Impact of Climate Variability on Flood Management in Dhaka City

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Abstract

Impact of climate change on the flood protection of Dhaka City is presented for 2030 and 2050. Impact assessment has been done by employing hydrograph analysis and rating curves to link projected peak discharge and runoff for major rivers to the water levels in rivers surrounding Dhaka. It has been found that to provide adequate flood protection, the height of the existing embankment should be raised by 1 meter. To prevent water logging, additional pumping capacity or internal storage has to be provided.

Keywords: Climate change; Flood protection; Sea level rise; Embankment; Water logging; Drainage system

Introduction

The scientific reality of climate variability came at the forefront with the publication of the first report of the Intergovernmental Panel on Climate Change (IPCC) in 1990. Taking 1990 as the base year, the latest climate change projections indicate that the average global surface temperature may increase by 1°C to 5°C by the year 2100 leading to the change in mean precipitation and sea level rise all over the world.

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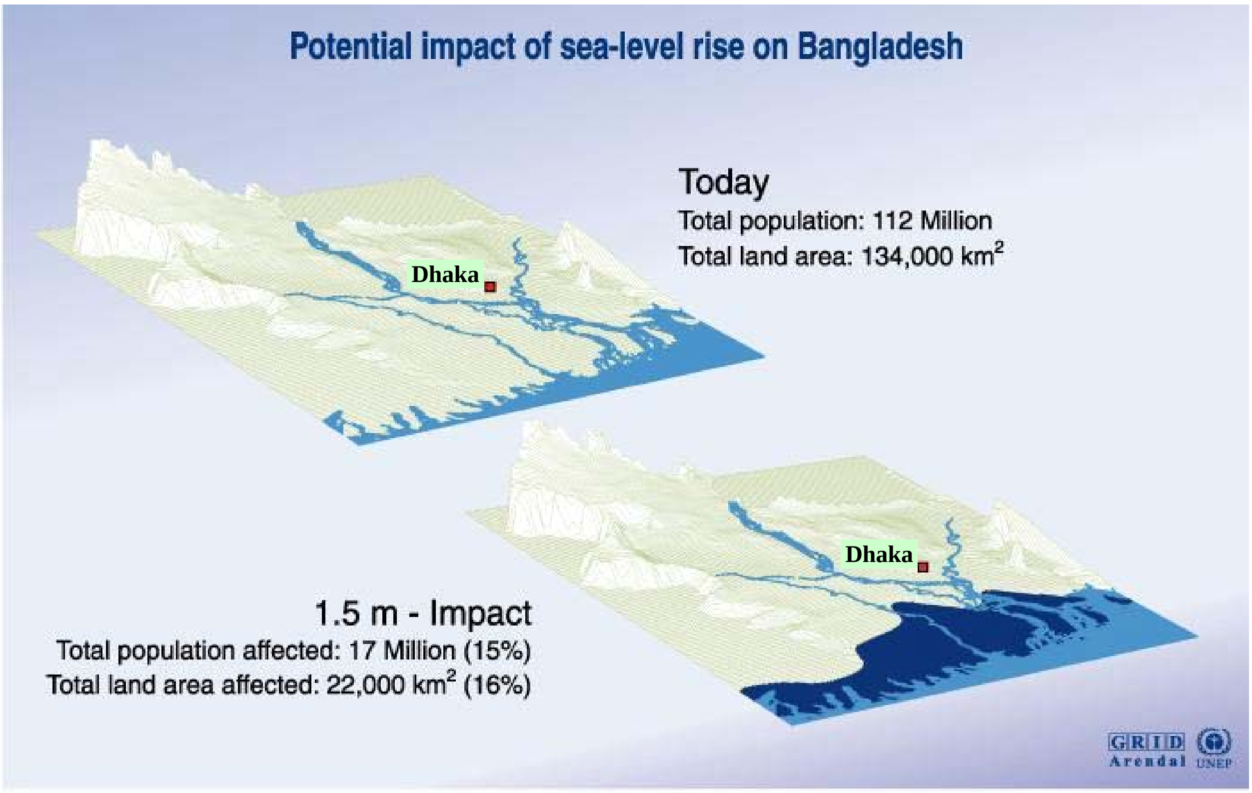
The first detailed climate scenario for South and Southeast Asia was developed by the Climate Impact Group (CIG), as part of the Asian Development Bank's 1994 regional study on global environmental issues (including climate change). This study used four general circulation models (GCMs) to make climate variability projections.

Temperature scenarios for Tropical Asia reported by CIG suggest that temperature would increase throughout most of the region, although the amount of warming is projected to be less than the global average. Warming is projected to be least in the islands and coastal areas throughout South Asia and greatest in inland continental areas, except from June to August, where reduced warming could occur. Bangladesh, being one of the South Asian Countries, will encounter impacts of such global warming due to change in temperature and precipitation accompanied by sea level rise in the Bay of Bengal (Fig. 1).



Source: UNEP/GRID Geneva, University of Dhaka, JRO Munich, The World Bank, World Resources Institute Washington DC

Fig. 1 Potential impact of sea level rise on Bangladesh

Objectives

The impact of climate variability will be felt across the country. But the nature of impact will be different in urban and rural areas. The former will face greater threat of inundation due to over-topping and possible breach of flood protection embankments, which may become further exacerbated due to internal drainage congestion. The latter will face prolonged inundation leading to substantial loss of life, property and crop. Whereas both are socially and economically important, this paper will deal with the former, with specific focus on Dhaka – the capital city of Bangladesh with more than 10 million inhabitants. Specific objectives of this paper are:

- Assess the impact of global climate change on Bangladesh in terms of major parameters that include temperature, precipitation and sea level rise;
- Relate the projected changes in these parameters to the stream flows and water levels of the rivers surrounding Dhaka City;
- Analyze the potential impacts on the flood situation in Dhaka in the years 2030 and 2050 based on the present status of flood management;
- Suggest adaptation and mitigation measures.

Methodology

In order to assess these impacts, computer simulation modeling was carried out for two projection years 2030 and 2050. The scenarios were developed by using a General Circulation Model (GCM) named GFDL 01 (Geophysical Fluid Dynamics Laboratory, 1% transient model), which assumed that the rate of forcing for global warming will be equivalent to 1 percent increment of CO_2 concentration per annum. The model allowed analysis of decadal rate of change in temperature, precipitation, and influx of solar radiation per unit area. The rates of change for these parameters were superimposed on long term trends of observed data for several weather stations within Bangladesh to develop country-specific changes in climate variables, a method which has been used earlier by Ahmed and Alam (1998). Modeling outputs were averaged for each calendar month and for the entire country.

These projected climatic parameters were used to develop flood hydrographs at three locations in the Ganges-Brahmaputra-Meghna system – Hardinge Bridge, Bahadurabad and Bhairab Bazaar according to Mirza and Dixit (1997). Rating curves at these locations were used to estimate corresponding water levels, which along with the projected sea levels, were used to derive the boundary conditions for the rivers surrounding Dhaka City. These boundary conditions, projected internal runoff from the city and existing flood protection embankments were incorporated in the scenario analysis and suggesting adaptation measures for the years 2030 and 2050.

Analyses

Climate Variability in Bangladesh

The country-specific changes in climate variables as per GFDL 01 based projections for average temperature and precipitation in Bangladesh are given in Table 1 for the years 2030 and 2050. As indicated in Table 1, excessive rainfall in the monsoon would cause flooding and drainage congestion, while there would be very little to no rainfall in the winter - therefore the country would face frequent extreme weather events.

Table 1 Projected climate change in Bangladesh (Base year: 1990)

Year	Temperature	Precipitation
2030	+ 0.7°C in monsoon + 1.3°C in winter	–3% in winter + 11% in monsoon
2050	+ 1.1°C in monsoon +1.8°C in winter	–3.7% in winter + 28% in monsoon

Projected Sea Level Rise

The southern part of Bangladesh being very active and morphology dynamic delta, it is difficult to develop a specific scenario for the net change in sea level along the coastal areas. Considering a combination of relative subsidence of the delta and rise in sea level will give an indication of net change in sea level. According to World Bank (2000), the overall change in sea level by the year 2030 will be 30 cm and by the year 2050 it will be 50cm.

The interesting aspect of net sea level change is that higher ocean stage along the river mouth will tend to generate a strong backwater effect, leading to further deceleration of draining water from the rivers. Such a possibility would have a compounding effect on flood vulnerability. Since the confluences of the GBM system is within 50~70 Km from the Bay of Bengal, it is likely that the presence of a strong backwater effect will impede recession of flood waters, thereby increasing duration of floods.

Impact on Flood Hydrographs

Kenny et al. (1998) have studied impacts of climate change on peak discharge of various rivers. In this paper, changes in peak discharge for the three largest rivers in Bangladesh have been used as shown in Table 2. It may be noted that the changes in peak discharge are relatively higher between 2050 and 2030, than between 2030 and 1990.

Table 2 Change of peak discharge in Ganges-Brahmaputra-Meghna

River	Change in Peak Discharge (m^3/s)	
	1990 to 2030	2030 to 2050
Ganges	+ 2745	+ 3708
Brahmaputra	+ 377	+ 509
Meghna	+ 793	+ 1071

In addition, Mirza and Dixit (1997) have given as estimate that a 2^0C warming combined with a 10% increase in precipitation would increase runoff in the Ganges-Brahmaputra-Meghna Rivers by 19%, 13% and 11% respectively. This, along with the projected changes in precipitation in the monsoon as shown in Table 1, has been used to calculate projected runoff volumes at three key locations on the Ganges, Brahmaputra and Meghna respectively.

The projected hydrographs have been drawn at these locations incorporating the expected peak discharge and the projected runoffs. After generating the discharge hydrograph in this way, the water level hydrographs have been drawn using appropriate rating curves. Generated discharge hydrographs at Hardinge Bridge, Bahadurabad and Bhairab Bazaar are shown in Figs. 2a, 2b and 2c. Corresponding water-level hydrographs are shown in Figs. 3a, 3b and 3c.

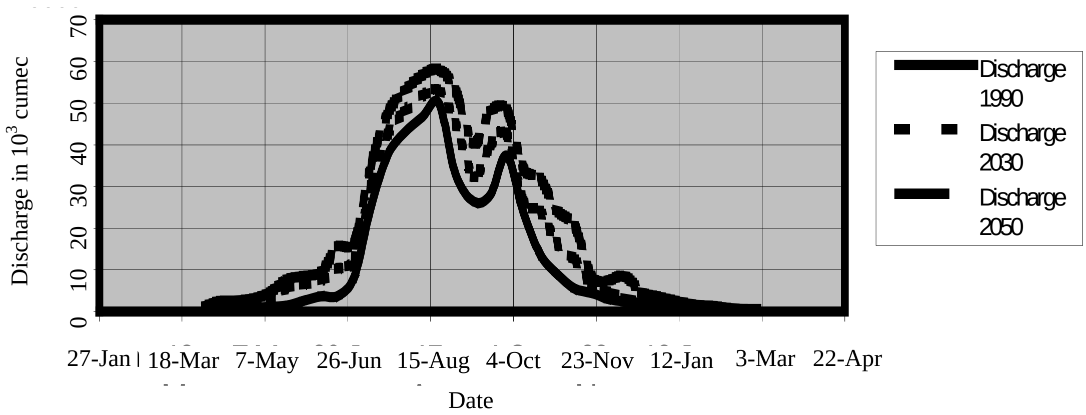


Fig. 2a Hydrograph for Ganges (at Hardinge Bridge)

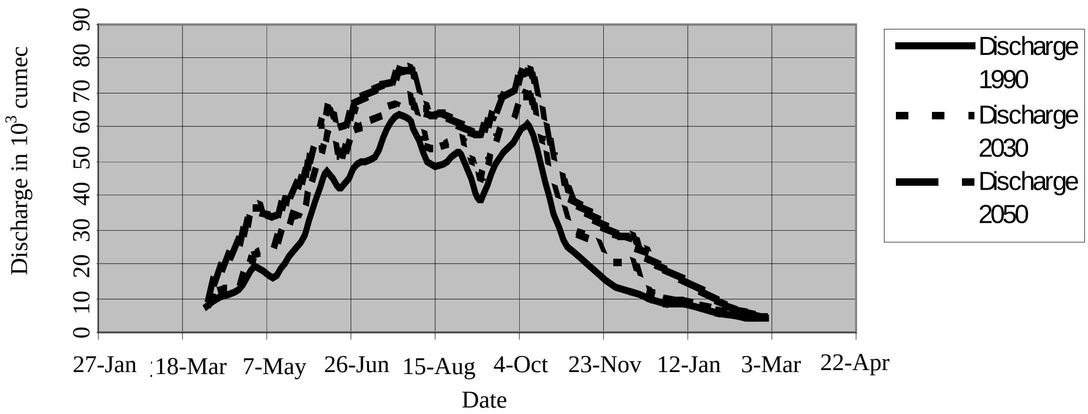


Fig. 2b Hydrograph for Brahmaputra (at Bahadurabad)

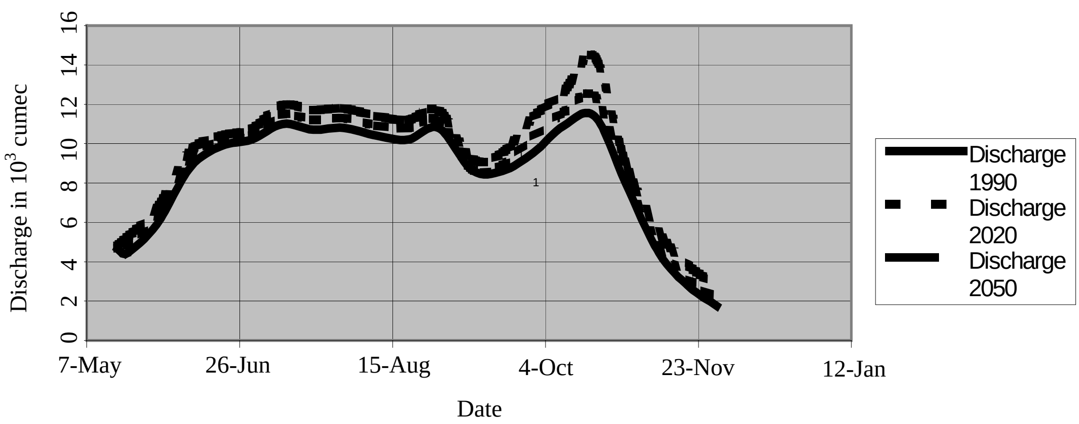


Fig. 2c Hydrograph for Meghna (at Bhairab Bazaar)

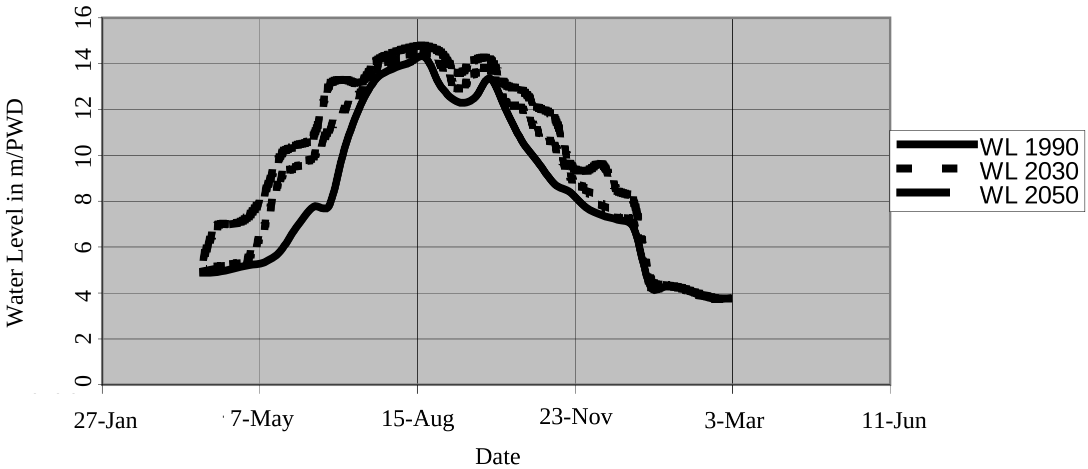


Fig. 3a Water Level Hydrograph for Ganges (at Hardinge Bridge)

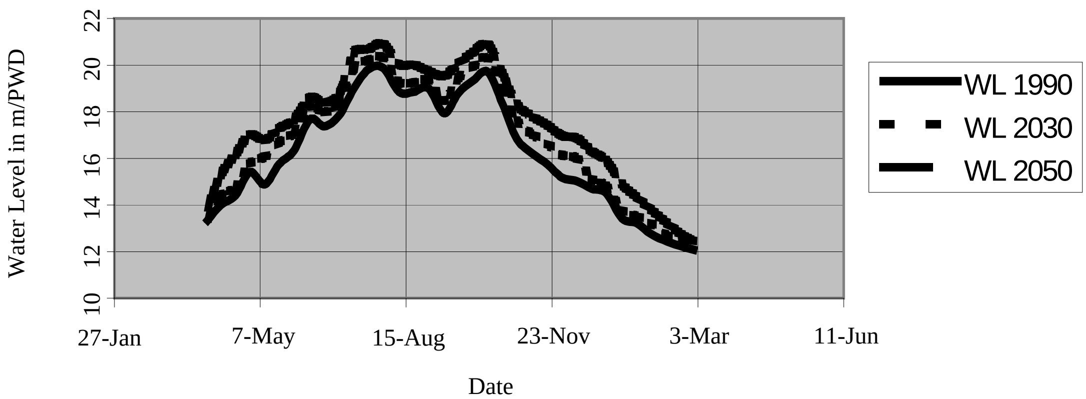


Fig. 3b Water Level Hydrograph for Brahmaputra (at Bahadurabad)

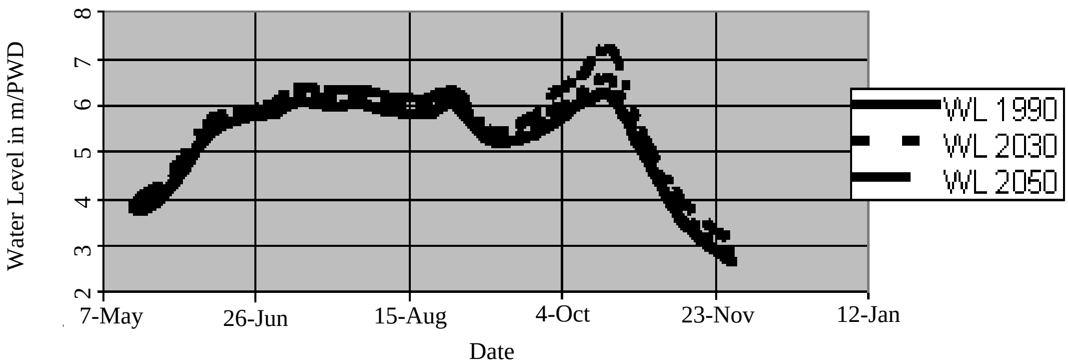


Fig. 3c Water Level Hydrograph for Meghna (at Bhairab Bazaar)

The projected discharge hydrographs show a general trend of increase in discharge in the Ganges-Brahmaputra-Meghna due to climate change for the years 2030 and 2050. The projected water level hydrographs show that the maximum water level will cross and remain above the danger level for 35 days in Hardinge Bridge, 30 days in Bahadurabad and 22 days in Bhairab Bazar respectively in the year 2030. The corresponding values for the year 2050 are 61, 66, and 38 days respectively. Compared to the flood durations at these locations in 1990, the projected flood durations in 2030 and 2050 suggest significant worsening of flood situation as summarized in Table 3.

Table 3 Percent change in flood peak and duration above danger level

Location	2030		2050	
	Peak	Duration	Peak	Duration
Hardinge bridge, Ganges	0.14	169.23	1.72	369.23
Bahadurabad, Brahmaputra	1.30	100.00	4.80	340.00
Bhairab Bazar, Meghna	18.23	144.44	23.71	322.22

Table 4 Projected peak water level for rivers surrounding Dhaka City (m-PWD)

River	1990 HFL (m)	Effect of Brahmaputra		Effect of City Runoff		Expected Water level (m)		Existing Embankment Height (m)
		2030	2050	2030	2050	2030	2050	
Buriganga	5.36	5.44	5.55	4.19	4.20	9.63	9.75	9.40
Turag	5.35	5.43	5.54	4.19	4.20	9.62	9.74	
Tongi Khal	5.33	5.41	5.52	4.19	4.20	9.60	9.72	
Balu	5.34	5.42	5.53	4.19	4.20	9.61	9.72	

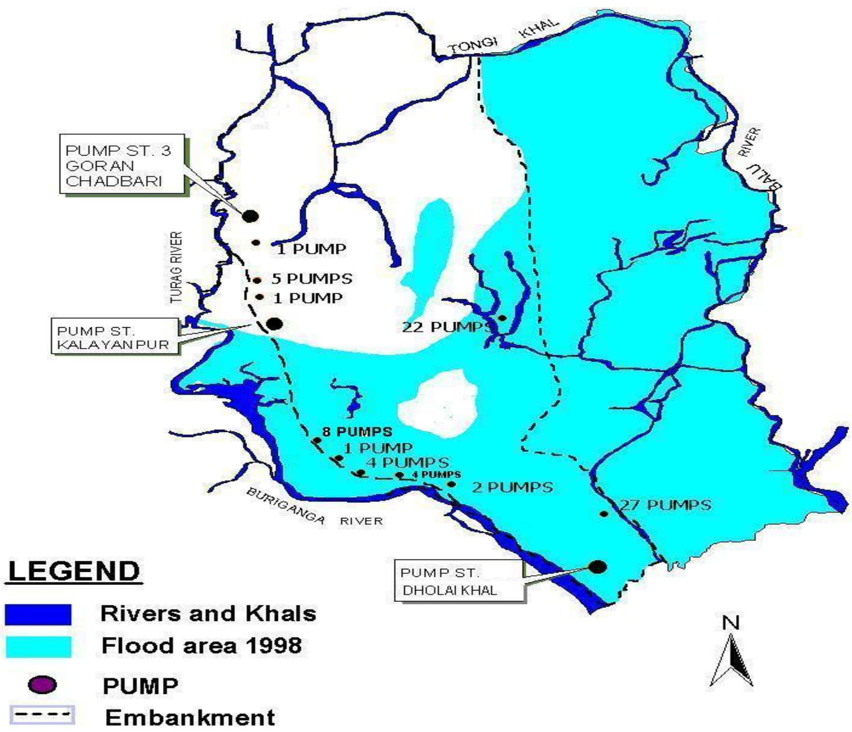


Fig. 4 Rivers and *khals* (canals) surrounding Dhaka

The combined effects of increased precipitation and increased discharge and water level in the major rivers will directly affect the Dhaka City, which is surrounded by the Turag on the west, the Buganga on the south, the Balu on the east and Tongi Khal on the north (Fig. 4). The increased discharge and water level, particularly for the river Brahmaputra, will affect the discharge and water level in the rivers surrounding Dhaka. This and the impact of the change in local rainfall around Dhaka have been used to estimate the projected water levels in the rivers surrounding Dhaka (Table 4).

Impact of Climate Change on Dhaka City

The increased river discharge and water level will cause flooding, while the expected increase of precipitation will cause water logging in the city. The average existing embankment height in the west part of the city is about 9.4 m. The projected peak water level given in Table 4 shows that in all parts of the city, floodwater will overtop the existing embankment. In the year 2030 the existing embankment height needs to be raised by 0.82 m (including a free board of 0.6 m). The corresponding value by the year 2050 is 0.95 m. In other words, to provide adequate protection against flood in 2050, height of the existing embankment will have to be raised by about 1 m.

Total capacity of the pumps used for draining runoff generated within the city is about 60 cumec. This will not be adequate to pump the increased runoff generated by the increased precipitation. Projected scenario for the runoff volumes due to rainfall inside the city for the years 2030 and 2050 are shown in Table 5.

Table 5 Projected runoff volume due to rainfall in Dhaka City

Month	Week	Rainfall 1990 (mm)	Runoff 1990 (m^3/s)	Rainfall 2030 (mm)	Runoff 2030 (m^3/s)	Rainfall 2050 (mm)	Runoff 1990 (m^3/s)
June	1	5.43	7.84	6.03	8.71	6.95	10.04
June	2	13.71	19.80	15.22	21.98	17.55	25.35
June	3	7.12	10.28	7.90	11.42	9.11	13.16
June	4	6.42	9.27	7.13	10.29	8.22	11.87
July	1	0.43	0.62	0.48	0.69	0.55	0.80
July	2	37.57	54.27	41.70	60.24	48.09	69.46
July	3	5.14	7.42	5.71	8.24	6.58	9.50
July	4	14.29	20.64	15.86	20.91	18.29	26.42
July	5	26.57	38.38	29.49	42.60	34.01	49.12
August	1	9.29	13.42	10.31	14.89	11.89	17.18
August	2	2.43	3.51	2.70	3.90	3.11	4.49
August	3	13.28	19.18	14.74	21.29	17.00	24.55
August	4	6.43	9.29	7.14	10.31	8.23	11.89
August	5	2.00	2.89	2.22	3.21	2.56	3.70

It is evident that runoff volume exceeds the existing installed pumping capacity in the second week of July, both in the years 2030 and 2050 (the flood season has been divided into 14 weekly intervals). The existing pumping capacity is 60 cumec, whereas, in the second week of July 2030 and 2050 the runoff volume will be 60.24 cumec and 69.46 cumec respectively. This runoff volume has been calculated based on 7-day average rainfall. Similar calculation was performed based on the 2-day average rainfall, which also gave similar but more critical results - runoff volume for 2030 and 2050 came out to be 105.82 cumec and 122.03 cumec respectively. Thus, the existing pumping capacity is going to fail only in one week during the monsoon based on 7-day average rainfall pattern. Since there would be episodes of intense short duration rains, the installed pumping capacity will be exceeded by internal runoff more frequently.

Adaptation and Mitigation Measures

The combined effects of increased precipitation, discharge and water level in the major rivers will directly affect the Dhaka city through external flooding and internal drainage congestion. A number of coping and mitigation measures can be envisioned to deal with this issue.

In terms of physical adaptation, it is imperative that the height of the present embankment has to be raised by about 1 meter. At the same time, this consideration has to be included in the design of the embankment for the eastern part of the city, which is supposed to be built in the near future.

In terms of drainage management, it seems that the present pumping capacity will be able to provide protection for many years with occasional failure to meet the peak demand. This aspect may be dealt with by either having a few emergency pumps stand-by for the most critical week of the monsoon, or by having increased temporary storage inside the city by creating lakes and reservoirs. This second option can be easily pursued for the presently unprotected eastern part of the city by procuring adequate lands for drainage lagoons.

In addition, a series of other structural and non-structural and institutional measures will be needed to make these major physical adaptations more effective. These may include better flood forecasting, enhancing internal drainage system and ensuring prompt inter-agency co-ordination between the agencies involved in flood and drainage management of the city.

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