I

INTRODUCTION: THE FLOOD PROBLEM AND HUMAN RESPONSES

Bangladesh regularly experiences various types of natural hazards including cyclone-generated coastal floods, river floods, riverbank erosion, tropical cyclones, and droughts. The socioeconomic impact of riverine hazards in the region is more extensive and devastating relative to other types of hazards. With a per capita GNP of only around US $160, Bangladesh ranks as one of the poorest countries in the world. The average national population density has surpassed 800 persons per sq. km., and many parts of rural Bangladesh significantly exceed this density. Because of the predominance of subsistence agriculture, Bangladesh is one of the most intensively cultivated areas in the world, often supporting in excess of 12 persons per hectare of arable land. While the demographic and socio-economic setting is already precarious, the high vulnerability of most of the country to abnormal natural events such as cyclones and floods adds to the insecurity and risks faced by the majority of the population. For example, 13 tropical cyclones struck coastal areas between 1960 and 1970; the cyclone and related storm surge of November, 1970, caused a death-toll of more than 300,000 lives. Historical records show that there were at least six major floods in the 19th century and there have been 14 so far this century. While the most devastating flood on record occurred during the late monsoon of 1988, other catastrophic flooding occurred in 1954, 1955, 1977, and 1987. The direct impacts of severe floods can be disastrous and the casualties high; even the moderately severe floods of 1974 caused over two thousand deaths. The indirect impacts of floods can be even greater; the 1974 flood was followed by a devastating famine which caused more than 30,000 deaths. The 1988 flood inundated 66,360 sq. kms. or about 46 percent of the country. While several thousand people become homeless during a normal flood season, during the 1988 flood, more than 45 million were uprooted and over two thousand died. The disruptions and havoc caused by such periodic large scale disasters are lasting and the process of reconstruction is slow and expensive.[1]

Bangladesh lies at the confluence of three of the world's mightiest rivers -- the Ganges, the Brahmaputra, and the Meghna. The watershed of these rivers, commonly known as the Eastern Water basin, occupies 1,758,000 sq. kms. of the Himalayas and their neighboring regions. Although only about 8.2 percent of this watershed lies within Bangladesh, almost all of their discharges pass across the low lying deltaic plain of

Bangladesh. Except for the tertiary hills of the Chittagong Hill Tracts and Sylhet, the elevation of the country is very low, averaging only between five to six meters above sea level. Thus, during the annual season of 'normal' precipitation from June to October (i.e., the monsoon period from June to October), some 25,000 to 40,000 sq. kms. of the country is regularly flooded. This implies that about one-quarter of Bangladesh experiences a regular annual flood. Such normal annual flooding is a desirable event since it commences at the right time for cultivation, lasts for an appropriate duration for paddy rice and other major crops, and is of a limited severity which the local conditions of settlement and housing, agriculture, and physical infrastructure can normally withstand. For centuries, this annual event has played a vital role in maintaining the high fertility of cultivable land and thereby supporting an expanding sedentary population in this region. Over time, people of the region have also developed numerous adaptive strategies to reap the benefit from this regular event. Floodplain users' concerns are therefore focussed only on abnormal floods which surpass their adjustment ability and may have devastating effects both on their lives and resources.

Although the history of deliberate human responses to cope with the threat of abnormal floods in the region goes back to the early development of civilization in the Indus Valley, large scale institutional efforts commenced only four decades ago. Since the Partition of India and Pakistan in 1947, public demand for formulating effective policy measures to mitigate abnormal floods and other riverine hazards grew rapidly. Such a growing concern was reflected in various governmental actions undertaken since the 1950s in the area of water sector planning and flood mitigation. Following the severe flood of 1955, the then government of Pakistan sought advice from United Nations Technical Mission on flood prevention strategies. On the basis of the Krug Mission Report of 1956, a project planning, implementing, and monitoring agency was created in 1959. The name of this new agency was East Pakistan Water and Power Development Authority (EPWAPDA). A massive construction work of riverbank and coastal embankment began under the auspices of the EPWAPDA, and the guidance of the Krug Mission. Similarly, after the 1962 floods, reports of the two United Nations consultants (i.e., the Hardin Report of 1963 and Thijsee Report of 1964) examined the alternative options of flood control and recommended various types of large-scale engineering construction for confining flood-waters within the main channels of large rivers. These measures included embankment construction, channel improvement by dredging, river training and cut-off, and construction of by-passes or flood-ways and were embodied in the Master Plan of the EPWAPDA, 1964.[2]

The 1988 floods received widespread coverage from the international media resulting in a swift reaction by the international community in addressing the immediate relief requirements. The international community also provided technical assistance to help formulate longer-term solutions to Bangladesh's chronic flood problems. The World Bank, the United Nations Development Programme (UNDP), national donor agencies from the United States, France and Japan, in collaboration with the Bangladesh government, commissioned a series of flood studies. The resulting reports have proffered an array of viewpoints; the most dramatic and costly proposals were made by a French engineering consortium which recommended the construction of 3,350 kms. of high embankments to *prevent* abnormal flooding. It is estimated that such a project will cost US $10 billion to put in place and have an annual maintenance cost in the range of US $200-$600 million; they would also take some 20 years to construct (see Bingham, 1989).

A careful consideration of the socio-economic and socio-cultural characteristics, as well as realistic alternatives that might be employed, causes one to seriously question the viability of expensive "technological-fix" strategies. In recent years, academics and policy makers have arduously debated the question of whether solutions lie primarily in the prevention of floods through *structural* (mega-engineering) measures or whether there should be a much greater emphasis in the development and implementation of *non-structural* measures that mitigate the impacts of floods. The central purpose of this paper is to critically evaluate some of the elements of this debate within the context of the 1988 catastrophic flood, and to determine the major limitations and potentials proffered by the two paradigms. In order to shed light on some of the alternatives to implementing *'la grande'* engineering schemes, an attempt is made here to outline the nature and potential of indigenous adjustment and coping strategies made by residents of flood prone areas. This paper is organized in the following way. The following section reviews the causes and physical characteristics of the devastating 1988 flood. The third section reviews the aspects of flood loss and damage. The fourth section analyses the human response strategies, focusing on the engineering-structural measures and the indigenous flood prevention and flood-loss mitigation measures. Finally, some policy issues concerning hazard prevention policy, environmental impact, and sustainable floodplain development and management are discussed.

II
CAUSES OF THE 1988 FLOOD: HUMAN ACTIVITIES VERSUS MOTHER NATURE

The research literature supports the contention that floods in Bangladesh result primarily from snow-melt in the high Himalayas and in their adjoining drainage basins; localized precipitation contributes mainly to to the inundation of the many basins contained within the deltaic plain. Nevertheless, three major thrusts are adopted in explaining abnormal floods in Bangladesh. The first of these, and the one which has become widely cited in the popular media, is that which attributes abnormal floods to the impact of increasing human interference with the natural ecosystem. In particular, deforestation in the upper catchment areas of mountainous regions is blamed for the floods. International development agencies such as, the World Bank, the United Nations Development Program (UNDP), as well as much of the Western media, argue that the rapid elimination of all accessible forest cover in Nepal is accelerating direct run-off of precipitation and is reducing stream flow during the subsequent dry season. It is maintained that this process results, in turn, in rapid siltation of river beds and concomitantly increases the frequency of high flooding in the rivers' lower reaches. However, several recent studies , based upon longitudinal observation, have questioned these assertions. For an example, Ives and Messerli (1989) and Hamilton (1987) have suggested that deforestation in the Himalayas could not have anywhere near as significant an impact on the floods in the furthest downstream zone of the Bengal Basin as is generally purported; they also argue that the terraced cultivation that replaces the forests prevents excessive soil erosion in the mountainous region (also see Ives, 1989). Also, based upon an analysis of rainfall data, both Miah (1989) and Islam (1989) established that the bulk (i.e., some 90 percent) of the 1988 floodwater originated from areas adjacent to the Bangladesh border rather than from the upper reaches of the watershed in Nepal and China. Such data lend support to the proposition that deforestation in Nepal was not a dominant cause of the 1988 flood.

A second argument also blames human activity for increased frequency of high floods. It is asserted that embankments, dykes, and other flood-related engineering schemes along the upstream reaches of the rivers reduce the basins' storage capacity which leads to higher flood peaks and a steeper rise in downstream water level. In support of this viewpoint, several of the national newspapers and political parties in Bangladesh have claimed that India's opening of the Farakka Barrage on the Ganges at the height of the monsoon flow was the prime cause of the 1988 floods (Bangladesh Observer, 1988, New Nation, 1988). While some studies produced by the International Engineering Company

(IECO, 1977), did show that there was a substantial reduction in the winter flow in the lower distributaries of the Ganges, no scientific evidence has hitherto been produced which links the effect of the Barrage with high floods during the monsoon (also see Crow, 1981)

We would like to propose that that a third assertion, based upon an analysis of meteorological and hydrological characteristics of the region, provides the most plausible explanation of the 1988 floods. In general, floods in Bangladesh are a product of both the excess runoff through the drainage basin and the hydraulic characteristics of the river channels. Precipitation in the upper catchment areas of all the major rivers flowing through Bangladesh ranks among the highest in the world.[3] When such copious rainfall occurs simultaneously and for a protracted period over several tributary systems, the combined runoff translates into high flood levels in the main channels downstream. An analysis of rainfall during July-September, 1988, reveals that the flood that year was caused by a combination of exceptionally high monsoon rainfall in the northern and eastern zones of the Eastern Water basin and a rare coincidence of the peak flows of the Ganges and the Brahmaputra. Normally, the interval between the flood peak of the Brahmaputra at Serajganj and the Ganges at Hardinge Bridge is about four weeks (see Figure 1a). Even in some of the abnormal flood years of 1954, 1974, and 1987, flood peak intervals of 30, 27, and 34 days, respectively, were experienced. In 1988, however, the interval was less than three days (Figure 1b). Even when water levels between normal flood years and extreme flood are compared, an interval of between three to four weeks appear to be the normal condition (Table 1). Moreover, between June 1 and August 23, 1988, 50 percent more water flowed into Bangladesh through the channels of the Brahmaputra compared with the same period in 1987. Consequently, out of 34 hydrological stations along the river, 10 recorded flood peaks higher than at any previously recorded time and 22 recorded peaks higher than during the 1987 flood.

In addition to the high precipitation and the coincident flood peaks, Islam (1989) has demonstrated that the back-water effect of spring tides in the large estuaries of southern Bangladesh added to the severity of the 1988 floods. He suggests that "... due to the new moon coming in conjunction with the solar eclipse on September 11, 1988", the coastal water inflated and blocked the passage of flood water downstream". This resulted in both the extensive spread of floodwaters across the flood plain as well as in the prolongation of flood period.

[INSERT TABLE 1 HERE]

III
IMPACT OF FLOODS: MAGNITUDE OF LOSS AND DAMAGE

Unavailability of systematic time series data on flood damage and loss in Bangladesh precludes us from drawing any clear inference on this issue. It is, however, possible to review the generalized trend and the extent of flood effects from a number of independent studies. It has been reported that although the recent floods are not physically different than many previous occurrences (Rogers *et al.*, 1989), the degree of economic losses and vulnerability of population has dramatically increased in recent decades. This trend is primarily attributed, first, to the increased proneness of majority of the population by perpetual impoverization and marginalization, and second, to the growth of tangible resources such as, crops, and physical infrastructure of roads, railways, buildings, factories, electrical networks in riverine floodplain areas that are more liable to natural hazards.

Based on data compiled from various sources, Table 2 shows the magnitude of major flood damages during the last two decades. It appears that the total seasonal loss of rice production, which is the staple crop of the country, was above one million tons in each of the catastrophic flood years. Also, more than 200,000 tons were lost in each of the other severe flood years. In 1988 alone, the worst flood year of this century, the estimated loss of material damage exceeded US $2 billion (UNDP, 1989). According to the report of the Bangladesh Red Cross, more than 45 million people were directly affected. Among them, more than two thousand lost their lives. More than 172,000 livestock were lost, and 7.3 million houses were fully or partially damaged. Besides such immense loss of agricultural components, the growing physical infrastructure was also severely damaged due to the 1988 floods; about 900 bridges and culverts were destroyed and more than 15,000 kms. of rural and trunk roads were affected. The destruction of these infrastructural facilities was primarily caused by poor planning strategies with regard to potential risk to excessive run-off. The public policies of the 1970s and 1980s overemphasized infrastructural development as a prerequisite for economic and industrial growth and pursued them through a number of schemes. The Food for Works Programme (FFWP) was one of them, which achieved a remarkable success in recent years (see Table 3). Nonetheless, the apparent correlation of these achievements with increased flood frequency as well as flood loss is partly due to the lack of necessary considerations of environmental risks in the infrastructure projects (see Mirza, 1984).

An analysis of flood loss in Bangladesh reveals that the people are highly adaptive to floods relative to other extreme natural events. For example, compared to the loss of over 200,000 lives from the cyclone-driven storm in November, 1970, and over 70,000 lives due to the coastal cyclone in May, 1985, the magnitude of direct fatalities by the flood occurrences had been limited to less than two thousand. A first-hand Western observer of the 1988 flood succinctly expressed this ability of people to cope with extreme situations. In the midst of the flood period, he reported:

> The world has already recognized a catastrophe in a nation where the country's worst floods have left 1,000 dead...and more than 25 million homeless. But Bengalis themselves are coping astonishingly well with the enemy they've always known..."We are all right here", says a women named Sabera, who crept to the edge of her tin roof to talk to a reporter in a boat... Although rice paddies are under several meters of water and the precious jute crop badly damaged, morale among beleaguered Bengalis seem surprisingly high (Johnson, 1988).

Hurdus (1988) and Brammer (1990a) further found that during the abnormal flood years, the spread of flood water in extensive areas plays a compensatory role in crop damage. That is, the damage of the two wet season paddies, namely *aus* and *aman*, is largely overcome by better soil moisture conditions, especially for *boro* production (i.e., dry season crops; see Table 4). Consequently, the net loss due to abnormal flood is less than the superficial estimates. Does this imply that the impact of floods is nominal? An account for indirect effects of flood reveals that their perpetual progression causes immense socioeconomic and human cost. An extensive survey of the 1974 famine by Alamgir (1980) indicated that the severe flood occurrences leave the poor and marginal peasants much more impoverished. This is because abnormal floods damage their assets and force them to draw on past savings as well as by falling into further debt. Among other indirect effects, the demand for agricultural labour decreases drastically as crops are damaged. The capacity to hire labours by landowners is reduced by lower incomes accruing to them. Coupled with the steady increase in seasonal price of food grain and related commodities, the poor peasants and wage labourers become increasingly prone to starvation and famine over time (see Rahman, 1989).

[INSERT TABLE 4 HERE]

IV
CHOICE OF HUMAN ADJUSTMENTS IN MITIGATING FLOOD HAZARDS

The principal themes in the current literature on natural disasters include both the causes of disasters and the adjustment strategies leading to prevention and mitigation of hazards. In natural hazards research, the term 'adjustments' is used to refer to any human activity intended to mitigate the adverse impact of a hazard. In this connection, two major paradigms have evolved with regard to what can be done to lessen the impacts of floods. The first of these conceives environmental hazards as solely a nature-generated phenomena requiring structural adjustments; it stresses the application of technology biased measures to prevent or to modify the physical processes to produce flood mitigation.[4] A second paradigm emphasizes non-structural adjustments to floods (i.e., not involving massive engineering works) which include an array of adaptive actions taken by communities before and during floods in order to mitigate loss, as well as other pertinent strategies such as flood forecasting and early warning systems, flood insurance, and flood relief and rehabilitation.

Structural Engineering Adjustments: A Critical Review

There are two principal thrusts among the 'structural adjustment' proponents. The first group focus upon strategies aimed at reducing the amount of water in an area at any given time through surface or underground storage. In the case of Bangladesh's flood problem, this has led to proposals for mitigating floods by building large storage reservoirs upstream in the mountainous reaches of the major rivers and on their tributaries. Such an approach is strongly favoured by a former senior advisor to the Government of Bangladesh who argues that Bangladesh must interact much more closely with Nepal in dealing with water resource problems of the region. It has been estimated that as much as 66 million cubic meters of water would need to be stored if there was to be any significant reduction of major floods in Bangladesh (see Rogers *et al.* 1989). However, as Colombi (1988; cited in Rogers *et al.*, 1989) has argued, the consequent competing demands in Nepal for the use of any stored water for irrigation and hydropower management would likely result in less than 10 percent of the storage capacity being specifically available for flood water storage in the peak-flood month of September. If this was indeed the case, it suggests that a massive investment of as much as US $60 billion in dam construction may only produce as little as 0.4 meters in the reduction of flood peaks in Bangladesh. In brief, the flood control benefits of such a structural strategy are not sufficient to warrant the the huge investments in dam construction and upstream storage.

A second group, and one that is the most popular 'structural' approach to flood mitigation in Bangladesh, is that of favouring the construction of embankments to prevent, divert, and regulate flood waters. Both preventive and corrective objectives are set in respect to the question of where to build these embankments. On the 'preventive' side, the aim is to to ensure that floodwaters never inundate the areas outside the banks along the whole length of the river. A large French consortium of engineering companies currently addressing the problem in Bangladesh is particularly in favour of such an approach; it has proposed an elaborate and costly set of new embankment constructions along both the Ganges and the Brahmaputra and their four major distributaries, as well as seven other smaller rivers. In contrast, 'corrective' objectives are less grandiose, proposing to allow the river to overflow into relatively unimportant or under-populated areas while protecting important areas and large population concentrations. Both U.S. and Japanese flood study teams are supportive of such a strategy.

The application of major preventive structural adjustments would create a number of serious problems for Bangladesh. First, the construction of embankments along the major rivers requires a capital cost as much as US $10 billion (Bingham, 1989), as well as an annual operating costs on the order of more than US $500,000 (Rogers *et al.* 1988). Since the lion share of the national development budget continues to come from foreign sources, a costly preventive program will result in a steady rise in the nation's foreign debt burden. Second, the preventive programme will result in a further rise in the nation's already severe foreign debt burden. Second, preventive embankments tend to provide a false sense of security and, ironically, may actually lead to an increase in flood damage. The findings of a recent study in the southern Bangladesh by Stewart (1988) show that the average material damage was worse in areas inside the embankment compared to areas outside of it. Third, embankments impede the movement of freshwater fish and cut-off their spawning areas which threatens the occupation of more than a million fishermen and jeopardizes the already marginal supply of animal protein in the diet of the majority of people.[5] Last but not least, embankments deprive the farmers from the beneficial effects of 'normal' seasonal floods. Normal annual flooding in Bangladesh, known as *borsha,* is part of peasant life; it is viewed as a beneficial phenomenon (see Paul, 1984) producing leaching and eluviation processes which have rejuvenated the soil -water properties and fertility of soils in the region for centuries. New inorganic materials from the Himalayan region have drained downstream and alongside floodplains accumulated in this deltaic plain for thousand of years. The deposited silt by floods, however, remains infertile for several years before it can become effective in improving soil fertility (Brammer, 1990b). Brammer (1990b: 164) notes that flood related soil fertility is generated "from nitrogen-fixing blue-green algae living in the water from decomposing, submerged, plant remains, and from the increased availability of phosphorus and other nutrient elements in the chemically reduced, submerged top-soils".

A total flood prevention would not allow these natural fertility benefits and the necessary moisture supply to continue. In view of the potential damage and destruction to the existing natural resource base, there was a growing opposition to the proposal of the French consortium to construct preventive embankments (see Haque, 1989; Islam, 1989; Rasid, 1989; Rogers *et al*, 1989). The major aid donors to Bangladesh discussed the flood mitigation problem at the G7 summit meeting in Paris in July 1989. They agreed that the World Bank should "coordinate the efforts of the international community so that a sound basis for achieving a real improvement in alleviating the effects of flood can be established". In 1989, the World Bank prepared an Action Plan for Flood Control in which both the "flood prevention" and "flood control" approaches are accommodated. Actually, the Plan is directed to create the preparatory arrangements for an eventual implementation of the Flood Master Plan proposed in the UNDP Policy Study. Although the study did not completely agree to embank four major distributaries of the Ganges and the Brahmaputra-Jamuna, and seven smaller rivers, it proposed to build embankments all along the major river courses in Bangladesh. In addition to these structural measures, the plan intends to create "compartments" inside the main embankments by constructing internal embankments. A controlled flooding would be allowed by means of regulators and sluices in both main and internal embankments. Ironically, the proposal ignores the fact that local rainfall often leads to high floods, and compartmentalization is rather likely to aggravate the problem of drainage in many cases. Moreover, it has already been observed that confinement of run-off to river channels intensifies the bank erosive capacity during monsoon period in both the Brahmaputra-Jamuna and the Ganges rivers (Haque, 1988; Rahman, 1984). The Brahmaputra Right Bank Protection Embankment, a 217 km. long flood control measure, has been cited as a major cause of rapid westward migration of the Brahmaputra-Jamuna channel. Even if the proposed embankment succeeds in achieving flood control purposes, it is probable that the accelerated bank erosion of these braided rivers might outweigh the benefits in this land-scarce country. This is because riverbank erosion hazards effect the predicament of the hundreds of thousands of displaced people which becomes a permanent feature compared to the temporary effects of seasonal flooding.

An Exploration into Indigenous Adjustments Strategies

The non-structural adjustments to floods include adaptive actions taken by communities before and during floods to mitigate loss, and other pertinent human actions without involving major engineering work such as, flood forecasting and warning systems, flood insurance, and flood relief and rehabilitation. The people of the Eastern Water basin have long been associated with the flooding phenomenon, and adopted numerous adjustments to cope with abnormal flooding based on indigenous inventions and innovations, and material and societal resources. In contrast to the English meaning of "flood" as a destructive phenomenon, its usage in Bengali refers to it as both a positive and a negative resource. As noted earlier, the term *borsha* refers to normal flooding, and *bonna* implies an abnormal flooding. This literal expression, which is based on real life experience, reflects the awareness, and adjustments to flood hazards, of the common people of the region.

Most of the indigenous adjustments are of corrective type; some of them are related to social organization and relationships, others are associated with material responses at an individual level. The concept of resource sharing and income redistribution in ameliorating famine effects in an agrarian economy has been employed by a number of scholars (Sen, 1981; Alamgir, 1980; Desai, 1959), however, attempts at investigating the role of social organizations and other societal forces in mitigating hazard effects has been scanty.

In order to explore the indigenous adjustment strategies and measures, a questionnaire survey was conducted in December 1988 in the Sreenagar Upazila of Munshiganj district. A sample size of 280 households (i.e., primary sampling units) was covered, and a simple random sampling procedure was followed in selecting these units. Only the household heads were directly interviewed to represent their corresponding family units.

The survey showed that majority of the respondents took some corrective measures to minimize flood loss. That is, more than 71% of respondents attempted to reduce their loss to floods by selling their land, livestock or belongings; some moved housing structures, livestock, and family members to other safer places (Table 3). It is evident that flood victims opted for a number of responses aimed at reducing hazard loss through deliberate measures.

[INSERT TABLE 3 HERE]

It was further observed that, although most of the villagers received some assistance from various sources to cope with flood hazards, less than 12 percent actually were recipients of support from the local and national government sources. As indicated in Table 4, the principal source of assistance to adjustment efforts are relatives (78.6%), and other community members (32.9%). The items of assistance received from these major sources consist of moral support, free shelter and accommodation, free labour at the time of move, and cash loans and food. Also, non-government organizations provided a great deal of support to the respondent households in hazard mitigating efforts. More than 50% of the sample received food and clothes, housing materials, seeds and loans from them to regain their pre-disaster status. More importantly, this support not only helps the flood victims to survive through the disaster period, but also to assist in saving many of the belongings, utensils, housing materials, livestock, and moral of the hazard victims.

[INSERT TABLE 4 HERE]

More than half of all respondents considered it important to remain within, or to maintain closer ties with their traditional *samaj* organization during the coping stages with hazards. The *samaj* is an informal but predominant social grouping based on kinship, social, and religious interests of its members. It is the primary forum within which members interact frequently and are mutually involved in networks of social and ceremonial links and interdependence (Zaman, 1986; Haque and Zaman, 1989). The *samaj* people are obliged to help in ameliorating difficult situations of its members.

Further evidence of the benefits of institutionalized networks in the mitigation of hazard loss was revealed in the survey responses (see Tables 3 and 4). Both in terms of hazard preparedness and coping ability, the households which were members of the institutionalized groups[6] demonstrated a better performance compared to their counterparts (i.e., non-members). These observations support the hypothesis that developing the social and institutional networks can be effectively employed in minimizing hazard effects.

At the individual level, some small scale structural measures are also employed by the resource users in rural Bangladesh. One of the most common strategies is the construction of homesteads on relatively elevated natural levees. The plinth of houses, locally called *bhiti*, is further raised by digging earth from local depressions (see Currey, 1979). The rural non-metalled roads (i.e., *katcha*), courtyards of local schools and mosques are often raised to the level of abnormal floods, and used as flood shelters. People also build platforms or *machans* using bamboo, straw, water hyacinth, and banana stalks during abnormal flooding years.

The agricultural adjustments to flood hazards is an important part of the indigenous measures in Bangladesh. As Rasid and Paul (1989) cited, farmers of this wet monsoon region have had made a careful selection of the most adaptive varieties of rice over the centuries to face the high floods. For instance, certain varieties of *aus* rice is cultivated only in elevated areas (i.e., *tans*). Since some broadcast and transplanted *aman* grow with flood, and are harvested following the recession of flood water, they are grown in the low lying areas (i.e., *dhoabs*) such as backswamps, channel scars, and shallow beds of oxbow lakes. *Chamara*, a broadcast variety of *aman*, can grow by more than 15 cm in a day with the rising flood levels.

Overall, it is evident that, in the context of the rural habitat and agriculture of Bangladesh, flooding is a vital agent to its resources. Although some extreme events turn out to be a serious threat to local resources and human lives, their frequency is measured in the range of the 50 to 100 year event. The floodplain inhabitants would gain little from prevention of such rare events.

V
POLICY IMPLICATIONS AND CONCLUSIONS: A CONSIDERATION FOR SUSTAINABLE FLOODPLAIN DEVELOPMENT

The concept of a sustainable floodplain development is a synthesis of my ideas discussed above as well as in the international conference on Bangladesh floods and their solutions, held in Montreal, Canada in May, 1989. Human intervention and modification of elements of the natural environment such as, alluvial floodplains, continues to grow at a dramatic rate because human strives to produce more resources, and to safeguard the existing ones. This trend is expected to continue into the foreseeable future, and with it will come conflicts between flood-prevention activities and the environment. Without significant attention toward more sustainable forms of floodplain development, it is quite probable that severe damage to ecological and cultural habitats will accelerate.

The notion of "sustainable development", put forward by the World Commission on Environment and Development in 1987, laid a broad conceptual framework. The Commission defined it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (1987: 43). This broad theme generated a stimulating semantic debate in the literature, and is reported elsewhere (Manning, 1990; Daly, 1988; Hawarth, and Norgaard, 1990). In brief, the overall discussion revealed that the concept underlying sustainable development is an anthropocentric approach to the globe -- a human perspective relating to human use of the biosphere. This notion explicitly recognizes interdependencies that exist among environmental, economic, social, and cultural phenomena.

We would like to assert that an application of this broad notion to the context of floodplain development and management policy could form an exemplary step toward a sustainable future. Sustainable floodplain development can be envisaged as leading to the promotion and management of all resources of alluvial plains such that economic, social, aesthetic, and environmental needs can be fulfilled while cultural integrity, essential ecological processes, biological diversity and life support systems are maintained.

The guidelines and implications of such a policy strategy would include a broad spectrum of fields: (i) The implementation of a sustainable floodplain development policy would shift the focus away from the traditional sectoral planning of the complete flood-prevention approach. The emphasis should increasingly be placed on controlling floods only when its severity surpasses an optimum magnitude so that all developmental and ecological concerns are accommodated. (ii) Floodplain development plans involving any loss of existing natural or cultural wealth or environmental capital would increasingly indicate how future generations will be compensated. The loss of natural and cultural assets can no longer simply be substituted for by capital wealth created by new water resource related development efforts. (iii) Development plans should avoid all actions that might trigger irreversible natural processes. Some physical and cultural resources can be replaced; but crops, plant, wildlife, fish, and other similar species, once lost, can never be enjoyed by future generations. (iv) Floodplain development in one region or country clearly can have positive or negative effects on other regions or countries. Regional cooperation should receive priority to ensure that water resource planning is integrated into regional economic planning and management of the environment. (v) In situations where the resource base has been seriously degraded, mitigation and rehabilitation actions must be undertaken to reflect the concept of sustainable environmental development. (vi) In flood mitigation measures, mobilization of human/social components, along with minimum physical modification, should be used as effective means to allow the progress of normal ecological processes. Human adjustment modification should receive more attention in terms of loss minimization efforts. Various types of indigenous adjustments, particularly the adaptation of different types of crops to varied flood depths, should be reinforced. (vii) Finally, a policy of "sustainable floodplain development" would promote an approach "to live with floods" and other natural processes and make it tolerable by developing measures for human preparedness and loss reduction.

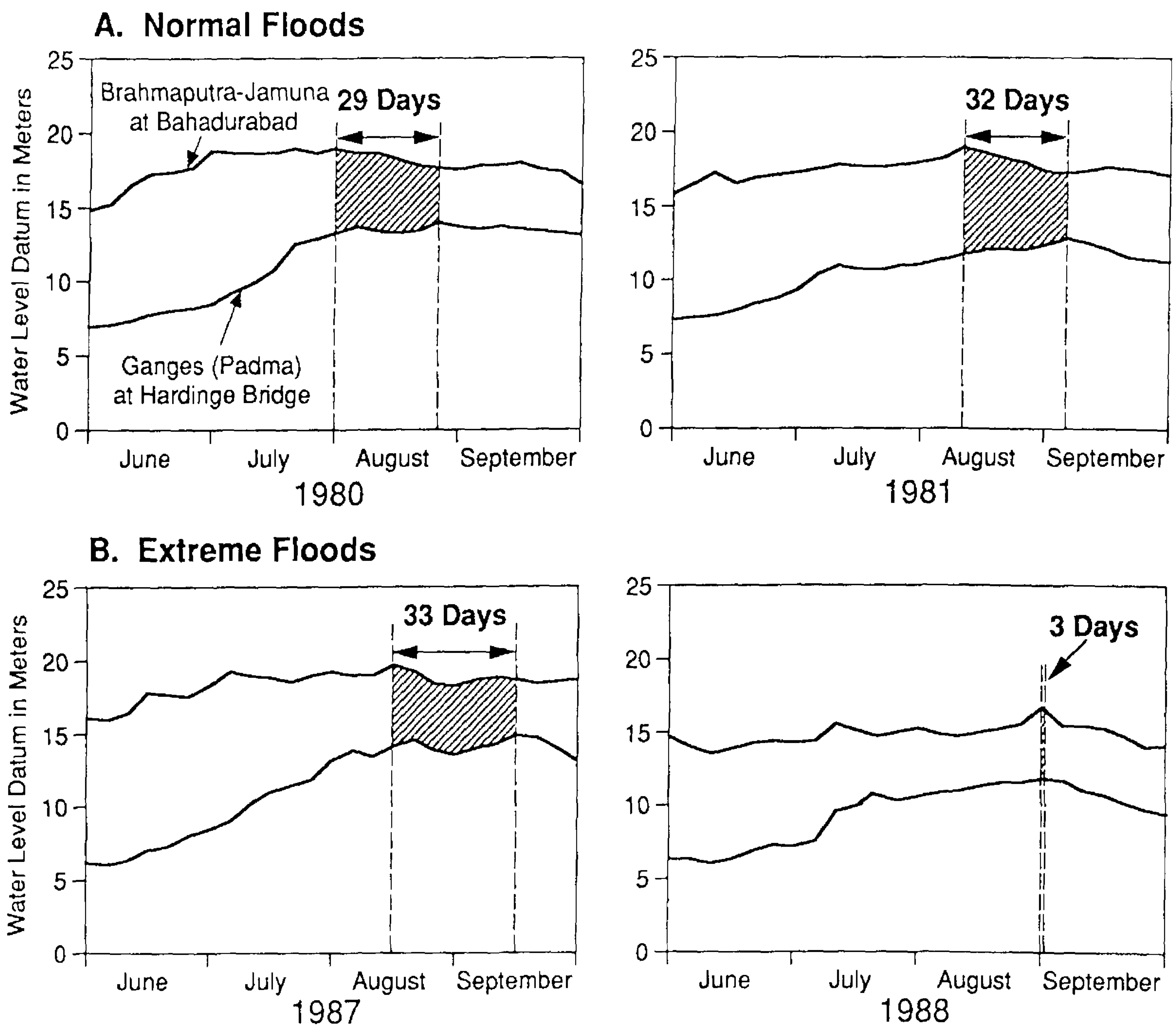

FIG. 1 Water-level hydrographs of the Brahmaputra-Jamuna and the Ganges rivers. Some selected extreme and normal flood years of the eighties are shown for each river-reach.

TABLE 1

Timing and the Length of the Gap between Flood Peaks of the Brahmaputra-Jamuna and the Ganges

Year	Water Level (in Meters)		Length of the Gap between Flood Peaks (in Days)
	Brahmaputra-Jamuna	Ganges	
A. Typical (Normal) Flooding Years*			
	(at Bahadurabad)	(at Hardinge Bridge)	
1977	18.4	14.2	**25**
1978	18.3	13.8	**20**
1979	18.6	14.3	**22**
1980	19.0	14.0	**29**
1981	18.9	12.8	**32**
1982	18.7	13.1	**10**
B. Extreme Flooding Years**			
	(at Serajganj)		
1954	14.2	14.9	**29**
1974	14.2	14.4	**26**
1987	15.1	14.8	**33**
	(at Bahadurabad)		
1988* **	**20.8** (at Serajganj) **15.1**	**14.9**	**3**

* Obtained from the plotted data prepared by Rahman (1984).

** Source: Islam (1989)
*** Source: Miah (1988)

TABLE 2

Damage due to Abnormal Floods (bonna), 1971-1988

A. Loss of human lives and livestock

Year	Loss of human lives	Loss of livestock ('000)
1971	120	2
1974*	1,987	46
1975	15	n/a
1976	54	n/a
1984*	553	76
1987*	1,657	65
1988*	2,379	172

B. Loss of crop production and housing structure

Year	Loss of rice production ('000 metric tons)				Houses totally/ partially damaged
	Boro	Aus	Aman	Total Seasonal	
1971	n/a	56	229	285	229
1974*	187	613	562	800	6,165
1975	n/a	68	25	93	19
1976	67	351	264	682	89
1980	4	30	251	285	n/a
1984*	373	475	1,299	2,147	536
1987*	n/a	695	1,341	2,036	2,536
1988*	n/a	1,357	1,565	2,922	7,179

* More catastrophic flood years

Sources: Mirza (1984); Bangladesh Red Cross (1988); Brammer (1990b)

TABLE 3

Food for Works Projects and Acievements, 1974/75-1983/84

Year	Nos. of projects implemented	Roads (kms.)	Embank-ment constructed (kms.)	River and canal excavation (kms.)
1974/75	21,479	3,824	1,402	1,756
1975/76	1,554	1,448	1,246	1,611
1976/77	2,328	1,735	3,067	2,694
1977/78	2,087	2,366	488	3,639
1978/79	2,113	1,770	3,487	3,082
1979/80	2,124	3,301	3,262	4,212
1980/81	3,927	4,981	5,064	6,693
1981/82	3,431	6.910	6,437	1,292
1982/83	3,029	9,213	8,582	1,724
1983/84	4,292	22,083	8,405	3,333

Source: Bangladesh Bureau of Statistics (1985)

TABLE 4

Cereal Production in Bangladesh, 1986-88

Year	Production (M tonnes)				
	Aus	Aman	Boro	Wheat	Total Cereals*
1986-87	3.13	8.27	4.01	1.09	16.50
1987-88	2.99	7.69	4.73	1.05	16.46
1988-89	2.86	6.86	5.80	1.02	16.54

* Excluding minor cereals. Rice production as milled rice.

Source: Brammer (1990a)

TABLE 5

Distribution of Adjsutment Measures Taken by Respondents

during the 1988 Floods in Sreenagar(%)

Types of Adjustment Measure Taken (Multiple Response Possible)	All Households n = 280	Not-Member of of Institutional Groups n = 144	Member of Institutional Groups n = 136
Sold Land	2.1	4.4	-
Sold Livestock	17.1	26.4	7.4
Sold Belongings	25.7	33.3	17.6
Mortgaged Land	4.3	5.6	2.9
Dismantled Housing Structure	38.6	30.6	47.1
Borrowed Money	39.3	65.3	11.8
Spent Previous Savings	24.3	44.4	2.9
Moved Family to Other Areas	65.7	79.2	51.5
Moved Livestock and Belongings to Other Areas	26.4	20.8	32.4

Source: Author's field survey

TABLE 6

Sources of Assistance Received by the Flood Victims

during the 1988 Floods in Sreenagar (%)

Sources of Assistance (Multiple Response Possible)	All Households n = 280	Not-Member of of Institutional Groups n = 144	Member of Institutional Groups n = 136
Relatives	78.6	86.1	70.6
Other Villagers	32.9	31.9	33.8
Local Government	7.1	8.3	5.9
National Government	4.3	4.2	4.4
Relief Agencies and Other Institutions	51.4	18.1	86.8

Source: Author's field survey

Acknowledgements

The authors are thankful to John R. Rogge and Marcia A. Faurier, Department of Geography, University of Manitoba, Canada, for their useful comments and suggestions on an earlier draft of the paper. Special thanks are due to Morshed Alam, Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka, Bangladesh, for his help in obtaining the survey data during the 1988 floods.

Notes

1. For instance, almost half of the 1988-89 national development budget was diverted to pay *ad hoc* relief and rehabilitation programmes (see Brammer, 1990a).
2. In total, 91 projects were identified in the Master Plan to address flood problems of what was then East Pakistan. As of the mid-1980s, only 19 large scale projects were completed and an additional 14 were under implementation (Rahman, 1985). Among the major completed projects, the most noticeable were: (a) the Brahmaputra right bank flood protection embankment, (b) Dhaka-Demra flood control and irrigation project, (c) Chandpur flood prevention project, (d) Karnafully multipurpose reservoir, and (e) 3,500 km long coastal embankment (polders).
3. An extreme example is Cherapunji of Assam state of India, where the average annual rainfall is 10,820 mm (426 inches).
4. For example, the US Corps of Engineers has implemented multi-billion dollar water resource development and flood prevention schemes since World War II.
5. Fisheries supply over 70% of animal protein in a typical diet of rural Bangladesh.
6. The institutionalized groups were defined as the registered target groups of government and non-government organizations such as, agricultural cooperatives, credit unions, banks, and integrated rural development programme based women's groups, etc.

References

Alamgir, Mahiuddin (1980) *Famine in South Asia: Political Economy of Mass Starvation.* Oelgeschlager, Gunn and Hain, Cambridge, Mass.

Bangladesh Bureau of Statistics (BBS) (1985) *Statistical Pocket Book of Bangladesh, 1984-85.* Statistics Division, Ministry of Planning, Dhaka.

Bangladesh Observer (1988) September 6, Dhaka.

Bingham, Annette (1989) Floods of Aid for Bangladesh. *New Scientist* 1693, 42-46.

Brammer, H. (1990a) Floods in Bangladesh I. Geographical Background to the 1987 and 1988 Floods. *The Geographical Journal* 156, 12-22.

Brammer, H. (1990b) Floods in Bangladesh II. Flood Mitigation and Environmental Aspects. *The Geographical Journal* 156, 158-165.

Crow, Ben (1981) Why Are the Ganges and Brahmaputra Undeveloped? Politics and Stagnation in the Rivers of South Asia. *Bulletin of Concerned Asian Scholars* 13, 35-63.

Currey, Bruce (1979) *Mapping Areas Liable to Famine in Bangladesh.* Unpublished Ph.D. Dissertation, University of Hawaii, Honolulu, Hawaii.

Daly, H. (1988) Sustainable Development: From Concept and Theory Towards Operational Principles. *Population and Development Review* 1-34

Desai, A.R. (1959) *Social Background of Indian Nationalism.* Popular Book Depot., Bombay.

Hamilton, L.S. (1987) What Are the Impacts of Himalayan Deforestation on the Ganges-Brahmaputra Lowlands and Delta? Assumptions and Facts. *Mountain Research and Development* 7, 256-63.

Haque, C.E. (1988) Human Adjustment to River Bank Erosion Hazard in the Jamuna Floodplain, Bangladesh. *Human Ecology* 16, 421-37.

Haque, C.E. (1989) Comments and discussion in international conference on Bangladesh Floods: What Area the Solutions? International Society of Bangladesh, Montreal.

Haque, C.E. and Zaman, M.Q. (1989) Coping with Riverbank Erosion Hazard and Displacement in Bangladesh. *Disasters* 13, 300-14.

Howarth, R.B. and Norgaard, R.B. (1990) Intergenerational Resource Rights, Efficiency, and Social Optimality. *Land Economics* 66, 1-11.

Hurdus, Alan R. (1988) *Outlook for the 1988/89 Aman Crop and Early Projections for the 1988/89 Wheat and Boro Crops*. Memorandum, Office of Food and Agriculture, USAID, Dhaka, Bangladesh.

International Engineering Company (1977) *Special Studies*, IECO Ltd., San Francisco.

Islam, M. Aminul (1989) Floods in Bangladesh: Causes, Consequences and Adjustments. Paper presented at the international conference on Bangladesh Floods: What Area the Solutions? International Society of Bangladesh, Montreal.

Ives, Jack D. (1989) Deforestation in the Himalayas: The Cause of Increased Flooding in Bangladesh and Northern India. Paper presented at the international conference on Bangladesh Floods: What Area the Solutions? International Society of Bangladesh, Montreal.

Ives, Jack D. and Messerli, Bruno (1989) *The Himalayan Dilemma: Reconciling Development and Conservation*. Routledge, London.

Manning, E.W. (1990) Conservation Strategies: Providing the Vision for Sustainable Development. *Alternatives* 16, 24-29.

Miah, Maniruzzaman (1989) *Flood in Bangladesh: A Hydromorphological Study of the 1987 Flood*. Academic Publishers, Dhaka.

Mirza, Munirul Qader (1984) Flood Has Become a Nightmare. *Bangladesh Today* 2, 26-35.

New Nation (1988) September 4. Dhaka.

Paul, Bimal K. (1984) Perception of and Adjustment to Floods in Jamuna Floodplain, Bangladesh. *Human Ecology* 12, 3-19.

Rahman, Atiur (1989) Human Responses to Natural Hazards: The Hope Lies in Social Networking. Paper presented at the 23rd Bengal Studies Conference, Winnipeg, Manitoba.

Rahman, M.A. (1985) *Situation and Future Trends of Energy and Water Resources Development in Bangladesh: Water as a Factor in Energy Resources Development*. United Nattions Water Resources Series no. 60. 41-43.

Rahman, Shamsur (1984) The Brahmaputra Right Bank Flood Embankment: Its Problems and Probable Solutions. Paper presented at the seminar on Brahmaputra Right Bank Flood Embankment, Bangladesh Academy for Rural Development, Bogra (Bangladesh).

Rasid, Harun (1989) Mini-Projects for a Mega-Problem: A Pragmatic Solution for the Flood Problem in Bangladesh. Paper presented at the international conference on Bangladesh Floods: What Area the Solutions? International Society of Bangladesh, Montreal.

Rasid, Harun and Paul, Bimal K. (1989) Flood Problems in Bangladesh: Is There an Indigenous Solution? *Environmental Management* 11, 155-173.

Rogers, Peter, Lydon, Peter and Seckler, David (1989) *Eastern Water Study: Strategies to Manage Flood and Drought in the Ganges-Brahmaputra Basin.* Irrigation Support Project for Asia and Near East (ISPAN), Arlington, Virginia.

Sen, A.K. (1981) *Pove. ty and Famines: An Essay of Entitlement and Deprivation.* Clarendon Press, Oxford.

Stewart, K. (1988) Post Flood: Assessment and Nutritional Status of Children in Matlab, Bangladesh. Paper presented at the seminar on Regional and Global Environmental Perspectives, Dhaka.

United Nations Development Programme (UNDP) (1989) Bangladesh Flood Policy Study. Final Report. UNDP, Dhaka.

World Commission on Environment and Development (1988) Our Common Future. Oxford University Press. New York.

Zaman, M.Q. (1986) The Role of Social Relations in the Response to Riverbank Erosion Hazards and Population Resettlement in Bangladesh. *Studies in Third World Societies* 36 (Special Issue on Natural Disasters and Cultural Responses, Guest Editor: Anthony Oliver-Smith), College of William and Mary Williamsberg, Virginia.

teaching conservation overseas (African Studies Centre, University of Cambridge, Cambridge)

UNESCO (1989) *National seminar in environmental education in Ethiopia*, (Ethiopian National Agency for UNESCO and the Environmental Education Project of the Ministry of Education in cooperation with UNESCO-UNEP International Environmental Education Programme, Deber Berhan)

Vulliamy G (1987) 'Environmental education in third world schools: rhetoric or realism?' *The Environmentalist, 7*, 11-19

Walker P (1989) *Famine early warning systems: victims and destitution* (Earthscan, London)

Watson K (1983) 'Rural primary school teachers as change agents in the Third World: three case studies' *The International Journal of Educational Development, 3*, 47-59

Watts M (1983) *Silent violence: food, famine and peasantry in Northern Nigeria* (University of California Press, Berkeley)

World Commission on Environment and Development (19887) *Our common future* (The Brundtland Report) (Oxford University Press, Oxford)

Wood A (1987) 'The state, soil erosion and environmental conservation in Ethiopia' (Paper prepared for the Conference on Environmental Crises in Developing Countries, Institute of British Geographers)