INTRODUCTION

CHAPTER 01

Bangladesh is one of the most flood prone countries in the world which is situated in south Asian sub-continent. The country has about 130 million populations with an area of approximately **147,000 sq km**. It is one of the highly dense populated countries and every year different flood types and magnitudes occurs because of its unique topography and geographical location. At least eight extreme flood events occurred affecting about 50-70% of land area during last fifty years. Due to the floods economic loss was huge, e.g. in two consecutive floods of 1987 and 1988 flood damage was estimated at US$ 2.2 billion and in 1998 flood damage was estimated at US$ 2.8 billion. Flood management in Bangladesh is, therefore, perceived as an indispensable component of poverty reduction initiatives.

At the present time the **Ganges-Brahmaputra Delta** and its 130 million people living in Bangladesh are facing a serious challenge. While delta growth is striving to keep pace with local relative sea-level rise, the people are repeatedly confronted by natural and human-made catastrophes such as cyclones, tornadoes, earthquakes, riverbank erosion, surface and groundwater pollution, air pollution, droughts, wetland loss, coastal erosion, and floods. While some of these environmental degradations are not directly related to human activities and land-use practices (such as earthquakes, tornadoes, and cyclones), others are related to human interactions with the nature. Flooding is one such water related environmental problem magnitude of which is very much dependent on land-use practices in the watershed of each rivers or streams.

Hydrology of Bangladesh

Bangladesh has unique hydrological regime. It has been divided into 7 hydrological zones. Hydrological zones are shown in fig. 1. It has **230 nos**. rivers of which **57** are **trans-boundary Rivers**. In all most all cases Bangladesh is a lower riparian country. A picture of its river network is also given in the following

fig. Three large rivers systems e.g. **Ganges, Brahmaputra and Meghna**, in the world covering a combined total **catchments area** of about **1.7 million sq. km**. extending over *Bhutan, China, India* and *Nepal*, flow through this country. Out of these huge catchments only **7%** lies in Bangladesh. Rivers are classified into three broad categories depending on the flow range and are as follows:

i) Major Rivers: 300 to 120,000 cumec e.g *Ganges, Brahmaputra, Padma, Meghna*

ii) Semi major Rivers: 100 to 15000 cumec e.g. *Old Brahmaputra, Dhaleswari, Gorai, Arial Khan, Surma, Kushiyara, Teesta etc.*

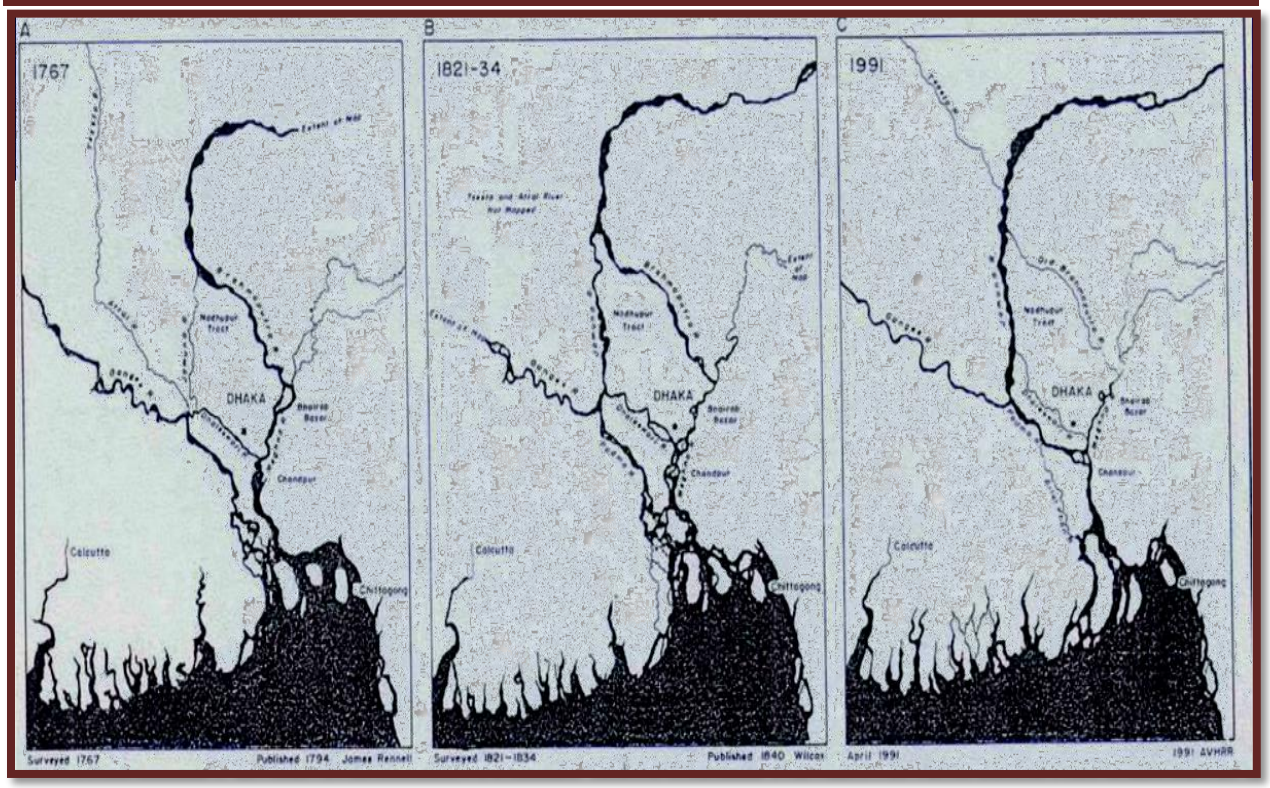
iii) Minor River: 1 to 1000 cumec e.g. *Sitalakhya, Buriganganga, Khowai, Manu, Gumti, Dharla, Dudkumar, Karnafuli, Halda, Sangu etc.*

Fig. 1. Hydrological Regions of Bangladesh

Rivers of different morphological characteristics e.g. *meander, braided, incise etc*. are found in this country. **Major rivers** having *length* of **500 to 2500 km** and *width* range from **1km to 20 km** can also be found in this country. Water surface slopes of the major rivers are also very flat e.g. *av. slope of* ***Ganges*** *is 5-6*

cm/km, av. slope of ***Brahamaputra*** *is* ***8-9 cm/km*** *and av. slope of* ***Meghna*** *is* ***4-3.5 cm/km***. **Annual flow volume** of the rivers is to the tune of **1200 billion cum**. Rivers of Bangladesh carries huge **sediment annual amount** of which is between **1.8 to 2.0 billion tons**.

Changes In The Main River Courses Of Bangladesh 1767 - 1991



Disaster

- **Disaster** is a natural or human , caused phenomenon, which causes serious disruption of the functioning of a community or a society causing widespread human, material, economic and environmental losses which elicited the ability of the affected community, society to cope using its resources.
- **Floods** are a common feature in the country that occur every year in many parts including South Asia.

Flood

- An area goes under and remains under water for some times, it is **inundation**.

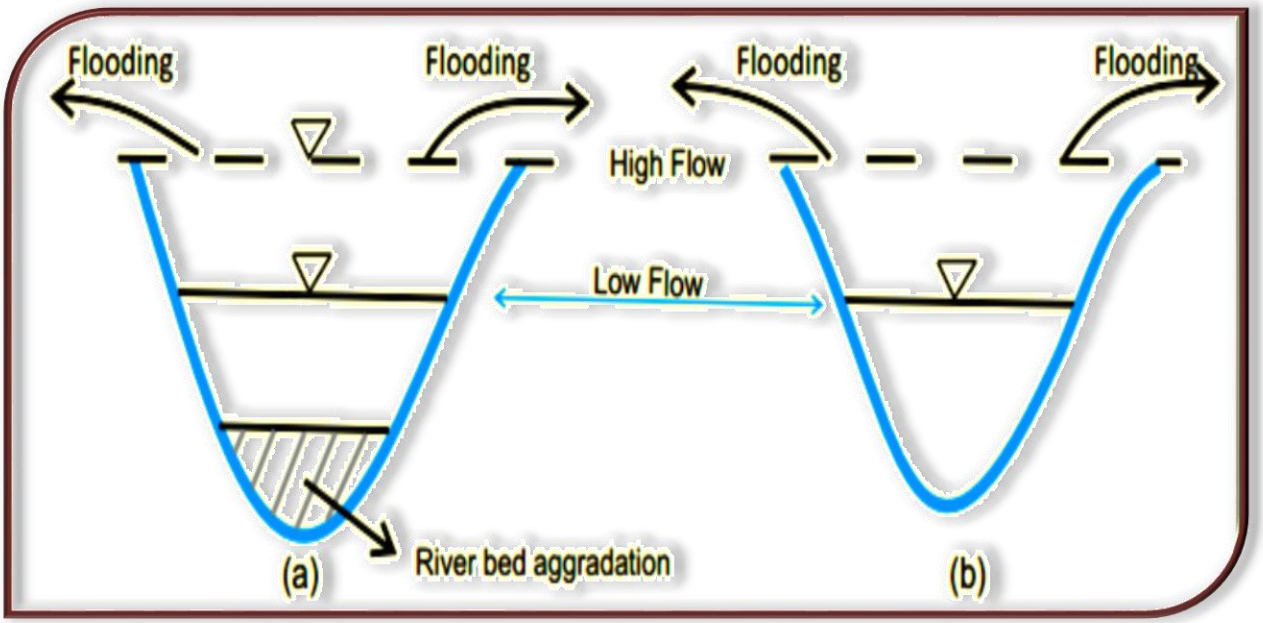
- *When inundation causes damage to property and crops, disrupts communication and brings harmful effects to human beings as well as to flora and fauna, we call it* ***flood***.
- Inundation supports fish, navigation, soil fertility, ecosystems, ground water recharge etc.

INUNDATION + DAMAGE = FLOOD

- Floods in major cities especially during rainy season are proving to disastrous not only to the environment but also have serious implications for human life and property.
- A flood occurs when the **Geomorphic Equilibrium** in the river system is disturbed because of intrinsic or extrinsic factors or when a system crosses the geomorphic threshold.

  (a) Flooding in a river due to aggradation of river bed (***intrinsic threshold***);

  (b) Flooding in a river due to heavy rainfall (***extrinsic threshold***)



Life-Threatening Characteristics of Floods

- **Absence of warning** of a flood (either 'official' warning or warning derived from cues e.g. heavy rain).
- **High floodwater velocities** (like in hilly or mountainous terrain or where stream disgorge on to plains from upland areas; in river valleys with steep

gradients; in areas behind floods embankments or natural barriers which may breach or overtop, below dams which may break).

- **Rapid speed of flood onset** (like in areas when streams are 'flashy' i.e. rise and fall rapidly; these are usually urban areas or arid rural areas where soil surface becomes compacted and hard; or in areas where high floodwater velocities are expected).
- **Deep floodwater:** where floodwater is in excess of one meter depth (occurs in or close to river channels; in depression which may not be easy to identify by eye; behind overtopped flood embankments and in basements of buildings).
- **Long duration floods** (like where land is flat, flooding is extensive; river gradients are very low, channels are obstructed, and flood water become trapped behind natural or artificial barriers).
- Flood has **more than one peak** (not atypical on complex river systems where tributaries contribute to river flows, or where flooding is tidal).
- **Debris load of floodwaters** (usually greatest in high velocity floods; floodwater may contain trees, building debris etc which may either provide floating refuge, or threaten life).
- **Characteristics of accompanying weather** (especially windy, unusually cold or hot weather).
- Flood may display combinations of characteristics!

Flood Management

- Is it 'Flood Control' or 'Flood Mitigation' or 'Flood Management?'
- Flood Management measures are aimed at reduction of damage *and harmful effects, and creation of an environment for enhanced economic activity*.
- Urban flood vs. flood in rural areas need to be treated differently.
- Total Flood Control is neither possible nor desirable.

Flood Hazard

Flood hazard *can be defined as the risk to life and limb and damage caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain.* The Floodplain Development Manual (NSW Government, 2005) describes various factors to be considered in determining the degree of hazard. These **factors** are:

I. Size of Flood;
II. Effective Warning Time;
III. Flood Readiness;
IV. Rate of Rise of Floodwaters;
V. Depth and Velocity of Floodwaters;
VI. Duration of Flooding;
VII. Evacuation problems;
VIII. Effective Flood Access; and
IX. Type of Development.

Hazard categorization based on all of the above factors is part of establishing a *Floodplain Risk Management Plan*. Provisional flood hazard is flood hazard categorized based on hydraulic principles only (*depth and velocity*). When provisional flood hazard is considered in conjunction with the above listed factors it provides a comprehensive assessment of the flood hazard, known as the "**true hazard**".

Not all of the above listed factors are applicable to all floodplains, in terms of affecting hazard definition. Similarly, the application of these factors is rarely consistent across all floodplains.

Observations about Historic Floods

Documentation of floods in terms of flood depth, area affected, damage to crops, damage to infrastructures, and number of people affected, and overall monetary damage started in **1953**. Other major recorded floods prior to **1953** took place in **1787, 1917**, and **1943**. Based on the historic records, it is obvious that the frequency, magnitude, and duration of floods have increased substantially during the last few decades. For example, all major floods covering more than **30%** of the country (total area of Bangladesh is **144,000 km^2**) occurred after **1974** only. Four floods of such great magnitude (**1974, 1987, 1988,** and **1998**) took place during the last **25** years, averaging one in every **6 years**. According to Elahi, the floods of both **1980** and **1984** covered an area more than **30%**, making the number of such floods to be 6 since **1974** (i.e. one in every 4 years). In addition, the total area covered by major floods has been steadily increasing since **1974**, with an exception of 1984 floods. The data showing the total affected area varies widely from one source to the others. The area affected by major floods has increased from **35%** in **1974 to 68%** in **1998.** Variations in data pose a problem in analyzing the findings. However, all sources of data seem to show a general trend of increased flooding propensity.

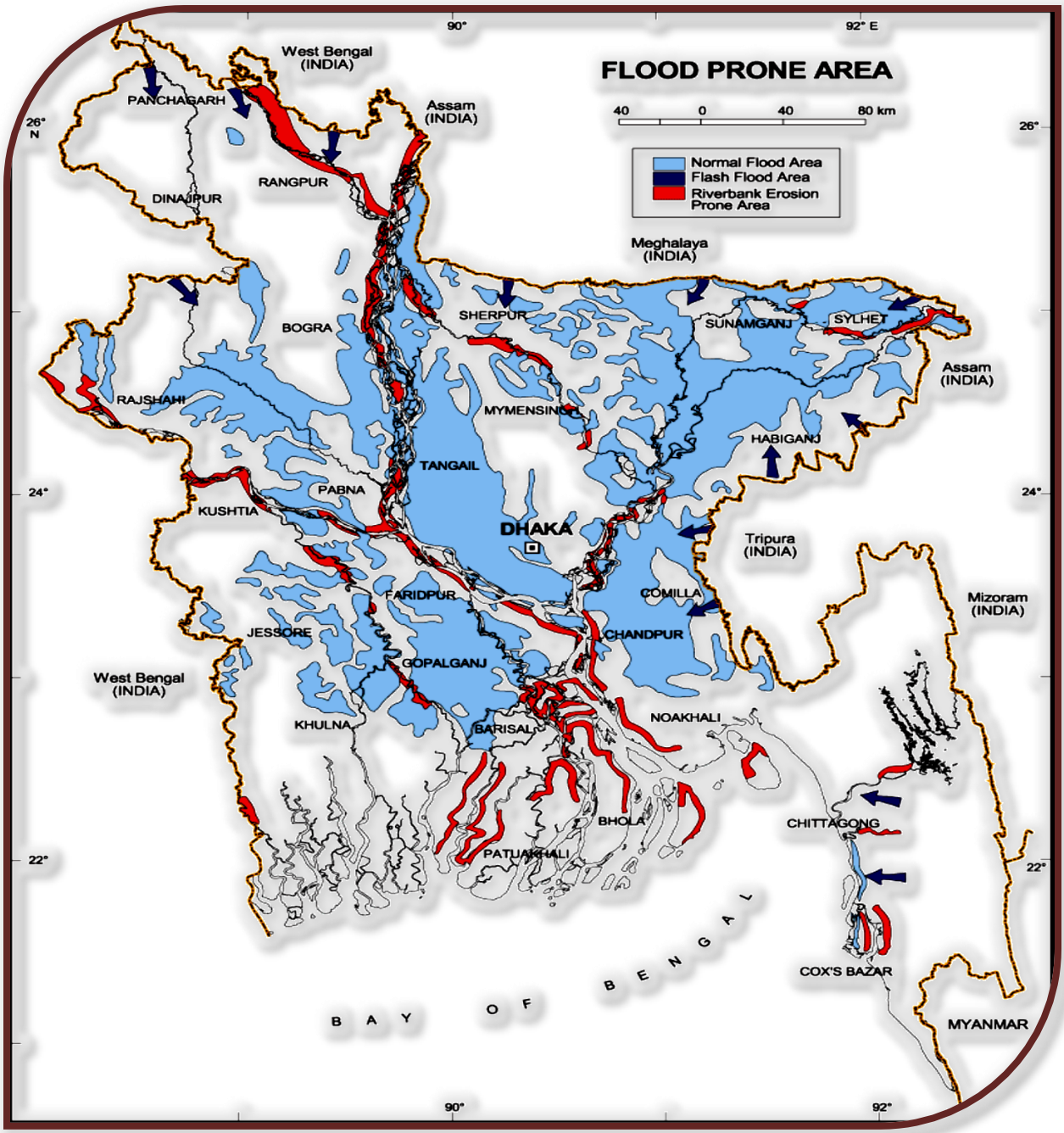


Figure 2: ***Flood Prone Area.***

TYPES & CAUSES OF FLOOD

CHAPTER 02

Types of Flood

Generally there are following types of arises in Bangladesh:

- *Rain-fed flood*
- *Flash flood*
- *Rivers' flood*
- *Flood due to cyclone*

Flash Flood

- Is a type of flood which can be described by observation of fall in water levels and by rapid water rise. It occurs during mid-April before the on-set of the south-westerly monsoon and when it occurs it can last between few minutes to few hours.
- **Flash flood** occurs mostly in the northern most area, north-central part, northeastern part and southeastern part of Bangladesh. These Northern land areas are lying mostly at foothills but most of the hilly catchments in India and if it rains heavily in the Indian parts of the catchments the run-off quickly accumulates and flow to Bangladesh causing severe flood.

Rain-Fed Flood

- This type of flood generally happens in the ***Gangetic Deltas*** in the south-western part of Bangladesh where most of natural drainage systems are being deteriorated due to fall in up-land inflow from the main river Ganges and are increasing in low-lying urban areas.
- This kind of flood also occurs in the flood plains where natural drainage systems have been disturbed either due to human interferences e.g. construction of unplanned rural roads and encroachment of river courses etc. or due to gradual decay of the natural drainage system.

- When intense rainfall takes place in those areas, the natural drainage system cannot carry the run-off generated by the storm and causes temporary inundation in many localities.
- 9 *Upazilla* of *Satkhira, Jessore* and *Khulna* district are facing rain-fed flood and severe water logging from **2000**.
- Major flood and water logging crisis occurred in **2000, 2004,** and **2011**.
- Dhaka and Chittagong city are regularly facing the urban flooding due to **rain-fed** situation. In the year **2004**, Dhaka urbanites faced a severe urban flooding that lasted for a week. In **June 2014**, Chittagong city dwellers faced flooding situation due to heavy rain.

Rivers' Flood

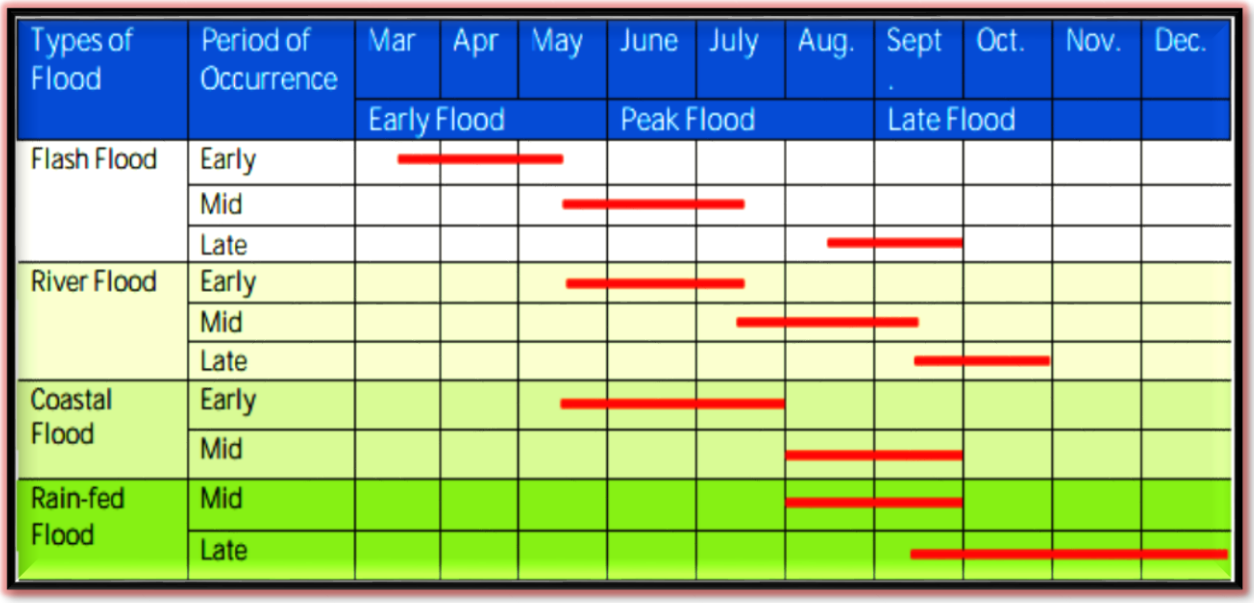
- This type of flood is mostly common in Bangladesh and it occurs during monsoon season along the river and covered **50% to 70%** of the country's land area.
- Climatologically, the discharge into Bangladesh, from upper catchments, occurs at different time of the monsoon. In the Brahmaputra maximum discharge occurs in early monsoon in June and July whereas in the Ganga maximum discharge occurs in August and September. Synchronisation of the peaks of these rivers results in devastating floods. Such incidents are not uncommon in Bangladesh.
- The rivers of Bangladesh drain about **1.76 million sq km area** of which **93%** lies outside its territory in *India, Nepal, Bhutan and China*. The annual average runoff of the cross boundary rivers is around **1200 cubic kilometres** (WARPO, 2004). All the districts of **GBM** catchment area are prone to normal flooding during the monsoon.
- The country experienced many severe floods in the past **50 years** and one of the most flood affected year was in **1998** in terms of magnitudes and during.

Flood Due To Cyclone

- In Bangladesh the coastal line of the northern part of the **Bay of Bengal** is about **800 km** and this type of flood occurs alongside the coastal area.
- The entire coastal belt is flooded when cyclone hits strongly and the approximate height of the surges is about **10 m to 15 m**, which sometimes cause great loss of lives. From **June to September** coastal areas are also subjected to tidal flooding.

- Continental shelves in this part of the **Bay of Bengal** are shallow and extend to about **20-50 km.**
- Moreover, the coastline in the eastern portion is conical and funnel like in shape. Because of these two factors, storm surges generated during any cyclonic storm which is comparatively high compared to the same kind of storm in other parts of the world. During super-cyclones (*category 5*) maximum height of the surges were found to be **10-15 meter**, which caused severe flooding in the entire coastal belt. The worst kind of such flooding occurred in last *45 years* were on **12 Nov 1970**, **29 April 1991**, and **15 November 2007** which caused loss of **300,000 , 138,000 and 3,406** human lives respectively (FFWC, 2011).
- Coastal areas are also subjected to tidal flooding during the months from **June to September** due to the southwest monsoon wind over **Bay of Bengal.**

Flood Calendar of Bangladesh



According To Their Duration Flood Can Be Divided Into Different Categories

Slow-Onset Floods

Slow Onset Floods usually last for a relatively longer period, it may last for one or more peeks, or even months.

Rapid-Onset Floods

Rapid- Onset Floods last for a relatively shorter period; they usually last for one or two days only.

Flash Floods

Flash Floods may occur within minutes or a few hours after heavy rainfall, tropical storm, failure of dams or levees or releases of ice dams. And it causes the greatest damages to society.

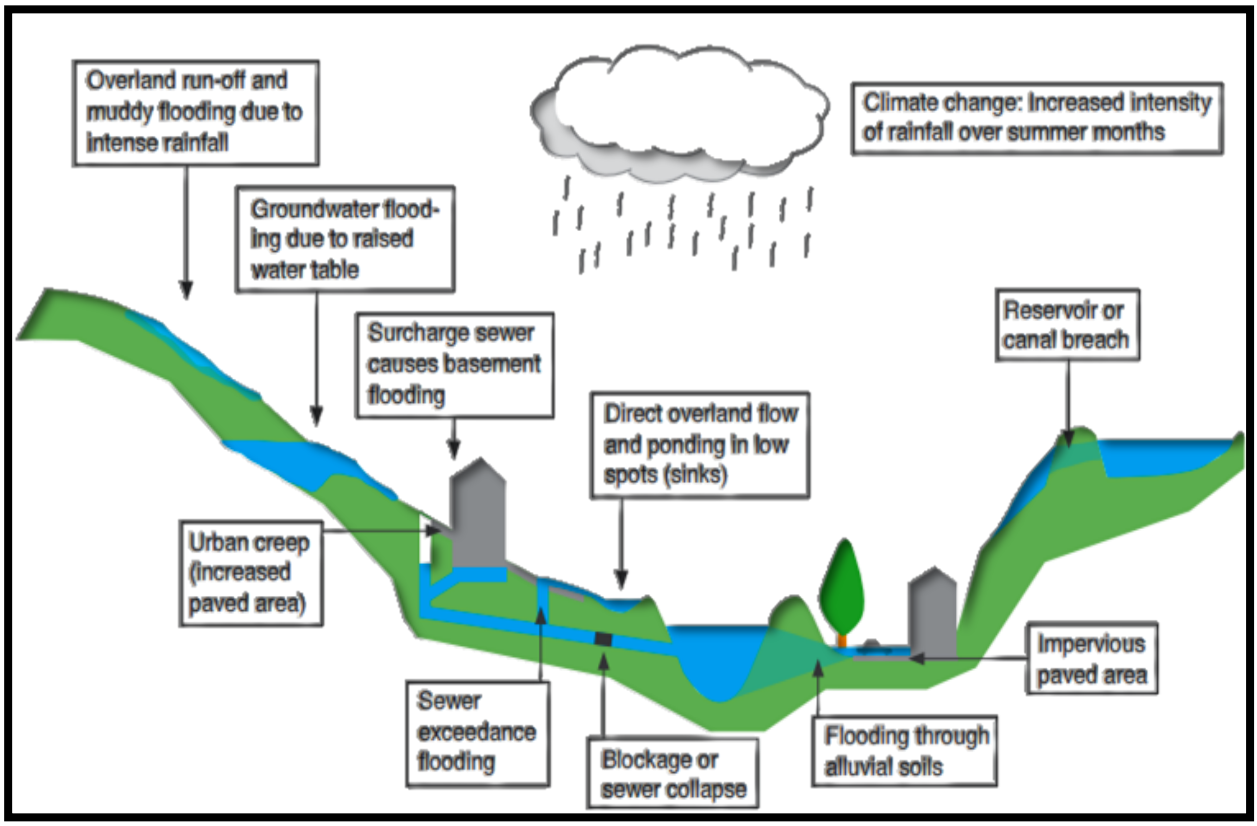


Fig.: Principal causes and types of flooding

CAUSES FOR FLOODING

There are several causes for flooding which are well demonstrated in the following:

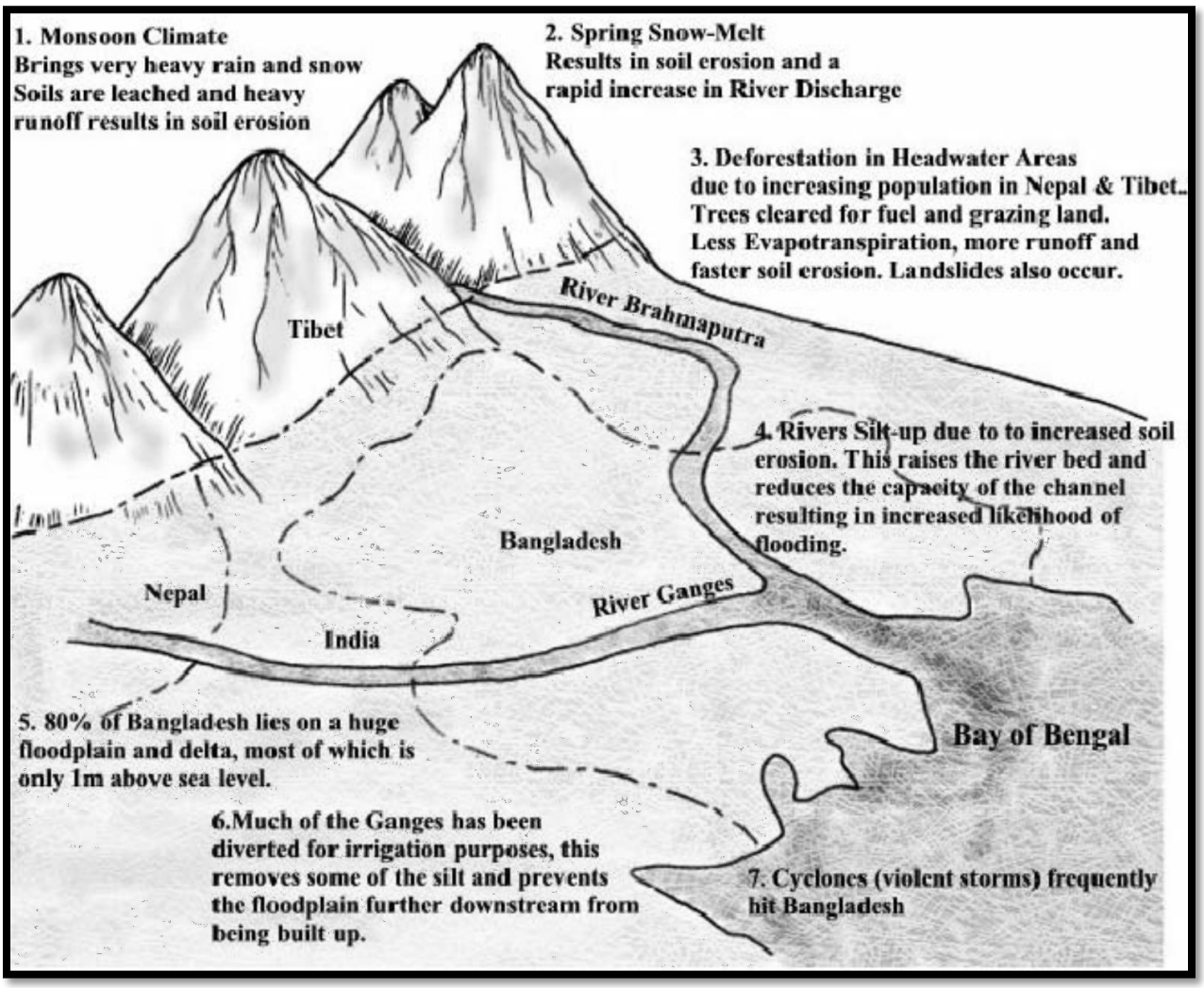


Figure: Major Reasons of Floods in Bangladesh.

Climatologically, the country has two distinct seasons, a dry season from November to May and the wet (flood) season from **June to September** (**or October**). Over 80% of the rainfall occurs during the monsoon or rainy season when flooding normally occurs. Floods in Bangladesh occur for number of reasons. The main causes are excessive precipitation, low topography and flat slope of the country; but others include:

Monsoon downpour: An increased amount of precipitation can cause flooding. An above normal monsoon downpour in the **Ganges-Brahmaputra-**

Meghna drainage system is thought to be the primary cause of the **1988** flood in Bangladesh (GOB and UNDP, 1989; Brammer, 1990).

The geographic location and climatic pattern: Bangladesh is located at the foot of the highest mountain range in the world, the Himalayas, which is also among the highest precipitation zone in the world. This rainfall is caused by the influence of the south-west monsoon. The confluence of three major rivers, the **Ganges, the Brahmaputra and the Meghna** and the runoff from their vast catchments (about **1.76 million km²**) passes through a small area. Only 7% of these catchments lie within Bangladesh. During the monsoon season the amount of water entering Bangladesh from upstream is greater than the capacity of the rivers to discharge in to the sea. Bangladesh is a land of rivers: there are about **230 major and minor rivers** in the country. Most of the rivers flow from north to south direction while some of those flow from east to west to keep a natural balance of water flow along the catchment areas. The total annual runoff of surface water flowing through the rivers of Bangladesh is about **12,000 billion cubic meters**.

Man-made environment: the construction of embankments in the upstream catchments reduces the capacity of the flood plains to store water. The unplanned and unregulated construction of roads and highways in the flood plain without adequate opening creates obstructions to flow from north to south and east to west. As a result, most of the east-west bound rivers died or dried out due to obstructed natural flow. Damming of a river reduces the velocity of water flow downstream from the dam. As a result of reduced velocity, the sediments carried by the river start to settle down faster on the riverbed, causing riverbed aggradation and in turn reducing the water carrying capacity of the river (Shalash, 1982).

The influence of tides and cyclones: the frequent development of low pressure areas and storm surges in the Bay of Bengal can impede drainage. The severity of flooding is greatest when the peak floods of the major rivers coincide with these effects.

Long term environmental and climate changes: climate changes influence the frequency and magnitude of flooding. A higher sea level will inhibit the drainage from the rivers to the sea and increase the impact of tidal surges. Deforestation in hilly catchments causes more rapid and higher runoff, and hence more intense flooding. The Springtides of the **Bay of Bengal** retards the drainage of floodwater into the sea and locally increases monsoon flooding. A rise of MSL at times during the monsoon period due to effect of monsoon winds also adversely

affect the drainage and raise the flood level along the coastal belt. The rate of local relative sea level rise is **7 mm/year** around the coastal areas of Bangladesh (Emery and Aubrey, 1990). The backwater effect caused by sea level rise can result in more flooding of land from "piled up" river water inland (Warner, 1987). This certainly seems to be one of the reasons for the increase in flood intensity in recent years in Bangladesh.

Riverbed Aggradation: Riverbed aggradation is most pronounced for the Ganges and its distributaries. From the border with India to the point where the Ganges meets the Brahmaputra River, the riverbed has aggraded as much as 5 -7 meters in recent years (Alexander, 1989b). According to a study done by Kalam and Jabbar (1991), the average width of the Ganges has decreased from 1.27 km in 1973 to 1.01 km in 1985. Riverbed aggradation is so pronounced in Bangladesh that changes in riverbed level can be observed during one's lifetime. For example, the Old Brahmaputra River was navigable for steamers only about 30 years ago, and is presently an abandoned channel. This situation is true for many other distributaries of the Ganges and Meghna Rivers, such as the Madhumati, Bhairab, Chitra, Ghorautra Rivers, etc. Riverbed aggradation reduces the water carrying capacity of rivers, causing bank overflow. This recent increase in riverbed levels has undoubtedly contributed to the increased flooding propensity in Bangladesh.

Soil erosion: Ploughing makes the land surface more susceptible to soil erosion. Surface run-off can easily wash away the topsoil from cultivated lands. This surface erosion reduces land elevations, which in turn increase flood intensity in an area. According to the Report of the Task Forces (RTF) on Bangladesh Development Strategies for the 1990s (1991), soil erosion is a serious problem in many parts of Bangladesh. Hilly areas in Sylhet, Chittagong, and Chittagong Hill Tract districts are more susceptible to soil erosion. About 55% of Chittagong Hill Tract area is highly susceptible to soil erosion (RTF, 1991). Heavy monsoon showers remove the surface soil through runoff. Eroded sediments are deposited on the riverbeds, reducing the water carrying capacity and increasing flooding propensity in a watershed. Soil erosion also reduces land elevations and increases elevations of riverbeds, contributing to increased flood depths. The land elevations in other parts of Bangladesh must have been reduced over time due to soil erosion. Aside from this, the tilling on the mountain slopes of the Himalayas is thought to be responsible for massive soil erosion in Nepal (Dregne, 1987; Thapa and Weber, 1991; Sharma, 1991), which eventually causes rapid riverbed aggradation in

Bangladesh (Alexander, 1989a). Moreover, construction sites in cities can contribute to soil erosion if silt fences or retention ponds are not employed properly (Allen, 1999). In Bangladesh, no such measures are in practice at construction sites.

Local Relative Sea Level Rise: The ultimate destination of all rivers is the ocean. The land elevation is measured with respect to sea level in an area. Therefore, any change in sea level causes land elevation to change. At the present time sea level is rising globally (Pilkey et al., 1989). If sea level rises in an area at a rate faster than the rate of land aggradation due to sedimentation, then land elevation decreases. Any decrease in land elevation can cause increased inundation by rivers overflowing at bank full stage.

Inadequate Sediment Accumulation: The only way for land to counter the effects of a rising sea is for sediment to accumulate at a rate that is sufficient to keep pace with the rate of sea level rise. Limited data show that the average sediment accumulation rate for the last few hundred years in the coastal areas of Bangladesh is **5-6 mm/year**, which is not enough to keep pace with the rising sea level (Khalequzzaman, 1989). As a result, net land elevations must have been decreasing over time, resulting in more flood inundations.

Subsidence and Compaction of Sediments: Sediments on a delta plain are rich in decomposed organic matter, and are subject to compaction due to dewatering and the weight of the overburden. Most deltas subside due to the weight of the thick sediment layer. Subsidence along with compaction reduces land elevation with respect to the rising sea level (Pilkey et al., 1989). Even though the rate of subsidence and compaction are not yet well documented, based upon our knowledge about processes active in other deltas it can be assumed that Bangladesh's delta is also undergoing subsidence and compaction.

Deforestation in the Upstream Region: A rapid increase in population in the Indian Subcontinent over the course of the present century has resulted in an acceleration of deforestation in the hills of Nepal to meet the increasing demand for food and fuel wood (Bajracharya, 1983; Ives, 1989; Sharma, 1991). Deforestation of steep slopes is assumed to lead to accelerated soil erosion and landslides during monsoon precipitations. This in turn is believed to contribute to devastating floods in the downstream regions such as in Bangladesh (Hamilton, 1987; The NY Times, 1988; Alexander, 1989a).

Specific Physical/Natural Causes of Flooding In Bangladesh

Bangladesh is a very low lying country, with 70% of its land area being less than 1m above sea level and 80% of it being floodplain.

- Bangladesh receives large amounts of water passing through it with two major rivers (the Ganges and Brahmaputra) converging and forming a huge delta (see figure 4) formed from silt deposited by the river as it enters the sea. Both rivers have large volumes of water flowing through them to the sea as they have large drainage basins which increasing the flood risk;
- The main cause was the above average and long period of heavy rain which caused all 3 rivers to have their peak flow at the same time.
- Bangladesh has a monsoon climate and the annual torrential rains which result often result in the rivers exceeding their capacity and flooding;
- In the spring, melting snow from the Himalayas further increases the flood risks as torrents of melt water enter the rivers at their source.
- Most of the country consists of a huge flood plain and delta.
- Two-thirds of the country is less than 5 meters above the sea level; and susceptible to river and rain water flooding and in low lying coastal areas, to tidal flooding during storm (MoWR, BCCSAP 2009)
- 10% of the land area is made up of Lakes and Rivers.
- Tropical storms bring heavy rains and coastal flooding.

Specific Human Causes Of Flooding In Bangladesh:

- Increasing population pressure in the foothills of the Himalayas where the rain contributes to the source of the River Ganges and Brahmaputra has resulted in intense deforestation. It is believed that this reduction in interception has resulted in more water entering the rivers - indeed with 92% of the area drained by the rivers being in countries other than Bangladesh.
- Deforestation in the headwaters is also believed to be responsible for the increased soil erosion which has led to large amount of silt being washed into the rivers and subsequently being deposited on the river bed, reducing its channel capacity and increasing the likelihood of flooding.
- Increasing population pressure in Bangladesh itself has resulted in the sinking of many new wells resulting in the lowering of the water table and the subsequent subsidence of land making it even more prone to flooding
- Urbanization and human habitation of the flood plain has increased magnitude & frequency of floods.

- Global warming is blamed for sea level rise, increased snow melt & increased rainfall in the region.
- The building of dams in trans-boundary Rivers of upper riparian countries has increased the problem of sedimentation in Bangladesh.
- Poorly maintained embankments (levees) leak & collapse in times of high discharge.