Flood Control in Bangladesh through Best Management Practices

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ABSTRACT

Analysis of historic data shows that the magnitude, intensity, and duration of floods have increased in Bangladesh during the last few decades. It also appears that most of the flood control embankments experienced breaching since their completion, and are not very effective in reducing the damage to the environment, economy, and property.

It is argued that solutions to flooding problems require an understanding of the long-term factors that contribute to increased floods, which include: unplanned urbanization, soil erosion, local relative sea-level rise, inadequate sediment accumulation, subsidence and compaction of land, riverbed aggradation, and deforestation. To mitigate flooding propensity in Bangladesh, both the government and people will have to adopt watershed-scale best management practices (BMPs) – a series of activities designed to: (a) reduce the run-off, (b) increase the carrying capacity of drainage system, and (c) increase land elevations. Proposed BMPs are: floodplain zoning, planned urbanization, restoration of abundant channels, dredging of rivers and streams, increased elevations of roads and village platforms, building of efficient storm sewer systems, establishment of buffer zones along rivers, conservation tillage, controlled runoff near construction sites, adjustment of life-style and crop patterns, good governance, and improvement on flood warning/preparedness systems.

INTRODUCTION

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.

Riverine floods occur when the amount of runoff originating in a watershed (the area that collects and directs the surface runoff into the rivers, streams and lakes that drain it) exceeds the carrying capacity of natural and constructed the drainage system. Flooding can occur due to river overflow or surface runoff. There are two types of floods which occur in Bangladesh: annual floods (*barsha*) that inundate up to 20% of the land area; and low frequency floods of high magnitude that inundate more than 35% of the area (*bonna*). While the annual floods are essential and desirable for overall growth of the Bangladesh delta and the economy, the low frequency floods such as those that occurred in 1954, 1955, 1974, 1984, 1987, 1988, 1993, 1998, and 1999 are destructive and cause serious threat to lives (1, 2, 3, 4).

This paper analyzes the possible underlying causes of recent unusual riverine floods in Bangladesh in light of hydrodynamic principles that take place in watersheds and land-use practices. Other types of floods, such as local floods due to heavy rainfall, coastal floods caused by cyclones, are not considered in this study. Solutions to the flooding problems are offered in the context of watershed-scale BMPs.

OBSERVATIONS ABOUT HISTORIC FLOODS

Documentation of floods in terms of flood depth, area affected, damage to crops, damage to infrastructures, number of people affected, and overall monetary damage started in 1953 (3, 4, 5, 6). Other major recorded floods prior to 1953 took place in 1787, 1917, and 1943 (7). 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 (5, 7), the floods of both1980 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 (4). The data showing the total affected area varies widely from one source to the others (Table 1). 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.

FLOOD CONTROL MEASURES AND THE OUTCOME

Flood control measures in Bangladesh are mainly limited to building of earthen embankments, polders, and drainage. A total of 5,695 km of embankments, including 3,433 km in the coastal areas, 1695 flood control/regulating structures, and 4,310 km of drainage canals have been constructed by Bangladesh Water Development Board (8). Embankments and polders have reduced floodplain storage capacity during floods, leading an increase in water levels and discharges in many rivers (9). Embankments can also create a false sense of security among residence living within embanked areas. For example, breaching of Gumti embankment at Etbarpur during 1999 flood caused substantial damage to the environment and property. Earthen embankments can easily breach and can be damaged by riverbank erosion. Most of the embankments in Bangladesh experienced breaching and erosion more than once since their completion. The effectiveness of embankments is being questioned in other countries as well. Flood control embankments along the Mississippi River are constructed using superior engineering designs and are maintained regularly by the US Army Corps of Engineers. During the floods of 1973, 1984, and 1993 these embankments and other embankments maintained by state governments in Illinois breached at many places and proved to be ineffective as flood control measures. During the 1993 flood, some 1,082 levees, out of 1,576 levees on the Upper Mississippi and Missouri River basins were either overtopped or failed (10).

Following 1988 flood the Government of Bangladesh (GOB) has adopted a World Bank sponsored flood action plan (FAP) that calls for the construction of hundreds of kilometers of tall embankments along the great rivers of the Bangladesh delta, enormous drains, and compartments on the flood plains (11, 12, 13). The feasibility of the FAP has been criticized by numerous researchers on the basis of technical, economical, environmental, socio-political, and ecological grounds (6, 12, 13, 14, 15). Dhaka Integrated Flood Protection Embankment cum Eastern Bypass Road Multipurpose Project, which is a component of the FAP, is underway at a calculated initial coast of 24758.21 million taka. The effectiveness of such embankment as flood control measure is debatable at best.

Despite flood control measures already administered by the Government of Bangladesh (GOB), the total amount of damage to economy, crops, and infrastructures due to floods has steadily increased during the period between 1954 and 1998 (Table 2). According to Shajahan (3), overall damage to economy ranged from $600 million dollars in 1974 to $1,200 million dollars in 1988; and crop damage has varied between 0.6 million tons in 1953 and 3.2 million tons in 1988. Another study by Elahi (5) estimated the economic loss to increase from 1,500 million taka in 1954 to 4,000 million taka in 1988, with a maximum of 20,000 million taka in 1974. Islam (4) determined that the total damage to the economy had increased from1,200 million taka in 1954 to 100,000 million taka in 1998. Further more, the number of deaths, have increased from 112 in 1954 to 2,379 in 1988 (4). Elahi (5) estimated the death toll to be 28,000 and 1,600 for the floods of 1974 and 1988, respectively. Although the numbers vary somewhat, it is very clear that flood control measures did not make a significant impact in terms of reducing the flooding propensity and total damage caused by floods.

The magnitude and duration of floods have changed during the last few decades. The duration of 1998 flood was 70 days. A prolonged flooding condition prevailed throughout much of the monsoon season in 1999. The obvious question is despite all the flood control measures taken and the money spent why is the flooding propensity in Bangladesh increasing, and what can be done to reduce such damage in the future? The answers to these questions lie in understanding of the long-term factors contributing to increased frequency and duration of floods. Once the causes of the problem are determined, then preventive measures can be taken to reduce future damage caused by floods.

FACTORS CONTRIBUTING TO FLOODING PROPENSITY

Flooding propensity in an area can vary greatly with a change in the: (a) amount of runoff that results from precipitation in a watershed, (b) water carrying capacity of a drainage basin, and (c) change in land elevations with respect to riverbeds and sea level. An increase in runoff component of the hydrologic cycle in a watershed, a decrease in water carrying capacity of a drainage system, and a decrease in land elevations will increase flooding propensity in an area. Therefore, the flooding problem and the solutions to such problems can (or should) be analyzed in the context of these three fundamental parameters: runoff, water carrying capacity, and land elevations. We need to analyze landuse practices in watersheds during the last few decades that have potentials to impact hydrodynamic behaviors of rivers, affecting three vital parameters mentioned above.

Unplanned urbanization: Rapid population growth creates extra pressure on the land of already overcrowded Bangladesh. Agricultural lands give way to housing developments and roads. This rapid development and urbanization must have aggravated the flooding problem in Bangladesh. Urban population has increased from 1.81 million (4.33% of total population) in 1951 to 25.2 million in 1990 (16). According to Islam (4), current urban population is more than 30 million (25% of total population). The urban population is projected to exceed 58 million (36% of total population) by the year 2010 (16).

Unplanned urbanization can adversely impact flooding situation in a watershed. Prior to urbanization there exists a greater lag time between intense rainfall and peak stream flow. After urbanization the lag time is shortened, peak flow is greatly increased, and the total run-off is compressed into a shorter time interval, creating favorable conditions for intense flooding. For example, in a city that is totally served by storm drains, and where 60% of the land surface is covered by roads and buildings (one like Dhaka City), floods are almost six times more numerous than before urbanization (17).

Following urbanization, it is necessary to adjust drainage capacity in the watershed to take into account the “basin development factor (BDF)” in order to accommodate the extra runoff that results due to urbanization. The amount of adjustment in the carrying capacity of natural streams following urbanization depends on the degree of BDF. For an increase the amount of impervious surface by 10% in a watershed, a 23% increase in the drainage capacity by dredging or deepening of streams is suggested by Sauer et al. (18). Dhaka City is located in the watersheds of Buriganga and Sitalakha Rivers. A significant increase in the amount of impervious surface in these watersheds has taken place due to expansion of Dhaka Metropolitan area over the last few decades. However, no attempts have been taken to increase the carrying capacity of these rivers to accommodate for the BDF. To the contrary, the internal drainage system consisting of tributaries to Buriganga and Sitalakha Rivers has been diminished due to unplanned landuse practices. For instance, it is apparent from topographic maps, Dhanmondi Lake and Baridhara Lake are remnants of tributaries of Bugiganga-Sitalakha Rivers. Also, filling up of Dholaikhali chnnel has also reduced the runoff capacity from Dhaka City. The lack of an efficient storm sewer system in Dhaka City also contributes to the reduction of water carrying capacity, causing water-logging throughout monsoon season. According to the reports published in national newspapers, Dhaka City has experienced serious water-logging problems during the wet months of July to October in 1999.

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 (19). According to a study done by Kalam and Jabbar (20), 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 must have 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 (16), 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 (16). Heavy monsoon shower removes the surface soil through runoff. Parts of 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 (21, 22, 23), which eventually causes rapid riverbed aggradation in Bangladesh (24). Moreover, construction sites in cities can contribute to soil erosion if silt fences or retention ponds are not employed properly (25). In Bangladesh, no such measures are in practice at construction sites.

Deforestation in the upstream region: A rapid increase in population in the Indian Subcontinent over the course of the 20th century has resulted in an acceleration of deforestation in the hills of Nepal to meet the increasing demands for food and fuel wood (23). Deforestation of steep slopes is assumed to lead to accelerated soil erosion and landslides during monsoon precipitation, which in turn is believed to contribute to devastating floods in the downstream regions such as in Bangladesh. Deforestation within Bangladesh also contributes to the soil erosion. The amount of forest cover in Bangladesh has been reduced from 15.6% in 1973 to 14.6% in 1985-86, and eventually to13.4% in 1987 (16).). A minimum of 25% forest cover is suggested for a healthy ecosystem. The amount of forest cover in Bangladesh at the present time believed to be less than 10%.

Local relative sea-level rise: The ultimate destination of all rivers is the ocean. The land elevations are measured with respect to the sea level in an area. Therefore, any change in the sea level causes land elevations to change as well. At the present time the sea level is rising globally (26). If the sea-level rises in an area at rates faster than the rates of land aggradation due to sedimentation, then land elevations decreases over time. Any decrease in land elevations can cause increased inundation by rivers overflowing at bankfull stage. The rate of local relative sea-level rise is 7 mm/year in the coastal areas of Bangladesh (27). According to another study by Das (28), the local relative sea level at Chittagong Port has increased by as much as 25 cm between 1944 and 1964. The relative sea level in the Bay of Bengal is predicted to rise 83 to 153 cm by the year 2050 (15). An increase in the sea level raises the base level of rivers, which in turn reduces the gradients of river flow. As a consequence, the amount of river discharge decreases, creating a backwater effect further inland. The backwater effect caused by sea-level rise can result in more flooding of lands from "piled up" river water inland. This certainly seems to be one of the reasons for the increase in flood intensity in recent years in Bangladesh.

Inadequate sediment accumulation: A delta can prograde if sediment accumulation rates are greater than the rates of local relative sea-level rise. Limited data shows that the average sediment accumulation rates in the coastal areas of Bangladesh is 5-6 mm/year for the last few hundred years, which is not enough to keep pace with the rising sea level at 7mm/year (29). As a result, land elevations must have been decreasing over time in Bangladesh, resulting in more flooding inundation.

Subsidence and compaction of sediments: Sediments on a delta plain are rich in decomposed organic matters, and are subject to compaction due to dewatering and sediment weights. Most deltas subside due to the weight sediments, and due to overdraft of groundwater. Subsidence and compaction reduce land elevations with respect to sea level (26). No direct measurements of subsidence or compaction are known for Bangladesh. However, the groundwater table in Dhaka City has had a considerable lowering by as much as 9 to 12 meters over the last 3 decades. Experience in other countries indicate that it needs at least 9 meters of permanent lowering of groundwater table to cause 30 cm of land subsidence (16). Therefore, it is likely that land elevations in many parts of Dhaka City have been lowered by up to 30 cm, contributing to increased flood depth.

BEST MANAGEMENT PRACTICES AS FLOOD CONTROL MEASURES:

Flooding is a natural phenomenon, which cannot be prevented. Complete flood control is not in the interests of most Bangladeshi farmers (30). The flood control measures and policies should be directed to mitigation of flood damage, rather than flood prevention. Resources should be allocated to help people adopt a life style that is conformable to their natural environment (31, 32). Indigenous solutions through changing the housing structures and crop patterns can help reduce flood damage (33, 34, 35). Moreover, good governance, appropriate environmental laws, acts and ordinances will be necessary to achieve sustainable economic development and to reduce any environmental degradation (36). In addition, implementation of an improved real-time flood and drought control warning system can reduce damage caused by floods.

A greater understanding of the processes that contribute to increased flooding propensity, however, can help us mitigate the adverse effects on human lives, environment, and economy. To mitigate flooding propensity in Bangladesh, both the GOB and the people will have to shift their paradigms, as well as will have to adopt BMPs in agriculture, forestry, landuse planning, water resources management, and urbanization (14, 37). The BMPs pertaining to flood control are those activities that will help reduce the run-off, will increase the carrying capacity of drainage system, and will increase land elevations with respect to sea level or riverbeds (Allen, 1999). Table 3 summarizes the BMPs and the expected effects on mitigation of flooding problems in Bangladesh.

CONCLUSIONS:

Formulating solutions to flooding problems requires a comprehensive understanding of the geologic settings of the region, and a better knowledge of hydrodynamic processes that are active in watersheds. Only solutions that take into account the underlying long-term factors contributing to flooding problems can prevail. Such contributing factors are as follows: unplanned urbanization, soil erosion, local relative sea-level rise, inadequate sediment accumulation, subsidence and compaction of sediments, riverbed aggradation, and deforestation.

Structural solutions, such as the building of embankments along the rivers and polders in coastal regions in Bangladesh, will not solve the flooding problems, but will result in many adverse environmental, hydrologic, economic, ecological, and geologic consequences. Solutions to flooding problems can be achieved by adopting and exercising watershed-scale best management practices that include: floodplain zoning, planned urbanization, restoration of abundant channels and lakes, dredging rivers and streams, increased elevation of roads and village platforms, efficient storm sewer systems, establishing buffer zones along rivers, conservation tillage, controlled runoff at construction sites, good governance, indigenous adjustment of life-style and crop patterns, and improvement on flood warning/preparedness systems.

Since Bangladesh is a small part of a larger hydrodynamic system that comprises several countries in the region, mutual understanding and cooperation among the co-riparian countries will be necessary to formulate any long-term and permanent solutions to the flooding problems.

REFERENCES:

1. Chowdhury, A.M.R., 1988, The 1987 flood in Bangladesh: an estimate of damage in twelve villages. Disasters, v. 12(4), p. 294-300.
2. Brammer, H., 1989, Monitoring the evidence of the greenhouse effects and its impacts on Bangladesh. In Moudud, H. (ed.) Proceedings of the Conference on the Greenhouse Effects and Coastal Area of Bangladesh.
3. Shahjahan, M., 1998, Flood disaster management in deltaic plain integrated with rural development. . In, Ali, M. A., Hoque, M. M., Rahman, R., and Rashid, S., 1998 (eds), Bangladesh Floods – Views from Home and Abroad: Dhaka, United Press Limited, p. 39-54.
4. Islam, N., 1999, Flood'98 and the future of urban settlements in Bangladesh: Center for Urban Studies, Dhaka, 19 pp.
5. Elahi, K. M., 1992, Flood hazard and the approaches to flood management in Bangladesh. In Elahi, K. M., Sharif, A. H. M. R., and Kalam, A. K. M. A. (eds), Bangladesh: Geography, Environment and Development: Dhaka, Bangladesh National geographic Association, 53-69.
6. Hughes, R., Adnan, S., and Dalal-Clayton, B., 1994, Floodplains or Flood Plans? International Institute for Environmenta and Development, London, and Research & Advosory Services, Dhaka, 94 pp.
7. Elahi, K. M., 1991, Riverbank erosion, flood hazard and population displacement in Bangladesh: An overview. In Elahi, K. M., Ahmed, K. S., and Mafizuddin, M. (eds), Riverbank erosion, flood hazard and population displacement in Bangladesh. Dhaka, Riverbank Erosion Impact Study (REIS), 364 pp.
8. Rahman, M. R. and Chowdhury, J. U., 1998, Impacts of flood control projects in Bangladesh. In, Ali, M. A., Hoque, M. M., Rahman, R., and Rashid, S., 1998 (eds), Bangladesh Floods – Views from Home and Abroad: Dhaka, United Press Limited, p. 55-66.
9. Chowdhury, J., 1998, Some hydraulic aspects of floods in Bangladesh and their implications in planning. In Ali, M. A., Hoque, M. M., Rahman, R., and Rashid, S., 1998 (eds), Bangladesh Floods – Views from Home and Abroad: Dhaka, United Press Limited, p. 209-17.
10. Bhowmik, N., 1998, Hydrologic and hydraulic aspects of the 1993 flood on the Upper Mississippi and Missouri Rivers in the USA. In Ali, M. A., Hoque, M. M., Rahman, R., and Rashid, S., 1998 (eds), Bangladesh Floods – Views from Home and Abroad: Dhaka, United Press Limited, p. 137-60.
11. GOB (Government of Bangladesh) and UNDP (United Nations Development Programs), 1989, A Flood Policy for Bangladesh: Mott MacDonald International, Cambridge, England, 6 pp.
12. Boyce, J. K., 1990, Birth of a Megaproject: Political Economy of Flood control in Bangladesh. Environmental Management, vol. 14, no. 4, p. 419-428.
13. World Bank (WB), 1990, Flood Control in Bangladesh – A Plan for Action, Technical Report Number 119, 92 pp.
14. Khalequzzaman, Md., 1994, Recent floods in Bangladesh: Possible causes and solutions. Natural Hazards, v. 9, p. 65-80.

15. Anwar, J., 1993, Bangladesh: The State of the Environment. Dhaka, Coastal Area Resources Development and management Association (CARDMA), 188 pp.
16. Report of the Task Forces (RTF) on Bangladesh Development Strategies for the 1990s – Environment Policy (Volume Four), 1991: Dhaka, University Press Limited, 265 pp.
17. Pipkin, B. W. and Cunnings, D., 1983. Environmental Geology - Practical Exercises: Belmont, California, Star Publishing Company, 215 pp.
18. Sauer, V. B., Thomas, Jr., W. O., Stricker, V. A., and Wilson, K. V., 1983, Flood characteristics of urban watersheds in the United States, U.S. Geological Survey Water Supply Paper 2207, 63 p.
19. Alexander, D., 1989, Consequences of floods in developing countries: international perspectives for disaster management. In the proceedings of the International Seminar on Bangladesh Floods: Regional and Global Environmental Perspectives, March 4-6, 1989, Dhaka, 11 pp.
20. Kalam, M. A. and Jabbar, M. A., 1991, River course monitoring of the Ganges at Godagari, Rajshahi using remote sensing techniques. In Elahi, K. M., Ahmed, K. S., and Mafizuddin, M. (eds), Riverbank Erosion, Flood and Population Displacement in Bangladesh: Dhaka, REIS-JU, p. 73-85.
21. Dregne, H. E., 1987, Soil erosion: Causes and effect. Land Use Policy, v. 6, p. 412-418.
22. Thapa, G. B. and Weber, K. E., 1991, Soil Erosion in Developing Countries: A Politicoeconomic Explanation. Environmental Management, v. 15, no. 4, p. 461-473.
23. Sharma, C.K., 1991, Energy and Environment in Nepal. Ambio, v. XX, no. 3-4, p. 120-123.
24. Alexander, D., 1989, The case of Bangladesh. University of Massachussetts, Amherst, 15 pp.
25. Allen, J. F., 1999, Georgia's Best Management Practices for Forestry. Georgia Forestry Commission, Atlanta, USA, 68 pp.
26. Pilkey, O.H., Morton, R.A., Kelley, J.T., and Penland, S., 1989, Coastal Land Loss - Short Course in Geology, v. 2, 28th International Geologic Congress: Washington, DC, American Geophysical Union, 73 pp.
27. Emery, K. O., and Aubrey, D. G., 1989, The Gauges of India. Journal of Coastal Research, vol. 5, no. 3, p. 489-501.
28. Das, S. C., 1992, Physical oceanography of the Bay of Bengal. In Elahi, K. M., Sharif, A. H. M. R., and Kalam, A. K. M. A. (eds), Bangladesh: Geography, Environment and Development: Dhaka, Bangladesh National geographic Association, p. 36-52.
29. Khalequzzaman, Md., 1989, Environmental hazards in the coastal areas of Bangladesh: a geologic approach (summary). In, S. Ferraras and G. Pararas-Carayannis (eds.), Natural and Man-Made Hazards, Proceedings of the International Conference on Natural and Man-Made Coastal Hazards, Ensenada, Mexico, p. 37-42.
30. Haque, C. E., and Zaman, M. Q., 1993, Human response to riverive hazards in Bangladesh: A proposal for sustainable floodplain development. World Development, v. 21(1), p. 217-29.
31. Alexander, D., 1998, Flood and drought perception: A review and comparative cultural perspective. In Ali, M. A., Hoque, M. M., Rahman, R., and Rashid, S., 1998 (eds), Bangladesh Floods – Views from Home and Abroad: Dhaka, United Press Limited, p. 161-82.

32. Islam, N., 1999, Flood control in Bangladesh: Which way now? Journal of Social Studies, Center for Social Studies, Dhaka, v. 83, p. 1-31.
33. Rashid, H. and Paul, B.K., 1987, Flood problems in Bangladesh: is there any indigenous solution? : Environmental Management, v. 11, no., 2, p. 155-173.
34. Islam, N., 1990, Let the Delta be a Delta – An essay in dissent on the flood problem of Bangladesh. Journal of Social Studies, Center for Social Studies, Dhaka, p. 18-41.
35. Islam, A., 1998, Alternative strategies for flood hazard mitigation programme in Bangladesh: Floodplain management approach. In, Ali, M. A., Hoque, M. M., Rahman, R., and Rashid, S., 1998 (eds), Bangladesh Floods – Views from Home and Abroad: Dhaka, United Press Limited, p. 85-100.
36. Alauddin, M. and Hasan, S., 1999, Development-governance-environment nexus: views, perspectives and issues. In, Alauddin, M. and Hasan, S. (eds), Development, Governance and the Environment in South Asia – A Focus on Bangladesh: London, Macmillan Press Ltd., p. 1-16.
37. Khalequzzaman, Md., 1999, Environmental philosophy in the context of Bangladesh. Weekly Holiday, Dhaka, July 30 issue.

Table 1: Area affected by floods 1953-1998. Total area of Bangladesh is 144,000 km^2. Years for which flood affected area exceeded 50,000 km^2 are shown in **boldface**.

Year	Area affected by floods (km^2)		
	Elahi (7)	**Shahjahan (3)**	**Islam (4)**
1953		27,000	
1954		37,000	36,920
1955		40,000	**50,000**
1956		36,000	35,620
1962		37,000	37,440
1963		35,000	43,180
1964		10,000	
1966		33,000	
1968		37,000	37,300
1969		41,000	
1970		42,000	42,640
1971		36,000	36,475
1972		21,000	
1973		29,000	
1974	**90,650**	**52,000**	**52,720**
1975		17,000	
1976		28,000	
1980	**64,750**	35,000	
1981		12,000	
1982		23,000	
1983		11,000	
1984	**64,750**	48,000	28,314
1985		22,000	
1986		18,000	
1987	**88,000**	**60,000**	**57,491**
1988	**98,000**	**98,000**	**77,700**
1998			**84,000**

Table 2: History of breaching and erosion in major flood control embankment projects. Data modified from Rahman and Chowdhury (8), and Islam (4)**.** Years for which flood affected area exceeded 50,000 km^2 (>35% of the country's area) are shown in **boldface**.

Year of completion	Embankment project	No. of years of breaching	Erosion	Flood damage (in million taka)
1953				
1954				1,200
1955				1,290
1956				900
1962				560
1963	Gumti	5 (* including in 1999)	continuous	580
1964				
1966				
1968	Brahmaputra Embankment	9	continuous	1,160
1969				
1970				1,100
1971				
1972				
1973				
1974				28,490
1975				
1976	Hatiya	2	continuous	
1978	Alfadanga	2	once	
1980	Chandpur Sari-Gowain	0 2	none none	
1981				
1982	Teesta	5	continuous	
1983	Ganges-Kobdak Manu	1 2	none continuous	
1984	N'ganj-Narsindi	2	none	4,500
1985	Karnafuli	1	none	
1986				
1987	Chenchury Muhuri	3 0	twice none	35,000
1988	Salta-Bagda	0	none	100,000
1998 ongoing	Chalan Beel	3	none	100,000

Table 3. List of BMPs and their effects on mitigation of flooding.

BMPs	**Expected effects on mitigation of flooding**
Dredging rivers and streams	Increase carrying capacity of drainage
Re-excavation of abandoned channels, ponds, and lakes	Increase carrying capacity of drainage; reduce run-off
Dispersal of dredged/excavated sediments on land	Increase elevations of earthen roads and village platforms
Conservation tillage	Reduce soil erosion and run-off
Establishment of vegetated buffer zone along rivers and streams	Reduce soil erosion, run-off, and bank erosion
Silt fence around construction sites	Reduce soil erosion and run-off
Sediment and run-off detention ponds in construction sites	Reduce soil erosion and run-off
Removal of coastal polders	Increase land elevations by tidal inundation
Efficient storm sewer system in cities	Increasing carrying capacity and reduce water-logging in cities
Planned urbanization and compact township	Reduce impervious surface and run-off
Watershed-scale landuse planning	Reduce run-off, soil erosion, and impervious surface; sustainable economic developments
Reforestation programs	Reduce run-off and soil erosion
Good governance, self-reliance, and implementation of environmental acts	Implementation of BMPs to mitigate flooding problems; sustainability in economy and environment
Integrated regional water resources development plan for Ganges-Brahmaputra-Meghna Basin in Indian Subcontinent	Flood/drought control; optimal uses of natural resources in the region; sustainable environment and development