredging, meander control works, etc. (CBIP, 1989; Mazumder, 2010; IRC-89) help in restoration of conveyance and thereby lowering of flood level in rivers flowing by the side of urban/ built up areas.

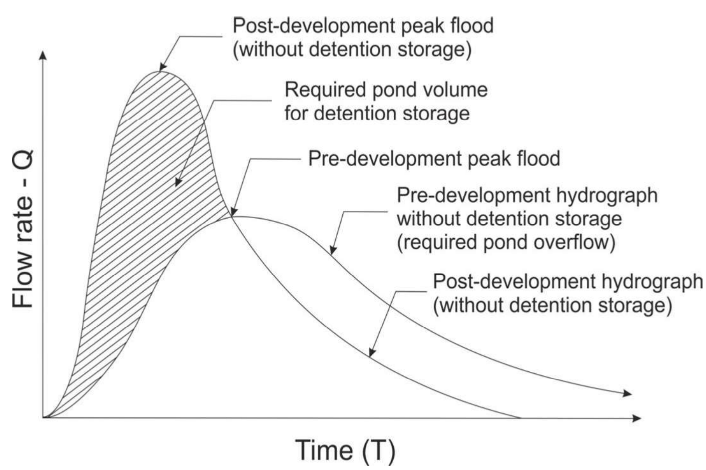

Figure-1 Illustrating Detention Storage Volume(Shaded Area)

Needed to Bring Post Development Peak Flood to Pre-Development Peak in Urban Areas

5.1.5 Drainage improvement

One of the major causes of waterlogging in built up areas is inadequate and unscientific drainage design as discussed under Section-4 above. Stormwater drainage should be separate and not combined with sewerage often resorted to for cost reduction. Apart from pollution of river water, combined drainage cause choking and loss of carrying capacity of the sewer.

5.1.6 Diversion of Flood Waters

Flood flow at any point/ stretch of a river should not exceed the carrying capacity/ conveyance of the river/ channel at that point/ stretch. Diversion of excess flow through diversion channels is effective in controlling flood and flood level. Flood in Mississippi and Missouri rivers was controlled (CWPC,1962) substantially through such flood diversion at suitable locations. NWDA, under the Ministry of Jalshakti, Government of India, proposes to interlink Indian rivers (IWRS,1996) by constructing 30 link canals connecting Indian rivers for diversion of excess flood water from surplus basins to deficient basins for food security and partial flood relief. Apart from flood relief, such flood diversions would be effective in recharge of ground water.

5.2 Non-Structural Measures

Structural measures of flood management discussed under section 6.1 are costlier compared to non-structural measures e.g. rainwater harvesting, soil and forest conservation, flood forecasting, etc. which are discussed briefly in the subsequent paragraphs.

5.2.1 Rain Water Harvesting

Surface run-off in built up areas can be substantially reduced by collection and diversion of run-off from roofs, lawns, drains in to recharge pits which helps in recharge of ground water (IRC:SP:42, 2016).

5.2.2 Soil and Forest Conservation

Erosion of soil and lack of vegetative cover in the catchments area is responsible for generation of high run-off, which causes floods in two ways. Firstly, it increases flood volume due to loss in infiltration rate and secondly the eroded soil causes sedimentation of rivers and reservoirs thus causing loss of carrying capacity/ conveyance of the river and storage capacity of the reservoirs.

5.2.3 Flood Forecasting

Loss of life and properties can be reduced substantially through flood forecast and warning ahead of the occurrence of flood event. Accuracy of forecast is extremely important to avoid inconvenience and hardships to the public. Most reliable forecast is river forecasting in which flood levels at different stations along the river are done by river gauge to gauge correlation. However, the Lead Time (the time between forecast and actual flood event at a site) is less compared to the hydrologic forecast through hydrologic modelling of the catchment. The maximum lead time is available from meteorological forecast. However, reliability of forecast is maximum in the River Forecast and least in the meteorological forecast. It is, therefore, important to use all the methods successively to improve the quality of forecast and its reliability. Flood Forecasting and Flood Warning in India was commenced in a small way in the year 1958 with the establishment of a unit in the Central Water Commission, New Delhi, for flood forecasting for the river Yamuna at Delhi. Presently, there are 878 Hydrological and Hydro-meteorological sites being operated by CWC across the country covering 20 river basins for gauge, discharge, sediment and water quality observations (Mazumder et al, 2018).

6.0 SUMMARY & CONCLUSIONS

Flood investigation is necessary for determining the cause of flood since flood management and control are area specific. Floods occur in both rural and urban India due to multiple reasons. One of the very common cause of sudden and severe flood resulting in damage to life and properties is breach of flood embankments. Although flood embankments are helpful in direct flood protection, they often result in drainage congestion in city areas due to waterlogging, unless properly designed sluices are provided under the flood embankment. Design of drainage system of adequate capacity depending on incoming flow and continuity of flow should be ensured throughout. Design rainfall intensity of given frequency and concentration time should be determined scientifically to arrive at design flow at all points of the city drainage system. Due consideration with regard to submergence should be made at all outfall points to avoid backflow. In such situations, provisions must be made for sumps and pumps to avoid waterlogging of urban areas. Flood management-both structural and non-structural -have been discussed with emphasis on non-structural ones, as they are less costly and highly effective not only in urban flood management but also for ground water recharge.

7.0 REFERENCES

1) ASCE(1992), “Design Manual for Storm Drainage”, American Soc. of Civil Engineers, New York, USA

2) CBIP (1989) “River Behaviour, Management and Training”, Central Board of Irrigation and Power, Malcha Marg, Chanakyapuri, New Delhi 7

3) CWC(1979) “Flood Estimation Reports” prepared jointly by CWC, IMD, RDSO &MORTH, Govt. of India, Pub. by Hydrology Division of Central Water Commission, Sewa Bhawan, R. K. Puram, New Delhi

4) CWPC (1962) “Flood Control Procedures and Practices in the United States”, pub. by Central Water & Power Commission, Govt. of India

5) HEC:22(2013) “Urban Drainage Design Manual” Hydraulic Engineering Circular No. 22, Third Edition Publication No. FHWA-NHI-10-009, September 2009 (Revised August 2013)

6) IRC:SP:13(2020) “Guidelines for the design of Small Bridges and Culverts”, pub. by Indian Roads Congress, Jamnagar house, Shahjahan Road, New Delhi-1, 2020

7) IRC:89 (2016)“Guidelines for Design and Construction of River Training and Control Works for Road Bridges, “The Indian Roads Congress, New Delhi

8) IRC:SP:42(2016) “Guidelines for Road Drainage” pub.by Indian Roads Congress, R. K. Puram, New Delhi

9) IRC-50 (2014) “Guidelines on Urban Drainage”-First Ed. Pub. By Indian Roads congress, R. K. Puram, New Delhi

10) IWRS, (1996) “Inter-basin transfer of water for national development-problems and Prospects”, theme paper published. on water resources day by IWRS, New Delhi

11) Mays, Lary W.(2012) “Ground and Surface water Hydrology”, Chapter-11: Hydrologic Design and Floodplain Analysis”, John Willey & Sons, Inc.

12) Mays (1999) "Hydraulic Structures Design and Construction Hand Book", Chapter-14, 'Hydraulic Design of Urban Drainage Systems' by Ben Chie Yen & A. Osman Khan, pub. McGraw Hill Book Co.

13) Mazumder, S.K.(2021), "Future of Hydro-Power Development in Himalayas post Chamoli Flood Disaster", Pub. In 'ViewPoint' Qly. J. by CEAI, June,PP.39-45

14) Mazumder, S.K., Dhillon, M.S. and Kanwal A.(2018) "River Action Plan, Flood Management & Basin Development"-Lead paper in a Souvenir "River Action Plan, Flood Management & Basin Development" published by Consulting Engineers Association of India, 27-28 July at Hotel Sangrila, New Delhi, pp.19-28

15) Mazumder, S.K. (2017a) "Computation of Flood Discharge With & Without Detention Basin", paper presented and published in the proc. of National Seminar 'Management of Storm Water Drainage System in Urban India', held on 21st January, 2017, organised jointly by Institution of Public Health Engineers, India (IPHE), Institution of Engineers India (IEI), Delhi State Centre and Indian Water Resources Society (IWRS), Roorkee at India International Center, New Delhi, pp.18-23

16) Mazumder, S.K. (2017b) "Role Of Detention and Retention Storage in Controlling Urban Flooding", paper presented in the All India Seminar on 'Urban Flood Management: Challenges and Strategies in India' held on June 16-17, 2017, organized by The Institution of Engineers (India), Delhi State Center, jointly with Institution of Public Health Engineers, India (IPHE) and Indian Water Resources Society (IWRS), Roorkee at Engineers Bhawan, New Delhi.

17) Mazumder, S. K. (2014) "Flood Damages In Kedarnath And Its Impact On Hydro-Power Development", pub. in ISH News Letter, Vol. 23, No. 1, July.

18) Mazumder, S. K. (2014) "Flood Damages In Kedarnath And Its Impact On Hydro-Power Development", pub. in ISH News Letter, Vol. 23, No. 1, July.

19) Mazumder, S. K. (2011) "Breaching of Flood Embankments with Particular Reference to Kosi &Farakka Barrages In India" paper published in the journal of 'Water and Energy International', Central Board of Irrigation and Power, Malcha Marg, Chanakyapuri, New Delhi, March,2011P

20) Mazumder, S.K. (2010) "Behaviour and Training of River near Bridges and Barrages-Some case Study"- Paper presented and pub. in the "Int. Conf on River Management-IWRM-2010" Org. by IWRS and WRDM, IIT, Roorkee and held at New Delhi, Dec.14-16

21) Mazumder, S.K. and Joshi, L.M.(1981) "Studies on Modular Limit of Critical Flow Meter" Proc of XIX Congress of IAHR held at New Delhi in 1981.

22) RBA(1987), "Rastriya Bar Ayog", A Govt. of India Publication International by Central Board of Irrigation & Power, New Delhi, March 2011

NEWS

INDIA TODAY

News/ World
China to India, floods wreak havoc across the world | See Pics

China to India, floods wreak havoc across the world | See Pics

From China to India, floods have wreaked havoc across the globe. Scroll down to see photos which show scale of devastation.

Deadly floods that have upended life in both China and ermany have sent a stark reminder that climate change is making weather more extreme across the globe.

The death toll in central China's unprecedented flash floods triggered after the heaviest rainfall in 1,000 years has reached 33 with eight people missing, officials told PTI on Thursday. Videos posted on Chinese social media showed petrified passengers trapped in subway trains clinging on to handlebars desperately waiting for help as floodwaters raised up to their necks.

In Europe, climate change is likely to increase the number of large, slow- moving storms that can linger longer in one area and deliver deluges of the kind seen in Germany and Belgium, according to a study published in the journal Geophysical Research Letters.

Torrential rain turned normally placid rivers into raging torrents in parts of Germany, Belgium and the Netherlands, dragging cars and roads with them, bringing down whole houses and leaving more than 150 people dead.

As the southwest monsoon continues to elude parts of India, it is wreaking havoc in parts of Himachal Pradesh and Uttarakhand.

Source:https://www.indiatoday.in/world/story/china-to-india-floods-wreak-havoc-across-the- world-see-pics-1831164-2021-07-22