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**STRUCTURAL FLOOD CONTROL AND SUSTAINABLE DEVELOPMENT:
AN ANALYSIS OF THE FLOOD ACTION PLAN FOR BANGLADESH**

by

VALERIE WARMINGTON, B.A.

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of**

Master of Arts

Department of Geography

Carleton University

Ottawa, Ontario

January, 1994

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**"STRUCTURAL FLOOD CONTROL AND SUSTAINABLE DEVELOPMENT:
AN ANALYSIS OF THE FLOOD ACTION PLAN FOR BANGLADESH"**

submitted by Valerie Warmington, B.A.
in partial fulfillment of the requirements for
the degree of Master of Arts

Thesis Supervisor

Chair, Department of Geography

Carleton University
January, 1994

Abstract

The World Bank-coordinated Flood Action Plan for Bangladesh is a large and complex development program that will affect the lives of millions of people. This thesis analyses the program and the socio-economic and bio-physical conditions within Bangladesh to predict the likely impacts of the program. Particular attention is paid to rural livelihoods and the role of natural flooding on the infiltration and storage of water. This enables the sustainability of the Flood Action Plan to be evaluated against criteria produced at the United Nations Conference on Environment and Development and the International Forum of NGOs. The evaluation suggests that embankment-centered schemes are not the best option to achieving sustainable development in Bangladesh, and that the manner in which the Flood Action Plan has been conceived, designed and is being implemented does not represent sustainable development. Redesigning the program such that it builds on the existing capacities of Bangladeshis to respond effectively to the advantages and disadvantages of their situation remains a challenge to achieving sustainable development in Bangladesh.

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Many people have contributed to the writing of this thesis. In particular, I wish to thank my supervisor Ken Torrance for his advice, direction and seemingly unending patience. I would also like to mention Valerie Melnikoff of the Canadian Council for International Cooperation, whose vision of development has inspired me. Special thanks also go to Farida Aktar of UBINIG, Syhed Assan of the International Society of Bangladesh, and, although we have not met, Shapnan Adnan of Bangladesh's Research Advisory Services for the wealth of information they have provided. To all the people of Bangladesh, I extend my best wishes.

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LIST OF BANGLA TERMS

Aman - varieties of rice planted just prior to or during the monsoon and harvested after the floods
Aus - rapidly maturing varieties of rice planted prior to the monsoons and harvested prior to the floods
Boro - varieties of rice planted in the dry season
Char - temporary island forming in a river
Dhune - traditional irrigation system
Jotedar - powerful landowner
Mouza - land revenue unit
Upazila - sub-district

LIST OF ACRONYMS

ADAB - Association of Development Agencies in Bangladesh
BEES - Bangladesh Extension Education Service
CIDA - Canadian International Development Agency
CSE - Center for Science and Environment (India)
EIA - Environmental Impact Assessment
FAP - Flood Action Plan
FPCO - Flood Plan Coordination Organization (Bangladesh)
FEC - French Engineering Consortium
GIS - Geographical Information System
HYV - High Yield Variety
IAO Network International - Information, Action and Opposition Network International
IASG - International Agrarian Studies Group
ICID - International Commission on Irrigation and Drainage
IDRC - International Development Research Center (Canada)
IFAD - International Fund for Agricultural Development
MPO - Master Plan Organization (Bangladesh)
NGO - Non-Governmental Organization
O&M - Operation and Maintenance
R&R - Reconstruction and Rehabilitation Fund (Canada)
UNCED - United Nations Conference on Environment and Development
UNDP - United Nations Development Program
USAID - United States Agency for International Development

CHAPTER 1

INTRODUCTION

1.1 The Flood Action Plan for Bangladesh

"Strategies and options for flood control in Bangladesh have been debated for many years. On one side is the argument that periodic flooding in Bangladesh is largely unavoidable because the works needed to eliminate flooding from the rivers are, in some areas, technically and economically infeasible and, moreover, tend to create as many problems as they solve. Those who support this argument believe there is considerable scope to build on the ability of the Bangladeshi farmer to cope with and recover from the annual floods. On the other hand is the widely held view that the country cannot be at the mercy of floods forever and that all the major rivers must eventually be contained so that the floods are safely passed through Bangladesh to the ocean. Those who support this argument believe this would reduce the risks associated with economic activity on the floodplains and increase the economic growth rate of the country" (World Bank, May 1990, 1).

Following severe flooding in 1987 and again in 1988, the international community appealed to the United Nations General Assembly for action on and international donor support of flood control in Bangladesh. To this end, a number of independent analyses and proposals were initiated¹. Recommendations incorporated in these reports ranged from the construction of extensive flood control embankments and other structures to a variety of non-structural approaches including early warning and other preparedness activities.

¹Four major reports were published in 1989. The UNDP in association with the Government of Bangladesh examined the nature and effects of flooding and recommended remedial measures (UNDP, 1989). The Government of Japan reported on the current state of flood prevention and preparedness planning in Bangladesh (Ministry of Foreign Affairs: Japan, 1989). The Government of France supported a prefeasibility study of extensive engineering approaches to flood control in Bangladesh (FEC, 1989). A report sponsored by USAID considered the potential for water resources development from a regional/watershed perspective (Rogers et al., 1989).

In 1989, the World Bank agreed to coordinate donor action in response to flooding in Bangladesh (Adnan, 1991, S-2). After reviewing the available documentation in consultation with the donor organizations, it was decided that extensive structural approaches to flood control are both feasible and necessary. The expectation is that once implemented, structural interventions will provide a "controlled environment where social and economic development can be undertaken with confidence" (World Bank, May 1990, 26, citing UNDP, 1989). No practical alternatives to achieving this objective are deemed to exist. The Flood Action Plan (1990 - 1995), represents the first round of activity towards achieving the longer-term flood-control objective² (Figure 1.1).

1.1.1 Components of the Flood Action Plan

The Flood Action Plan is comprised of twenty-six distinct components (World Bank, March 1992). Eleven components are referred to by the World Bank as "main components" (Table 1.1). Five of the main components examine local water regimes throughout the country to identify priority project areas. The six additional main components deal with projects already in the design and implementation stages. The remaining fifteen components of the Flood Action Plan are referred to as supporting studies (Table 1.2). These studies, including several pilot projects, are designed to identify and recommend actions in response to the social, environmental, and technical

²"(T)he Action Plan envisages that the Brahmaputra and the Ganges may eventually be embanked on both sides, possibly followed by the Padma and the Meghna rivers" (World Bank, May 1990, 89). It is estimated that the longer-term program will run until, and possibly beyond, 2010.

FIGURE 1.1 **EMBANKMENTS and COMPARTMENTS**
The Long-Term Program

From WORLD BANK, May 1989.

Table 1.1 **FLOOD ACTION PLAN MAIN COMPONENTS**

FAP #	COMPONENT TITLE	DESCRIPTION
1	Brahmaputra Right Bank Strengthening	Design measures to protect the Brahmaputra Right Embankment along critical sections,
2	Northwest Regional Study	Assess regional flood-control and drainage options. Identify priority projects and carry out feasibility studies. Explore ways to enhance capture fisheries.
3	North Central Regional Study	Assess regional flood-control and drainage options. Identify priority projects and carry out feasibility studies.
3A	Jamalpur Priority Project	Embank the angle between the Jamuna and the Old Brahmaputra to protect 90,000 ha. Examine the interaction of this project with adjacent areas, including chars.
4	Southwest Regional Study	Assess regional flood-control and drainage options. Identify priority projects and carry out feasibility studies.
5	Southeast Regional Study	Identify priority flood-control projects. Assess the potential for groundwater to alleviate current water shortages. Consider the feasibility of transferring water from the Meghna River into the Muhuri River
6	Northeast Regional Study	Design a regional flood-control program. Identify priority projects. Enlist NGO assistance towards incorporating public participation in project planning and operation.
7	Cyclone Protection Project	Reconstruct and strengthen coastal embankments. Upgrade roads in the protected area. Identify ways to ensure public participation in road and embankment maintenance.

FAP #	COMPONENT TITLE	DESCRIPTION
8A	Greater Dhaka Flood Protection Project	Formulate a plan for flood control and drainage of the Greater Dhaka Area (85,000 hectares). Identify priority projects and carry out feasibility studies.
8B	Dhaka Integrated Flood Protection	Repair, strengthen, and complete the embankment protecting Dhaka City (26,000 hectares). Install sluice gates and a pumping station to improve drainage. Undertake a pilot sanitation, slum improvement, and waste collection project.
9A	Secondary Town Protection	Construct embankments protecting six towns from flooding. Provide drainage, slum improvement, and solid waste collection systems in each town.
9B	Meghna River Bank Protection Study	Recommend measures to combat river erosion at critical points along the Meghna and Dhaleswari Rivers.
10	Flood Forecasting and Warning	Upgrade the capacity of Bangladesh's existing Flood Forecasting and Warning Center.
11	Flood Preparedness	Recommend ways to assist the Ministry of Relief to coordinate post-disaster responses.

(adapted from World Bank, November 1992)

Table 1.2 **FLOOD ACTION PLAN SUPPORTING STUDIES**

FAP #	STUDY TITLE	DESCRIPTION
12	FCD/I Agricultural Review	Review past flood-control efforts to draw lessons guiding FAP project design and implementation.
13	O&M Study	Identify the major constraints to effective O&M. Recommend and test new ways to improve local participation in O&M.
14	Flood Response Study	Assess the response of people to the floods. Assess the likely response of people to flood-protection.
15	Land Acquisition and Resettlement Study	Recommend measures easing land acquisition and minimizing the negative effects of displacement.
16	Environmental Study	Identify environmental issues associated with the FAP. Prepare EIA guidelines ³ .
17	Fisheries Study and Pilot Project	Evaluate the present status of floodplain fisheries. Predict the possible impacts of flood-control structures on floodplain fisheries. Assist in designing ways to optimize fish production in protected areas. Undertake a pilot project testing new approaches to aquaculture.
18	Surveys and Mapping	Provide topographic maps, thematic maps, aerial photography, and satellite imagery for the entire FAP area.
19	Geographic Information System	Establish a GIS network to meet the needs of FAP users.

³The FAP is categorized as a World Bank EIA Category-B program (Adnan and Sufliyan, 1993). The key environmental issues selected for further study are: the nutritional value of fish, bio-diversity, disease vectors, health and nutritional status of the population within and between embankments, and a resource inventory of the charlands (World Bank, November 1992).

FAP #	STUDY TITLE	DESCRIPTION
20	Compartmentalization Pilot Project	Assess the potential of the compartmentalization concept to meet the needs of various groups within the protected area.
21	Bank Protection Pilot Project	Develop new materials and designs to combat bank erosion. Undertake full-scale trials to test these innovations.
22	Active Floodplain Management Pilot Project	Test channel diversion and stabilization as a means of combatting bank erosion.
23	Flood Proofing Pilot Project	Identify and test ways to alleviate the adverse impacts of flooding on various social groups.
24	River Surveys Program	Collect hydrological and morphological data.
25	Flood Modelling and Management Program	Develop common hydrological modelling designs and criteria for FAP use.
26	Institutional Development Study	Prepare public and private entities for involvement in FAP implementation.

(adapted from World Bank, November 1992)

problems associated with the flood-control initiative. A number of the supporting studies draw on experiences with existing flood-control projects. Guidelines and criteria for the planning, implementation and evaluation of new projects are to be based on the results of the supporting studies.

A number of supporting studies aim to collect and examine hydrological and morphological data on river behaviour and flooding for modelling and forecasting purposes. Other studies aim at identifying new structural designs and construction materials. Full-scale trials will monitor the success of such innovations. Additional studies are aimed at reducing the adverse impacts of both flooding and flood control on various social groups. A number of these studies consider ways in which public acceptance of the flood-control program can be increased and the social constraints to implementation of the program eased. An environmental impact assessment procedure has been designed to reflect the environmental policies of Bangladesh and of the international donors (World Bank, November 1992, 24). New studies will be undertaken as necessary to overcome the problems faced during implementation of the long-term program.

Terms of reference for current investigations were developed by a variety of experts chosen by donors in consultation with the Bangladeshi government. In general, the investigations have been undertaken by donor-contracted foreign consultants working in association with Bangladeshi firms (World Bank, March 1992). Terms of reference were designed to give broad direction without foreclosing on the range of options

considered. Consultants are required to keep abreast of information generated by the supporting studies. In instances, workshops and seminars have been arranged to this end. Consultant's reports are reviewed by donors, the government, and a panel of foreign and Bangladeshi experts. A committee meets with consultants to resolve any points of difference prior to projects moving into the preparation stage.

The unpredictable impacts associated with attempting to structurally control Bangladesh's powerful hydrological environment have led the World Bank to implement the flood-control program in stages. Thus, although the interactive nature of flood-control structures is an important consideration, projects will be designed to function independently. This will be facilitated by a "compartmental" approach to design and construction whereby a piece of land is surrounded with embankments and provided with the appropriate water-management equipment.

Two pilot projects testing the compartmental approach are in the implementation stage. A full-scale bank protection project to prevent embankment undercutting, and a pilot project aimed at confining and stabilizing northern stretches of the Jamuna River via channel diversion and bank protection are underway (World Bank, November 1992, 22, 42). A project to embank the angle between the Jamuna and the Old Brahmaputra to protect 90,000 hectares of land is "nearing construction" (Adnan and Sufiyan, 1993). Bangladesh's Flood Forecasting and Warning Center is currently being upgraded.

Projects aimed at protecting vulnerable sections of the Brahmaputra right embankment and sections of the Meghna and the Dhaleswari Rivers from severe bank

erosion are "being prepared for implementation" (World Bank, November 1992). Additional projects in the preparation stage include: embanking the angle between the Jamuna and the Tista to protect 100,000 hectares of land, flood control and drainage to protect 140,000 hectares of land in the southeast region of the country, and embankment construction and strengthening to protect Dhaka City and six secondary urban centers. Sanitation and slum improvement components are included in the urban protection projects. Coastal embankments will be rebuilt and strengthened, and a government department to monitor disasters and coordinate post-disaster activities will be established in the near future. New projects will be integrated into the national flood-control program as they are identified.

1.1.2 Public Participation

Inclusion in discussions and access to information on the Flood Action Plan has been limited to selected foreign and domestic consultants, technical experts, and government officials (Adnan, 1991, 94). The role of the media has been limited to the ceremonial aspects of the process and to dissemination of government-controlled reports. Exposure of the Plan to public debate or to diverse professional opinion appears to have been avoided (Rashid, 1990; Adnan, 1991). Communication of information via word of mouth, a means to reach the many illiterate people who lack access to television or radio, has not played an important role. People are insufficiently aware of the scale of the

Flood Action Plan, and are uninformed as to the possible alternatives (Adnan, 1991; Environmental Coalition of NGOs, 1992).

Numerous reports from international groups have criticized the plan and questioned the need for massive structural interventions. These reports appear to have been ignored, and in recent years it has become increasingly difficult for people not associated with the Plan to gain access to documents relating to it (Adnan, 1991, 96). Although the Government of Bangladesh called for a complete review of the proposal in 1991, the scheme has yet to become the center of national policy debate and public discussion it merits.

The large community of Bangladeshi NGOs working directly with flood-affected populations was largely excluded from discussions of the Flood Action Plan. This NGO community stresses that rural people have coping strategies that preclude the need for large-scale structural intervention. Concerted attention to and support of such activities could produce many of the most needed benefits without the massive economic, environmental, and social costs of the structural alternatives advocated by the World Bank and donor countries (Environmental Coalition of NGOs, 1992, 9).

Local reactions to existing flood-control structures suggest that the costs associated with such approaches are unacceptable. Across the country, people have been meeting, marching, and demanding the modification or removal of existing structures not perceived to be in the public good (Adnan, 1991, 100). Instances of people deliberately breaching embankments to alleviate drainage problems or to reestablish flooding are common

(World Bank, March 1992). Active resistances to the reconstruction of damaged structural works have been reported.

This analysis responds to a demand for greater attention to the opinion, experience, and understanding of a broad spectrum of project stakeholders and to the requirement for an evaluation of the Flood Action Plan in light of such input.

1.2 Study Objectives

This paper considers the bio-physical, socio-economic, and political contexts of the Flood Action Plan for Bangladesh in order to consider the Plan's potential for sustainability. In addition to the analyses supporting the Plan's highly technical and structural focus, this study considers information generated by local observation and experience.

The central questions addressed are:

How will the control of surface water resources, via highly-technological, large-scale and extensive structural works, impact upon the livelihoods of the majority of Bangladeshis?
and

Are the potential socio-economic and environmental impacts associated with factors not considered in the predominantly engineering and economic analysis significant enough to warrant reconsideration of the proposed flood-control program or aspects of it?
Specific attention will be paid to the role of natural flooding on soil structure and the infiltration and storage of water.

1.3 Methodology

To address the questions posed by this thesis, an extensive literature review was augmented by meetings with involved Canadians and Bangladeshis, information gleaned during a trip to Bangladesh, and the results of laboratory tests performed on soil samples obtained while in Bangladesh.

1.3.1 Literature Review

The literature review provides information on environment, past experience with flood control, socio-political history, the present structure of the Bangladeshi resource economy, and development planning in Bangladesh. This information was obtained from a variety of indigenous and non-indigenous sources, from both experts and laypeople. Use was made of Bangladeshi and foreign media. Most of the donor-produced technical documentation relating to the Flood Action Plan was accessed through CIDA, except in the case of USAID which furnished documentation directly. The IAO Network International, an organization monitoring the Flood Action Plan, provided information regarding the current status of the flood-control program. Canadian and Bangladeshi NGOs provided extensive information regarding their experiences working with communities in Bangladesh.

1.3.2 Meetings and Interviews

Meetings at CIDA focused on Canada's role as a donor for the Flood Action Plan. Meetings were held in Canada and in Bangladesh with representatives of Canadian and Bangladeshi NGOs regarding their experience with existing flood control and their opinion of planned projects. Representatives of the Environmental Coalition of NGOs, a group of Bangladeshi agencies attempting to raise awareness of the Flood Action Plan within Bangladesh and at UNCED, were consulted.

1.3.3 Visit to Bangladesh

Beyond meeting with local organizations and community members, a two-week visit to Bangladesh provided an opportunity for direct observation of environmental and social conditions. Informal interviews with local farmers and community members provided a glimpse of local perspectives. Soil samples were collected, and simple on-site soil tests were carried out to provide information on soil structure and infiltration rates.

1.3.4 Laboratory Testing

Particle-size distributions, bulk densities, iron and aluminum oxide contents and organic matter contents were determined. Oxide and organic matter contents were measured by the Center for Land and Biological Resources Research, Agriculture Canada. The remaining tests were done in the Geotechnical Science Laboratories, Department of Geography, Carleton University.

1.4 Organization of the Study

The concept of sustainable development is introduced in Chapter Two. The criteria used throughout this analysis to facilitate consideration of the Flood Action Plan are presented.

Chapter Three provides an overview of the bio-physical environments of the Bengal Basin. The discussion highlights the interrelatedness of the environmental systems and processes in operation. Particular attention is paid to the fluvial geomorphology and other hydrological characteristics of the region.

Aspects of the social environment are introduced in Chapter Four. Cultural, political and economic trends are considered in light of rising population and increasing poverty, with a view to understanding current resource distributions within Bangladesh. The nature of foreign development assistance is analyzed to identify its impact on the direction of national planning.

Human responses to the environment are introduced in Chapter Five. The issue of what constitutes a disaster is developed as a topic of importance. Previously implemented flood-control programs are reviewed in an effort to identify associated environmental and social impacts. The effect of structural flood control on the supply and distribution of land and capital resources are highlighted.

In Chapter Six, the potential impacts of the Flood Action Plan on the demand, supply, and distribution of water resources are considered. The ability of surface soils to transmit water is examined in light of the results of preliminary soil tests undertaken

as part of this thesis. The role played by surface soils in regulating the behaviour of the groundwater system is discussed.

In Chapter Seven, the ideas developed throughout the analysis are integrated to consider the sustainability of the Flood Action Plan for Bangladesh. The potential effects of the Flood Action Plan on the supply and distribution of land, water, and capital resources necessary to sustain rural livelihoods are summarized. Alternative approaches to stimulating development in Bangladesh are presented in the concluding sections.

CHAPTER 2

CRITERIA FOR SUSTAINABILITY

It is generally agreed that development is sustainable when it is socially-responsible and environmentally-sound. To achieve this objective, the current economically-biased decision-making model must evolve to reflect the bio-physical costs and benefits inherent in development activities, as well as the full range of social costs and benefits beyond economic considerations. People whose opinions are not currently accounted for in conventional decision-making models must be assured a greater voice (UNCED, 1992; Pollard et al., 1992).

The criteria for sustainability used in this study, were agreed to at the United Nations Conference on Environment and Development (UNCED) as indicated in Agenda 21 (UNCED, 1992), and at the International NGO Forum as described in Alternative Treaties⁴ (Pollard et al., 1992). Within these documents there are differences of opinion as to the causes of, and solutions to, many of the global problems humanity now faces. Despite these differences, there is also agreement on issues of priority and actions to be undertaken. The criteria for sustainability used in this study reflect the agreement that exists between the political powers represented at UNCED and the grassroots

⁴Both conferences were held in Rio De Janeiro, Brazil, in June of 1992. UNCED was attended by representatives of member countries of the United Nations. The International NGO Forum was attended by several thousand representatives of non-governmental organizations from around the globe.

organizations represented at the International Forum of NGOs⁵. While points of difference are important indicators of issues in need of further research or broader opinion, the criteria included in this thesis enable a consideration of sustainability based on the current consensus⁶. In this sense, the criteria represent a point of departure. Additional issues and actions can be incorporated into the analysis of sustainability as they are agreed to.

2.1 Bio-physical Criteria for Sustainability from Agenda 21 and Alternative Treaties

Development must not aggravate environmental problems. Where there are threats of serious or irreversible damage, a precautionary approach must be taken. The lack of scientific certainty concerning a potential impact must not be used to justify postponing measures to prevent the damage.

2.1.1 Bio-diversity

Bio-diversity is threatened by development activities that overexploit, destroy habitats, or cause ecological imbalance through the introduction of foreign plants or animals. Existing species diversity is best conserved via in-situ conservation. The

⁵ The criteria outlined in this chapter do not reflect the full range of issues addressed in either of the documents referred to, but focuses on the issues of relevance to considering the sustainability of the Flood Action Plan.

⁶For example, actions on bio-diversity agreed to at UNCED include in-situ conservation and ex-situ storage in gene banks. However, because at the NGO Forum only in-situ conservation was agreed to, ex-situ storage is not included in the framework. Similarly, the NGO treaties address the issue of unfettered capital accumulation, but because the issue was not addressed in Agenda 21, it is not included in the framework.

integrity of ecosystems needs to be maintained. To this end, an understanding of traditional and indigenous knowledge and practices must be fostered, and the application of such approaches widened.

2.1.2 Land

Some current land management practices ignore impacts that lead to deterioration and permanent degradation of the resource base. Land degradation must be arrested. Waterlogging, salinization, and loss of land fertility must be halted. Erosion must be slowed. Land must be treated as a system of natural resources including soils, water, microorganisms, plants and animals.

Agricultural systems that respect the land's complexity and conserve its productivity are key to sustainably intensifying food and fibre production. Resources must be directed towards the identification of sustainable agricultural practices. The use of chemical pest controls must be reduced. Reliance on chemical fertilizers must be minimized.

Forests are rich reservoirs of bio-diversity and play an important role in soil conservation, the regulation of hydrological cycles, and carbon-dioxide exchange. However, forests have, and continue to be, exploited at unsustainable rates. It is imperative that current levels of forest cover be increased.

Areas prone to drought are particularly vulnerable to land degradation. Such environments require intensive soil/water conservation.

2.1.3 Fresh Water

A progressive destruction of global fresh water resources has resulted in widespread and increasing water scarcity. The availability and quality of water must be protected to ensure the functioning of aquatic ecosystems and to satisfy human needs. Sources of fresh water must be identified and protected. Demand for water must be managed at the lowest appropriate level. Equitable access to potable water supplies and sanitation systems must be ensured. New and indigenous water-use technologies and techniques to preserve water resources must be tested. Greater attention should be paid to small-scale and highly-efficient irrigation schemes. The consideration of land and water issues should be integrated.

2.1.4 Atmosphere

Present energy production and consumption is inefficient, wasteful, and polluting. The efficiency of non-renewable, particularly fossil fuel, consumption must be improved. A greater transition to renewable sources (biomass, wind, tidal, solar, small-scale hydro), is essential. The transportation sector consumes a particularly large proportion of global energy. Transportation can become technically more energy efficient, but locational issues also need addressing.

2.2 Social Criteria for Sustainability from Agenda 21 and Alternative Treaties

2.2.1 Effective Public Participation

The knowledge and opinions of populations affected by development programs must be reflected in project planning and design. Indigenous peoples, farmers, local authorities, trade unions, business/industry, science/technology and NGOs must actively participate. The role of NGOs must be enhanced by providing them with the data and information necessary for their effective contribution to research, design, implementation, and evaluation of development programs. The numbers of women in decision-making positions must be increased. Youth must play a decision-making role. People must be empowered to contribute their knowledge towards the current development challenges.

2.2.2 Poverty

Poverty is forcing millions of people to overexploit and degrade the environment. In addition, the poor are often victims of environmental crises caused by the actions of the rich. Poverty alleviation must become the primary goal of development. Assistance must be directed towards the most vulnerable.

Economic growth is essential to meeting acceptable levels of human well-being. The concepts of growth and prosperity must evolve to rely less on flows of natural resources through the economy and to reflect the availability and true value of resources and activities. In this respect, the value of unpaid work, including domestic work, must be recognized and reflected in national accounting.

A focus on the use of resources to achieve growth without regard for the livelihoods of those who depend on them will have an adverse effect on poverty. Secure, sustainable livelihoods must be ensured. To this end, more livelihood opportunities must be generated, and the range of livelihood activities widened. Equitable remuneration for women's work must be ensured. Local control over resources must be improved. In rural areas such resources include, but are not limited to land, water, technology, and credit. Essential services including health care, food, education, and safe water are key to poverty alleviation and must become universally accessible.

The economic resources of developing countries cannot currently be used to alleviate poverty because of the debt crisis. Debt is responsible for the current net transfer of resources from the developing countries to the developed countries. Debt and debt-servicing of low-income countries must be written off or substantially reduced. Substantial positive net flows to developing countries are essential.

Deteriorating terms of trade for commodities are also obstacles to poverty alleviation. To facilitate the adoption of sustainable practices, commodity prices must reflect the true cost of production. In light of the poor bargaining position of developing countries with respect to commodity prices, dependencies on primary commodity exports should be reduced.

The benefits of growth must be more equitably distributed than has occurred in the past.

2.2.3 Population

Rapid population growth hinders efforts to combat poverty. Poverty, in turn, hinders efforts to address population growth. People are too poor to access health care and education, and have no livelihood security. Because these are precursors to reductions in family size, universal access is essential.

CHAPTER 3 THE BIO-PHYSICAL ENVIRONMENT

3.1 Geomorphology and River Systems

3.1.1 The Bengal Basin

Bangladesh is located almost entirely within a region of Quaternary sediments known as the Bengal Basin (FEC, 1989, II-4.1). Of tectonic origin, the Basin was formed as the Indian plate underthrust the Asian plate, an ongoing process which has also given rise to Asia's Himalayan Mountain complex.

The Bengal Basin comprises the southeastern extent of a 1.5 million km² watershed drained primarily by the Ganges, Brahmaputra, and Meghna rivers. Bangladesh, with an area of 144,000 km², comprises less than 10% of the total catchment area yet operates as the drainage outlet for the south flank of much of the Himalayas (Figure 3.1).

3.1.2 The Rivers of Bangladesh

The three major river systems of Bangladesh, the Brahmaputra/Jamuna, Ganges/Padma, and the Meghna are among the largest and most powerful in the world (Figure 3.2). These rivers, along with an estimated 250 minor rivers, form a 24,000 kilometer, braided stream complex characterized by reaches of meandering morphology (FEC, 1989; Custers, 1992).

FIGURE 3.1 Ganges/Brahmaputra/Meghna Watershed

From TIMES ATLAS, 1989 and JAPAN, 1989

FIGURE 3.2
Major Rivers and Tributaries in Bangladesh

(from SPARRO, 1990)

3.1.2.1 Meandering Rivers

Meandering rivers are sinuous, with water flow typically contained within a single channel. Erosion tends to occur at moderate rates with the channel able to move both laterally and longitudinally⁷. Meandering is believed to be initiated as straight channels modify form to reduce resistance to flow (Leopold, 1964, 233; Chorley, 1969, 421). As flow velocity increases, meandering is intensified.

3.1.2.2 Braided Rivers

Braided rivers are generally wide and shallow, often forming in areas where incohesive, weak banks are subject to collapse (Chorley, 1969, 424). Such rivers are characterized by high levels of bedload sediment transport and the presence of bars or islands which form as larger particles are deposited on the channel bed⁸. In Bangladesh, these islands are called chars. Braided channels can experience periods of intense erosion accompanied by rapid, often extreme, shifting of channel course (Leopold, 1964, 291). Consequently, it is not uncommon for chars, even if existing for many years, to disappear as the result of one flood.

⁷Lateral migration involves the deposition of increasingly fine sediments on the inside of river curves as water levels decrease (Leopold, 1964, 322). Longitudinal or downstream migration is related to a misalignment of bank and flow curvature that increases the potential for bank erosion and caving slightly downstream of bend axes (Leopold, 1964, 291).

⁸Fluctuations in river flow allow particles to settle, but preclude re-initiation of their movement. As the deposits increases in height, flow is divided and the active channels are deepened and/or widened. This process enables an island to emerge above the surface of the water (Leopold, 1964, 292).

3.1.2.3 Channel Migration

The processes of erosion and deposition are responsible for changes in location experienced by both braided and meandering channels. While sediment deposition is primarily a low or declining flow phenomenon, erosion may be experienced as water levels increase and as they recede. In Bangladesh, erosion is particularly serious following the onset of the flood season but occurs throughout the dry season (Adnan, 1992, 6). Roughly 121,213 hectares of land were lost from along the country's three major rivers between 1973 and 1981. An estimated 107,315 hectares accreted in new locations during the same period (Haque and Zaman, 1989).

The intensity and extent of erosion are, in part, controlled by the location of structural resistances, such as bedrock, or impediments, such as embankments. However, major erosion-induced changes to channel morphology still occur during extremely-high river stages or in response to seismic activity (CSE, 1991, 77; Hossain et al., 1987, 18). Bangladesh is located in a highly-active seismic zone⁹ (FEC, 1989, II.4-12).

3.1.2.4 The Brahmaputra/Jamuna System

Of a total length of 2,900 kilometers, 270 kilometers of the Brahmaputra River flow through Bangladesh (Khan and Miah, 1983). Once emerging from the foothills of the Himalayas and entering the Bengal Basin, channel gradient declines to less than 0.2 meters/kilometer and the river assumes a constantly-changing braided morphology (CSE.

⁹The impacts of seismic activity on river behaviour are outlined in Section 5.4.2.

1991, 72). A gradual southerly shift has been observed as the river traverses the Assam Valley in India, north of Bangladesh.

Early in the twentieth century, the Brahmaputra River scoured a new outlet referred to as the Jamuna River. The west bank of the Jamuna River migrates an average of 120 meters/year in a predominantly westerly direction (Rogge and Elahi, 1989, 17). Satellite data indicates that, apart from a few nodes of stability, the entire length of bankline on both sides of the river is mobile (FEC, 1989, II-4.32). Bankline widths have been increasing in recent years (Rogge and Elahi, 1989, 20). Stretches of the river are currently between 10-15 kilometers wide (Custers, 1992).

The highly-braided Tista River, a main tributary of the Brahmaputra/Jamuna system, is also subject to dramatic shifts in course within Bangladesh. The entire system has been migrating back and forth within the Bengal basin for thousands of years, with records of the rivers' movements in existence from 1830. Extensive overbank spill and rapid char and bankline shifting occur regularly (Elahi and Rogge, 1990, 15).

3.1.2.5 The Ganges/Padma System

The Ganges is a predominantly meandering river with braided stretches (FEC, 1989, II.3-2). Of a total length of 2,600 kilometers, only 230 kilometers of the Ganges River lie in Bangladesh (Hossain et al., 1987, 3). At points within Bangladesh, the Ganges River is 5 kilometers wide. Within the country, a past tendency of the river to shift in a northeasterly direction is now hindered by heavy clay soils.

The Ganges and the Jamuna Rivers unite in west-central Bangladesh to form the Padma River. The Padma also has a history of channel migration (Rogers et al., 1989). Between February and December of 1966, downstream of Faridpur, this river dug a new 30 meter deep channel 1,500 meters north of its former location. In 1988, the river encroached on the Chandpur embankment and irrigation project when it dug a new 45 meter deep channel 550 meters east of its previous channel.

3.1.2.6 The Meghna System

The Meghna River originates in the Assam Hills as the River Barak. Like the Ganges, the Meghna River is predominantly meandering with braided stretches. The Meghna has a eastward migratory tendency.

3.1.2.7 The Lower Meghna

Two hundred kilometers before reaching the ocean, the three major rivers of Bangladesh combine to form an immense single river referred to as the Lower Meghna. This river carries an estimated 971 km³ of water annually. Where the three rivers meet to form the Lower Meghna, channel migration is erratic and dramatic. Annual channel shifts in excess of 1.5 kilometers have occurred. Overall, the location of the confluence is gradually shifting northward (FEC, 1989, II.23-9).

3.1.3 Landforms

The rivers of Bangladesh have constructed and are actively contributing to the formation of the world's largest delta (FEC, 1989, II.4-3). Active accumulation is occurring at the delta front, as fine silts and clays settle out of suspension during intertidal flood episodes to form mudflats. As the delta extends outwards, sediments are reworked by the rivers and overlain with additional deposits during flooding.

Extensive river flooding is an annual occurrence in Bangladesh and regularly affects an area which extends between five and ten kilometers on both sides of the country's major rivers (FEC, 1989). Channel migration determines that, over time, the total area influenced by the deposition of river sediments is much wider than the presently active floodplain (Leopold, 1964). Consequently, much of Bangladesh is overlain with alluvial deposits associated with channel migration and with the accretion of sediments during flood episodes (Figure 3.3).

The northern fringe of Bangladesh consists of a series of alluvial fans which formed along the southern flank of the Himalayas (Ministry of Foreign Affairs: Japan, 1989, 8). Other geomorphological formations within Bangladesh include small exposures of Pleistocene sedimentary deposits in northern and central areas, and Tertiary hills, composed of uplifted and faulted sandstones, siltstones and shales, along the eastern perimeter of the country (FEC, 1989, 11-4-2&4).

The rivers flowing through Bangladesh are estimated to carry more than two billions tons of silt annually (Rogers et al., 1989, 9; Ministry of Foreign Affairs: Japan, 1989, S-1). Much of this silt is deposited on the floodplains during flood episodes and

FIGURE 3.3 Geomorphology of Bangladesh

(from FEC.II.4-5, 1989)

contributes to the height of the alluvial plain¹⁰. Such additions to floodplain height are important as most of Bangladesh lies less than five meters above sea level (Milliman et al., 1989). These additions gain particular importance because the entire Bengal basin is subsiding. Data derived by radiometric dating of buried wood suggests an average rate of subsidence of 1 centimeter/year. The French Engineering Consortium estimates a maximum rate of 2.1 cm/year for areas experiencing major subsidence (FEC, 1989, II.4-13). Dependable long-term measurements of subsidence are not available.

The downwarping tendency of the Bengal Basin, associated with tectonic plate movement, and the compression of alluvial sediments are generally accepted as responsible for the subsidence of the ground surface. In general, flood-associated sediment additions and groundwater recharge appear to be counterbalancing the effects of subsidence (FEC, 1989, II.4-13).

Groundwater, which is recharged by water moving down through the soil profile, occupies interstitial spaces that would otherwise be lost to compression. By restricting pore compression, groundwater limits the amount of subsidence occurring¹¹.

3.1.4 Soils

The alluvial soils of Bangladesh are highly fertile, because flood-associated sedimentation of mineral and organic constituents promotes nutrient replenishment. The

¹⁰The degree to which silt deposition contributes to floodplain height on an annual basis is unclear. The French Engineering Consortium describes the process as contributing a "spatially variable increase of several centimeters annually" (FEC, 1989, II-4-3).

¹¹Processes governing the ability of water to enter the ground are discussed in Chapter 6.

region's distinct wet/dry seasons result in the alternating reduction and oxidation of minerals which improve nutrient availability to plants.

The chemical composition and size of soil particles arriving with the floods are important to their fertility-enhancing properties. The finest particles are the most chemically-active and productivity-enhancing components of the soil. Slow moving water is unable to carry relatively large particles but may carry large amounts of fine sediments for deposition. As flow velocity increases, increasingly larger particles will be transported if they are available. Deposition occurs as water velocity decreases and the ability of water to transport soil material declines. The finest particles take the longest to settle. Thus, the longer floodwater remains on the land, the greater the potential for the deposition of fine sediments¹².

Differences in the micro-topography of flooded areas determine a high level of variability in soil characteristics over a small area. Relatively-coarse sediments are deposited in areas of higher elevation. Deposits of fine clays and organic matter accumulate in slowly-draining depressions (Brammer and Khan, 1991).

In general, the topmost floodplain sediments become finer in a southerly direction. The Brahmaputra/Jamuna and Tista floodplains are characterised by fine sand and silty deposits. Deposits of the Meghna floodplain are predominantly silty. The Ganges floodplain presents an anomaly to the general southerly-fining pattern of alluvial deposits. The northern floodplain of the Ganges River is comprised of very-heavy swelling clays.

¹²The recession of floodwater generally occurs at low velocity and it generally has little ability to re-entrain deposited sediments.

while the southern floodplain is comprised of silts and fine sands. Central areas of the country flooded by the Padma are characterized by silty-clay soils. Deposits of the Lower Meghna floodplain are fine clays, due to both river and tidal influences.

Particles eroded from productive locations contribute to the productivity of the location where they are deposited. Sediments derived from degraded sources may reduce the productivity of their new environment. Sediments deposited in Bangladesh are a well-mixed blend of materials derived from both productive and degraded sources.

3.1.5 Estuary and Coastal Environments

Sediment deposition leading to delta formation occurs where rivers meet the ocean. The extent of the Bangladesh delta has remained virtually constant for nearly 200 years due to the balancing of sediment accumulation by coastal erosion and subsidence (Milliman et al., 1989). During the past two decades, river flow has induced exceptionally severe erosion along the eastern bank of the Lower Meghna estuary (Elahi and Rogge, 1990, 33).

River outflows to the Bay of Bengal control the salinity of water in coastal areas. High wet-season discharges push salt water away from the coast. During the dry season, the incursion of saline water upstream into groundwater aquifers is common. In the west, salinity is experienced in excess of 100 kilometers inland (Hossain et al., 1987; Milliman et al., 1989). In the east and close to the Lower Meghna Estuary, the higher volume of water discharging to the Bay of Bengal determines that the inland encroachment of saline water is significantly less.

Saline intrusion and coastal erosion are intensified by the cyclone-associated storm surges common to Bangladesh. Cyclones form over a warm ocean as moisture-laden air begins to travel in a circular pattern around an area of low pressure. Within the cyclone, mean sea level rises about one centimeter for each millibar of air pressure below the air pressure outside the cyclone. High winds within the cyclone, a gradually-sloping sea bed, and the funnel-shaped coastline morphology characteristic of the Bay of Bengal, cause water to pile up near the shore to form a storm surge. Such surges may reach 8-10 meters in height, and the effects may be experienced tens of kilometers inland, particularly if coinciding with high tides. High rainfalls associated with cyclones add to the local drainage burden. Cyclones affecting Bangladesh commonly occur toward the beginning and end of the monsoon season (Haider et al., 1991).

3.2 Rainfall, River Stages and Groundwater

3.2.1 Precipitation

Bangladesh has a monsoonal climate marked by well-differentiated wet and dry seasons. Average annual precipitation is estimated at 2,320 millimeters (Shailo, 1992, 59). Average annual rainfall declines from a high of 5,750 millimeters in the northeast region to a low of 1,250 millimeters in the extreme west. Local rainfalls in excess of 400 millimeters in a single day may be experienced throughout the country.

Some of the highest recorded annual rainfalls in the world are experienced within the Ganges/Brahmaputra/Meghna catchment. On average, over 75% of annual rainfall in

the entire watershed arrives with the monsoons between May and September. This concentration of precipitation exceeds the capacity of the soil to absorb water and the ability of the region's drainage network to remove the excess.

Drought is an irregular phenomena occurring in response to exceptionally low annual levels of precipitation (Clarke, 1991, 2). Poor monsoonal rainfall occasionally results in drought in Bangladesh (Shailo, 1992, 58).

3.2.2 Annual Flooding

Primarily, annual flooding in Bangladesh is associated with increased flows in the major rivers following rainfall in the upper catchments. This flooding is generally characterised by a slow rise and fall of water levels. When such flooding is accompanied by simultaneous localized heavy rainfall, flood levels increase rapidly. In poorly-drained areas, heavy rainfall may be independently responsible for flooding when its intensity exceeds the infiltration capacity of the soil. Floods may also result from high tides and storm surges in coastal areas of low elevation. Tides and storm surges aggravate flooding by congesting the drainage of floodwaters from other sources (Hossain et al., 1987, 16).

Water levels throughout the Brahmaputra system begin to rise in April; high stage occurs between June and September. Flooding is most severe in association with heavy local rainfall. The Brahmaputra system strongly influences the Meghna regime.

Water levels in the Ganges system begin to rise in May; peak flows occur in July or August. Ganges floods affect southwest Bangladesh and are often associated with poor

local rainfall but increased drainage through the river due to heavy rainfall in India (FEC, 1989, II.1-22).

In general, the Brahmaputra River peaks 26 to 40 days before the Ganges. Due to a late Brahmaputra peak, 19% of the time, peak discharges of these rivers at their confluence into the Padma River are reached ten days or less apart (FEC, 1989, II.1-9&13). When this happens, floodwaters remain backed up in both systems until water levels in the Padma River decline. Regional precipitation patterns strongly influence the flood regime in Bangladesh. Recently, a pattern of east/west alternation of rainfall has been noted in the Bengal Basin (Rogers et al., 1989, 12). In some years, droughts over central and north-west India coincide with exceptionally high rainfall within Bangladesh, while higher than average rainfalls in central and northwest India are associated with exceptionally low rainfall in Bangladesh. In the former case, flooding of the Brahmaputra is relatively severe, in the latter, flooding of the Ganges is intensified. In either case, the Padma and Lower Meghna Rivers carry the combined flows of the Ganges and Brahmaputra Rivers, with the result that south central areas of the country are extensively flooded annually.

Areas of the northeast and southeast are subject to flash floods associated with heavy rainfall in the hills coupled with the relatively short, steep courses of the rivers draining them (Hossain et al., 1987, 19).

An estimated 60% of Bangladesh is considered flood susceptible (Figure 3.4). An average of 28% of the country is flooded annually (FEC, 1989, II.1-12). A 20-year

FIGURE 3.4 Flood-Vulnerable Area in Bangladesh

(from FEC. II.2-6.1989)

flood event would inundate 40% of the land area. A 100-year flood event would inundate virtually all of the vulnerable area (FEC, 1989, II.1-11 & II.2-4).

The locationally-specific characteristics of annual flooding vary with the timing of rainfall, river, and coastal influences. In general, flood depths commonly range between 0.3 and 4 meters except on the Meghna floodplain where flood depths may exceed 6 meters (Hossain et al., 1987, 7).

3.2.3 Groundwater

Bangladesh has two distinct groundwater sequences. An upper aquifer is separated by an unsaturated zone from a deeper aquifer, the characteristics of which are now being investigated (FEC, 1989, II.1-32).

Most of Bangladesh is characterized by a surface layer of silty to heavy clay that restricts water movement into the ground. Although in areas of active floodplain erosion the clay layer does not always exist, in other areas it extends to depths of 120 meters. As this surface layer governs the rate of water recharge to the upper aquifer, it is afforded in-depth consideration in Chapter 6, which focuses on water resources.

Below the surface clay layer is a layer of fine sands. This layer is 3 meters thick in the north and northwest of the country, reaching 60 meters in the south and southeast. The fine composition of the materials in this layer determine slow water movement through it (FEC, 1989).

Below the layer of fine sands is the upper aquifer. This aquifer is composed of medium and coarse sands reached at depths of between 6 and 120 meters and extending

to maximum depths of 200 meters. Due to the coarse nature of the materials comprising the upper aquifer, water movement through it is relatively rapid.

3.3 Ecology

3.3.1 River and Floodplain Fisheries

Bangladesh has an environment ideally suited to fisheries productivity. Fluctuating water levels occurring throughout the river-floodplain complex give rise to a system of seasonally-variable habitats that encourage high species diversity (Whitton, 1975, 202). In general, nutrients washed into the aquatic system promote high fisheries productivity.

Most species of fish utilize both a wet season and a dry season habitat, often travelling great distances between these locations (Whitton, 1975, 201). These migrations may be longitudinal, within the main channel, or lateral, across the floodplain. Migration is primarily related to spawning practices and to the availability of food.

The ability of fish to migrate longitudinally is dependant upon temporal patterns of flow velocity and depth of water within the channels. For many fish species, successful reproduction is dependent upon access to the floodplain during the early stages of flooding. A late or inadequate flood may result in the complete failure of reproduction for that year (Welcomme, 1979, 153). Because young fish generally account for over half of the total fish biomass existing within the river/floodplain system, failure of the floods for even two years in succession may significantly reduce the ability of populations to recover (Welcomme, 1979, 3).

Currently, 251 species of fish have been identified as inhabiting Bangladesh's river-floodplain complex. Of these species, 60% require access to the floodplain (Boyce, 1990).

3.3.2 Estuarine Fisheries

Estuaries are those portions of rivers characterised by the mixing of fresh and salt waters. They extend as far inland as the upper limit of the tidal range affecting the river. The mixing of saline and fresh water creates a nutrient-rich environment. Mineral and organic materials, derived from both marine and riverine sources, facilitate high primary productivity which provides a direct food supply for fish. In addition, the brackish water that results, although tolerable by many species, is uninhabitable by many major predator species. Because of the safety and the abundant food supply, estuaries are an important breeding and nursery habitat which supports the productivity of adjacent river and ocean environments (McLusky, 1981, 57).

Estuaries are renowned for their high species diversity, particularly in association with fine, unconsolidated bottom deposits as are characteristic of the coastal areas of Bangladesh (McNeely et al., 1990, 17). Extreme fluctuations in salinity, if they occur, adversely affect species diversity.

3.3.3 Aquatic Vegetation

The pools and depressions of the floodplain and the sheltered alluvial banks of rivers are excellent environments for the production of emergent types of vegetation.

Such vegetation is extremely important to the water purification capacity of the environment (Karpati, et al., 1979, 33; Welcomme, 1979, 65). In Bangladesh, water hyacinths play a vital role in this respect. In addition, upon their decay following submergence by the floods, these plants contribute to the organic matter and nutrient content of the entire floodplain/river system.

Blue-green algae, important for their ability to enhance soil fertility by fixing nitrogen from the atmosphere, thrive in wet-season floodplain conditions, particularly when in symbiotic relationship with native floodplain vegetation (Reynaud and Roger, 1976; Burris, 1988).

3.3.4 Vegetation/Forests

Most floodplains in Bangladesh once supported flood-resistant forest vegetation (Waring and Schlesinger, 1985, 253). The near-complete deforestation of the floodplain represents the loss of an important nutrient sink whereby flood-associated nutrients were stored in the tree biomass and re-contributed to the ecosystem during the dry season. Deforestation also represents the loss of a mechanism whereby nutrients, which have been leached deep into the soil, are recaptured by deep and extensive root systems and returned to the surface. Such root systems once facilitated the downward movement and storage of water in the soil thereby ameliorating the extremes of floods and droughts. In addition, the stabilizing effects of trees growing along riverbanks reduced erosion and the intensity and rapidity of river migrations.

Coastal mangrove forests, capable of absorbing much of the energy of cyclone-driven storm surges, once protected Bangladesh's coast but have largely been removed.

3.4 Summary

A 24,000 kilometer river network, formed by three of the world's largest and most powerful rivers and an estimated 250 smaller rivers, determine that the bio-physical environments of Bangladesh are governed by hydrological processes.

Flooding gives rise to sediment deposition and promotes groundwater recharge, which are currently offsetting the effects of subsidence. Material carried by the rivers is also deposited at the delta front where it contributes to the formation of the delta and offsets the effects of coastal erosion and subsidence.

Flooding facilitates the replenishing of water supplies in both surface and subsurface reservoirs. Such stores of water offset the impacts associated with occasional drought in Bangladesh.

The nature of the hydrological regime is also responsible for high species diversity. Flow depth and velocity, and flood extent and duration determine the existence of migration routes, the variety and abundance of habitats, and the availability of nutrients essential to species survival.

Hydrological processes, particularly those associated with annual flooding, are integral to maintaining environmental balance in Bangladesh.

CHAPTER 4

THE SOCIO-ECONOMIC ENVIRONMENT

4.1 Socio-Political Experience

East Bengal¹³ has been a region of frequent political change. Prior to 1202 A.D., the Hindu caste system of inherited social status and responsibility operated to sustain a predominantly agricultural society. During this period, the vast wealth of a few was dependent upon resource concentration and exploitation of the poor masses via social repression (Baxter, 1984).

1202 A.D., marked the beginning of a period of external dominance by Muslim overlords, during which Islam replaced Hinduism as the dominant religion (Ahmed, 1986). The position of the poor masses was improved and many were able to purchase land from the previously powerful minority, whose economic advantages were now reduced. Resource redistribution encouraged innovation and investment, and the region's productive capacities expanded. The region's rich harvests and production of highly-prized fine muslin cloth earned it the title, *Sonar Bangla*, meaning Golden Bengal. This period of relative prosperity lasted through the seventeenth century (Malik, 1991).

In 1757, the British extended their control into East Bengal, such that the area became little more than a commercial hinterland providing textiles, agricultural products, and labour to Calcutta, the administrative seat of British India (Baxter, 1984). Because the British dealt exclusively with large landowners and industrialists, small farmers and

¹³East Bengal encompasses the portion of the Bengal Basin that is now Bangladesh.

businesses became relatively disadvantaged and economic disparities increased. Social unrest fuelled by rising inequality and poverty erupted into an unsuccessful vie for India's independence led by East Bengalis. This prompted the British to deny East Bengal representation within their administrative system and to drastically reduce the amount of goods, particularly fabrics, exported from the region. This devastated the economy and left East Bengal lagging behind the rest of the subcontinent in terms of infrastructure and industrial development.

In 1947, former British India was divided into India and Pakistan. Due to the region's Muslim majority, despite language differences and thousands of kilometers of India separating them, the area that is now Bangladesh joined Pakistan to become East Pakistan (Johnson, 1982).

West Pakistan had many experienced public servants able to undertake operation of the inherited British administrative system. Without experience and trained personnel, East Pakistan continued to lack effective political representation. Thus, although over 70% of Pakistan's export earnings were generated by East Pakistan's jute, only a negligible amount was reinvested into the region¹⁴. Consequently, when world jute demand declined in the 1960s, a lack of education and diversification left East Pakistan without economic alternatives. The West Pakistani-dominated government adopted a policy allowing the immediate procurement of land if taxes were not paid promptly. The procured land was generally granted or sold to West Pakistanis, who imposed virtually

¹⁴During this period it was estimated that the standard of living in West Pakistan was 60% greater than in East Pakistan (Johnson, 1982).

impossible leasing conditions on their tenants. Rack renting, absentee landlordism, intermediary rent-receiving interests, insecure tenancy, usurious money lending, and speculative trade in produce became a way of life for the region's agriculturalists. Twenty years of domination by West Pakistan was marked by agricultural stagnation, increasing food imports, and chronic near-famine conditions (Johnson, 1982).

In December of 1971, after years of conflict and nine months of brutal war, the region achieved political autonomy to become the People's Republic of Bangladesh (Ahmad, 1972). A newly-framed constitution encompassed the ideals of democracy and egalitarianism. The economic structure was based primarily on state ownership with an emphasis on cooperatives and private property within prescribed limits. Regardless, as property and other assets forfeited by wealthy West Pakistanis fleeing the country became available, members of the new government adopted corrupt practices ensuring their own access to them. Many wealthy Pakistanis were granted amnesty and allowed to retain their lands and other assets (IASG, 1987, 4).

Despite planned land reform measures, ranging from the abolition of oppressive leasing practices to redistribution of land in excess of ceiling amounts, efforts to improve equity were diluted and ineffective. Enacted reforms supported large-scale, input-intensive agriculture and the establishment of subsidized farming cooperatives, the benefits of which were monopolized by the relatively rich (IASG, 1987). Land tenure policies established by the Government of Pakistan were maintained despite ongoing rhetoric concerning reform (Baxter, 1984).

Since independence, the political/administrative system has been dominated by corrupt and unprincipled members of the military, the bureaucracy, and the government (Khan and Zafarullah, 1988, 179). Political and economic strategies have strengthened the position of non-productive intermediaries and monied elites at the expense of the country's primary producers. Members of public institutions have not used the parliamentary system to change things because opposition to the status quo jeopardizes personal power. There have been many instances of corruption within the Election Commission. Public confidence in the democratic process is low.

The present administrative structure was established by the now-imprisoned former President H.M. Ershad. Leading a "reformist" military regime, Ershad took power in 1981 and consolidated his power through political and administrative restructuring before staging an election marking a return to "civilian" rule (Khan and Zafarullah, 1988, 176). During Ershad's tenure, new constitutional provisions ensured decisions were difficult or impossible to resist or revoke. Major policies were designed primarily to strengthen the presidential position by favouring the urban moneyed class. It was in this political climate of unrepresentative and unresponsive government that the Flood Action Plan, the focus of this thesis, was approved by Ershad and ratified by his assembly. Although a new national leader took power in 1990¹⁵, an entrenched bureaucracy and a historical

¹⁵President Khaleda Zia is Bangladesh's first female president. She is the widow of former President General Zia who was assassinated in 1981 prior to Ershad's takeover (Malik, 1991).

legacy of repression, exploitation, and corruption perpetuate the almost total dependence on foreign aid that exists today¹⁶ (Khan and Zafarullah, 1988, 171).

4.2 Population and Poverty

Although historically a heavily-populated region, population rose sharply in response to declining mortality following 1950. Bangladesh is currently home to an estimated 110 million people (CIDA, 1990). 87% of the population is rural (Rogge and Elahi, 1989, 3). Average population density is 770 people per square kilometer, but in floodplain areas, population densities may exceed 1500 people per square kilometer (World Bank, May 1990). Population growth is currently 2.5% annually (CIDA, 1990).

Poverty is any deprivation relating to insufficient control over or access to the resources necessary to maintain acceptable standards of living (World Bank, 1990). The majority of Bangladeshis live in conditions that by most standards can only be described as absolute poverty (North-South Institute, 1985, 2). Although estimates vary widely, there is general agreement that calorie intake, literacy, rate of school enrolment, adequacy of shelter, and life expectancy are declining (CIDA, 1990).

In this predominantly traditional Muslim society, women are particularly disadvantaged. Women are less able to access resources, suffer more chronic malnutrition, are highly vulnerable to physical abuse, and have lower life expectancies than men¹⁷. Although Bangladeshi women have strong legal rights, few women are aware

¹⁶50% of government spending is financed by foreign aid (Malik, 1991, 75).

¹⁷Average life expectancy is 52 years of age (World Bank, 1992).

of them or are in a position to seek justice when wronged. Traditional perceptions and practices preclude women from accessing the opportunities that exist. While expanding networks of women's groups are introducing alternatives, most areas are in the very early stages of women's emerging from traditional constraints. In general, women remain highly dependant upon men for access to assets and resources.

Overpopulation is commonly said to be the cause of poverty throughout the developing world. While population pressures are a contributing factor, poverty is a symptom of institutional structures that initiate, maintain, and increase inequities within and between societies (North-South Institute, 1985, 7; UNDP, 1992; Pollard et al., 1992). Development assistance has contributed to this process by promoting programs that, through the provision of capital and material inputs, consolidate vested interests and facilitate the monopolization of resources by specific groups. Such resource control gives these groups access to and power over additional resources by increasing their social, economic, and political strength and flexibility. Conversely, loss of access to resources by the disadvantaged initiates a trend of declining opportunities and rights.

4.3 Current Economic Conditions

4.3.1 Agriculture

Landownership status is the most important predictor of income in Bangladesh (Elahi and Rogge, 1990, 40). Greater than 65% of rural households are landless or own less than .5 acres of land (CIDA, 1992). Of those who own land, 40% own between .5

and 1 acre. Only 12% of landowners own more than 5 acres¹⁸. A concentration of land ownership determines that currently, sharecropping is the predominant form of tenancy in Bangladesh.

National development programs are encouraging large landowners to modernize and adopt more mechanized farming practices. This reduces sharecropping opportunities, and induces a deterioration of contractual terms for sharecroppers (North-South Institute, 1985, 10). Since large landowners monopolize government credit and subsidized inputs, both sharecroppers and small landholding farmers generally suffer from perpetual indebtedness to the landed elites¹⁹. Interest rates charged by non-institutional money lenders often exceed 100% and occasionally even exceed 200% (Hossain et al., 1987, 35). By acting simultaneously as landlord, employer, moneylender, and often as government or marketing intermediary, large landowners are able to extract agricultural surpluses (Chowdhury, 1982; Hossain et al., 1987). Subsistence and marginal farmers motivated to improve productivity do not have access to resources enabling them to do so. Consequently, per acre yields of rice, the country's major crop, remain among the lowest in the world (North-South Institute, 1985, 13; IASG, 1987, 4).

Policies designed to stem the concentration of land ownership or to stop the rising numbers of landless farmers have not been implemented by the government or demanded

¹⁸For comparison, Bangladesh has a total cultivable area of 9.5 million hectares (Abbas, 1989, 8) and an average household size of 5.75 people (Hossain et al., 1987). Based on a total population of 110 million people, if land were equally distributed among all households, each family would be entitled to approximately .5 ha or 1.2 acres.

¹⁹"...over 80% of credit requirements are being met from non-institutional sources, often at exorbitant interest rates" (Inter Pares, 1986).

by financial donors. In part, this stems from the practice of quantifying development achievements in terms of rising GNP. Farms operated by wealthy owners are more conducive to the HYV and other modern agricultural technologies promoted for their contribution to export earnings. Modern farms also contribute more to GNP because of the wage labour required for their operation. Traditional farms provide more employment in real terms, but, because it is primarily monetarily unpaid family labour, its contribution to GNP is not considered (World Bank, 1987).

The most important alternative for farmers without access to land is to sell their labour. However, wage labour opportunities are scarce and wage rates insufficient to meet even the most basic family needs (World Bank, 1987). Real wages for agricultural workers fell 30% between 1950 and 1980 due to slow growth in demand for agricultural labour and rising labour supply (Wennergren, 1986, 78). In recent years, wages have further declined (World Bank, March 1992, 5).

The World Bank states that Bangladesh is nearly self-sufficient in terms of foodgrains production (World Bank, November, 1992, 6). Despite this, Bangladesh is heavily-dependant upon food imports to combat near-famine conditions experienced throughout the country each year (Inter Pares, 1989; Ministry of Foreign Affairs: Japan, 1989, 4). While the export orientation of agriculture has expanded the area of land devoted to HYV rice such that agriculture accounts for 85% of exports and 46% of GNP, the acreage under pulses, oilseeds and other important subsistence crops has diminished. Although these foods are now imported, their relative expense determines that they are out of reach of most Bangladeshis. Overall, famine and endemic malnutrition in

Bangladesh relate to the inability of the poor to afford to purchase the available food rather than to food shortages (ADAB, 1984; Sen, 1989; CIDA, 1990).

4.3.2 Fisheries

Fish provide 70% of the animal protein intake of Bangladeshis (Rogers et al., 1989), and it is estimated that 73% of all rural households rely on fishing as a livelihood for at least part of the year (Boyce, 1990). A concentrated emphasis on modernizing the agricultural sector has reduced the importance afforded and attention paid to the fisheries sector. In Bangladesh, this agricultural bias has undermined the productivity of both culture and capture fisheries (Treygo and Dean, 1989).

Embankments preclude the access of migrating species to the floodplain to breed. High velocity flows occurring within embankments wash fish downstream. Sharp declines in open-water capture fisheries followed the construction of a number of flood-control structures (Adnan, 71, 1991).

Some of the chemicals upon which modern agriculture has become dependant are toxic to fish. After application to the land, agricultural chemicals enter the drainage network. Even low-level exposure may cause reproductive failure in many species (Treygo and Dean, 1989).

River fisheries productivity is also undermined as increasing amounts of water are withdrawn from rivers to meet the demand for irrigation. Such withdrawals also reduce surface discharges to the ocean thereby altering the ecology of estuaries and mangrove swamps, often at the expense of their productivity (Milliman et al., 1989).

In the early 1980s, Bangladesh recorded the lowest inland fish yields in all of Asia despite a natural environment ideally-suited to inland capture fisheries (deVlyder, 1982). In total, inland fisheries declined by an estimated 25% between the mid-seventies and mid-eighties (North-South Institute, 1985, 14), and have continued to decline steadily (Treygo and Dean, 1989).

Currently, the use of submersible embankments to protect rice crops by delaying the onset of flooding is being researched as a component of the Flood Action Plan. Such embankments would enable fish to migrate onto the floodplain later in the flood season. However, to ensure successful reproduction, fish may require access at the same time that flooding will be precluded in support of HYV agriculture.

The development of fish hatcheries, in support of commercial restocking of the floodplain, is planned to ameliorate the adverse effects of Flood Action Plan projects on fisheries. (Multinational Monitor, April 1993; World Bank, March 1992). However, although commercial aquaculture will offset the loss of capture fish stocks by maintaining or even increasing the output of certain species, bio-diversity will be adversely affected. In addition, commercially-produced fish are relatively expensive and, therefore, less accessible by the poor.

4.3.3 Industry

The lead-up to and initiation of the Flood Action Plan has contributed to the growth and development of the local consulting industry (World Bank, March 1992). However, in general, industrialization has done little to alleviate the shortage of

employment opportunities in Bangladesh (North-South Institute, 1985, 13). In fact, urban-based, capital-intensive industrialization has accelerated impoverishment as modern industrial products are substituted for more labour-intensive local products. In particular, the traditionally-important handloom sector suffers in this respect.

A number of locally-important industries are suffering from the effects of widespread and severe wood shortages due to deforestation. In turn, wood shortages are exacerbating deforestation as the high prices offered for logs and fuelwood motivate farmers to fell their homestead trees. The sugar and molasses producing industry has been brought to near collapse as farmers, in need of immediate cash, have cut down their date palms to sell as fuelwood in lieu of tapping the sap²⁰ (Byron, 1985). The brick-making industry, which relies heavily on wood as an energy source, is generating a significant proportion of the demand for trees. In addition, the country's sawmills require a sufficient supply of increasingly scarce logs to maintain their operations.

The garment industry provides employment to many people and is promoted by the government and the World Bank for its foreign exchange earning capacity (World Bank, 1987). To remain globally competitive, over the last decade, the garment industry has systematically replaced male employees, who have agitated for better wages and working conditions, with even less-empowered women and children (Todd, 1992). Current working conditions are exploitive and inhumane.

²⁰ Additional information on the homestead forest industry is provided in Appendix I.

4.4 Foreign Assistance

World Bank figures indicate that development assistance to Bangladesh increased from \$1.2 billion in 1985 to \$2.1 billion in 1990 (World Bank, 1992, 256). The majority of these resources are channelled as government-to-government aid. Foreign aid channelled through Bangladesh's political and bureaucratic channels has repeatedly served the interests of the powerful. Despite such experience, under the guise of political non-interference, donors have not pursued an alternative pattern of resource organization and distribution (North-South Institute, 1985, 18; Brecher, 1989, 2; Brodhead, 1989, 5). As a result, poverty in Bangladesh has not only persisted, but has worsened. The numbers of poor people are increasing, both in absolute terms and as a proportion of the population, despite massive injections of foreign capital and expertise (CIDA, 1992).

4.4.1 Poverty Alleviation

The World Bank states that the primary objective of development is to eliminate poverty (World Bank, 1992, 29). Progress towards development is equated to rising GNP translated into increasing per-capita incomes. In the past, achieving this objective was believed possible by subsidizing the powerful sectors within a society as a stimulus to national growth. The trickle-down policy was expected to take care of social distribution of the benefits of such development. However, in practice, the relative poverty of the masses has increased, and the trickle down theory has been discredited (Amin, 1990; Dube, 1988).

The World Bank describes the disproportionate benefiting of the rich that accompanies growth as a short term and unavoidable cost of longer term development (World Bank, 1989). They maintain that with greater attention to the promotion of labour-intensive economic activities, with time, the benefits of growth will be experienced broadly. They suggest that in the interim, basic-needs programs are necessary to assist the poor. However, the domestic provision of basic-needs and other social programs conflicts with debt-recovery strategies upon which access to international economic assistance is currently contingent (Brodhead, 1989).

4.4.2 Structural Adjustment

Over the last two decades, a policy of structural adjustment has been espoused by the World Bank, the International Monetary Fund and most bilateral donor agencies. Structural adjustment policies are designed to expedite national growth and reduce developing world trade deficits, thereby easing the burden of debt repayment²¹. This is accomplished by channelling the bulk of available development resources to areas of high growth potential²², directing industrial and agricultural production toward export markets, and reducing government expenditures on public programs and services such as health care and education (Clark, 1987; House of Commons, 1989).

²¹ Developing countries pay \$50 billion more in debt servicing than they receive in new capital from the developed countries annually. Despite this, the foreign debt continues to grow rapidly (Pollard et al., 1992, 66).

²² Input-intensive HYV agriculture, manufacturing, and shrimp cultivation are considered areas of high growth potential in Bangladesh (World Bank, 1987). The relatively-recent introduction of shrimp cultivation has contributed to mangrove deforestation (Custers, 1992), and led to widespread violent conflict between shrimp cultivators and farmers with conflicting water needs (Adnan, 1991).

The implementation of structural adjustment requires large amounts of capital. Because the majority of developing world populations are poor, and the wealthy minority prefer to invest in foreign opportunities, land, or other non-liquid assets, domestic savings are insufficient to this end. Consequently, even when the provision of public services is reduced and taxes raised, imported capital must be relied on. Imported capital is generally only available when opportunities attractive to foreign governments and international institutions exist. What is attractive to foreign capital are inexpensive exports and aid programs relying on foreign imports of materials or expertise. Future dependencies on such inputs are easily developed through agreements and contracts that tie aid-financed purchases to donor countries, plans that rely on foreign experts, or other, often complex, concessional and commercial aid packages (Brecher, 1989). Contingencies imposed as a result of debt and other dependencies represent an effective loss of national sovereignty (Pollard et al., 1992, 63).

Structural adjustment has been widely criticized as promoting underemployment and declining wage rates, the deterioration of social services, and unsustainable patterns of resource use (House of Commons, 1989, 9; Clark, 1987). In Bangladesh, although facilitating a rise in GNP, structural adjustment has done little to promote equity, social justice, or resource access by the poor. Thus, economic growth continues to disproportionately benefit the socially and economically powerful who, in keeping with historical norms, continue to exploit the poor and to concentrate resources. To date, growth-oriented development has been largely ineffectual at alleviating poverty in Bangladesh. Many argue that this failure reflects ongoing inattention to the need for more

equitable distribution of the benefits of growth (Environmental Coalition of NGOs, 1992, 4). The World Bank maintains that current failures to alleviate poverty reflect inadequate growth. Failure to achieve the required levels of growth are in turn blamed on the floods intrinsic to Bangladesh.

4.4.3 Flood Control and Structural Adjustment

The primary objective of the Flood Action Plan is to reduce the risks associated with floodplain agriculture thereby facilitating the shift from traditional to modern HYV agriculture²³ (World Bank, November 1992). Flood-control investments are to be based on long-term loans²⁴. The cost of the initial studies and the construction of pilot projects begun in late 1992 have been estimated at US\$500 million. The projected cost of constructing embankments along Bangladesh's major rivers is US\$6 billion. Maintenance costs are expected to run about US\$600 million annually (Rogers et al., 1989). Although high, the estimated annual maintenance costs appear reasonable given that hundreds of kilometers of embankments are damaged or destroyed by high river flows each year²⁵. Annual maintenance costs of embankments along the lower stretches of the Mississippi River average US\$1 million per river mile (Rogers et al., 1989).

²³See Appendix II for a comparison of the characteristics of traditional and HYV rice varieties.

²⁴The World Bank estimates Bangladesh's total external debt to be U.S. \$12.3 billion. In 1990, debt servicing accounted for 25.4% of Bangladesh's export income. The ratio of debt servicing to export income is used to evaluate a country's ability to service additional debt (World Bank, 1992, 264 & 296).

²⁵The 1993 floods damaged or destroyed 1,080 kilometers of embankments (U.N., 1993).

Flood-control investments will add significantly to Bangladesh's foreign debt. It is expected that these investments will stimulate an increase in export income that enables this additional debt to be serviced while producing a surplus for domestic use.

Flood-control represents an attractive vehicle supporting structural adjustment programs by promoting input-intensive agriculture for export markets and requiring huge inputs of foreign capital, materials, and expertise.

4.5 Summary

The majority of Bangladeshis are extremely poor. Chronic malnutrition and near-famine conditions are endemic, and average calorie intake is declining. Literacy and the rate of school enrolment are declining. Women are particularly disadvantaged. Historical and ongoing processes of resource concentration, political and administrative corruption and irresponsibility have strengthened the position of a powerful minority of people at the expense of the majority of Bangladeshis. Development assistance has generally supported these trends.

The stated goal of official development assistance is to alleviate poverty. However, past efforts, although facilitating growth in GNP, have intensified poverty as distributive issues have not been adequately addressed. Current government-to-government assistance is contingent upon adherence to structural adjustment programs to enable debt repayment. Although easing debt servicing pressures, the implementation of such programs often lead to increasing indebtedness. Structural adjustment programs, aimed at ensuring debt repayment, adversely impact on the poor by reducing the ability

of the government to provide essential services and by promoting low wage rates. Proponents of structural adjustment believe that failure of the program to alleviate poverty in Bangladesh reflects an inability to achieve adequate levels of growth due to annual flooding. Therefore, the primary objective of the Flood Action Plan is to reduce risks associated with HYV agriculture on the floodplains thereby promoting the additional growth in GNP believed necessary for poverty alleviation.

Agriculture now accounts for the majority of Bangladesh's exports. This export orientation has reduced the land area devoted to important local food crops such that, although nearly self-sufficient in foodgrain production, Bangladesh has become heavily dependant upon expensive food imports inaccessible by the poor. Also adversely affecting the poor, past efforts to modernize the agricultural sector have undermined the productivity of the fisheries sector with negative effects on food supplies and livelihoods. Modern industry has done little to alleviate the presently severe shortage of livelihood opportunities.

Current social and political conditions within Bangladesh promote and intensify the impoverishment of an increasing proportion of the country's population. Although historically, resource redistribution led to economic diversification and growth, and a lessening of the effects of poverty, there is no political will to enact such change at this time.

CHAPTER 5

HUMAN RESPONSES TO THE FLOODPLAIN ENVIRONMENT

5.1 Floods as Opportunities

Floodplain dwellers have learned to prepare for and to benefit from the annual floods. Homesteads are built on earthen mounds raised just above the normal flood level to provide refuge for families and animals during the floods. Commonly, earth for the mounds is obtained by excavating tanks to store water for aquaculture, irrigation, and domestic purposes. Water supplies in such tanks are maintained through the dry season by lateral outflows of near-surface groundwater (FEC, 1989, II.1-53). Shallow hand-dug wells are used to exploit water, stored in the upper 2-3 meters of soil, for potable purposes (FEC, 1989, II.1-55).

Bangladeshi households are traditionally extended and often include the household head's grown son and/or brother and their wives and children. This arrangement is beneficial as it provides a labour supply for farming, tank excavation, homestead mound building, and other labour-intensive activities. For women confined to their household compounds by the traditional Muslim practice of purdah²⁶, it provides companionship and enables a division of domestic labour that increases the time available for income-

²⁶Purdah is the practice of screening women from the outside world. The ability of the women in a family to practice purdah often defines their family's social status regardless of economic position. Adherence to purdah facilitates a good marriage that may improve a family's social influence and ultimately their access to resources (Carr, 1985, 4).

generating activities such as raising animals, weaving, and fruit and vegetable growing²⁷.

In areas, rural housing is constructed from fine clay soils which become very resistant when baked in the sun. Alternatively, rural homes may be built using thatch matting generally woven from aquatic plants or palm leaves.

Platforms erected within homes provide refuge in the event of an unusually high flood. Since the current associated with the floods is generally very low, rooftops commonly function as islands. People seldom leave their homes unless their physical survival is threatened (Hossain et al., 1987, 24). Thatch homes may be collapsible and transportable (Rosberg and Desroches, 1992). Small boats, designed specifically for floodplain use, transport family and belongings to safety in the event of severe flooding. When flood depths are within the normal range, these boats are used to travel between homesteads and raised commercial areas to maintain community contacts and to enable trade. Floods provide opportunities for people with boats to generate income by using them as taxis, or for commercial transport. People in remote areas often depend on the navigation routes opened by flooding to get their goods to markets (Cuny, 1990, 66).

The vast majority of Bangladeshis rely on agriculture, fisheries, or a combination of the two for their livelihoods. Rice accounts for 78% of agricultural production (World Bank, May 1990, 33). Jute, the second most important crop is grown on an estimated 5% of cultivable land. In general, climate permits three croppings of rice annually although floodwater inundation and drought reduce this potential in some areas. The varieties

²⁷Women's dry season production of fruit and vegetables contributes between 28-46% of annual family income (CIDA, 1992).

planted and the agricultural systems used reflect each area's particular water regime. Because the extent and intensity of floodwater inundation are not static, farmers have become highly sensitive to the changing environment and know how to adapt their agricultural practices in response (Sadeque, 1991).

There are an estimated 10,000 indigenous varieties of rice in Bangladesh (Custers, 1992). Indigenous rice varieties are highly suited to the floodplain environment.

The Bangla term, *aus*, refers to the varieties of rice that are planted prior to the arrival of the floods in March or April. In general, *Aus* varieties are rapidly maturing and ready for harvesting in July or August. *Aus* provides farmers a relatively assured harvest even if the floods are early as, unless floodwaters are heavily silt-laden, these varieties can survive being submerged for several days (Hossain et al., 1987; Rogers et al. 1989).

Deepwater *aman* is sown at about the same time as *aus* but harvested after the recession of the floodwaters. *Aman* is damaged only if completely submerged. Since deepwater *aman* can grow .3 meters daily to a height of 6 meters, if the water arrives no faster, the crop will not be significantly affected (Hossain et al., 1987, 31). Deepwater *aman* is commonly grown in water so deep that it is harvested by boat (Boyce, 1990).

Subsistence farmers commonly broadcast a mixture of *aus* and *aman*. This strategy reduces cultivation costs while producing two seasonally distributed harvests from the same field, timed in accordance with subsistence requirements (Sadeque, 1991). Following the *aman* harvest, it is customary for farmers to broadcast a mixture of oilseeds and pulses. Dry-season varieties of rice are traditionally grown when a wet-season rice crop is precluded due to intense flooding. Harvests following heavy floods are generally

higher than otherwise as greater soil moisture reserves are available to sustain plants through the dry season (Figure 5.1 and Table 5.1).

Farmers may lower input costs by broadcasting rather than transplanting rice, but, because yields are higher, rice is likely to be transplanted if sufficient labour can be accessed and the risks associated with either flood or drought are considered acceptable.

In general, harvesting is done manually and agricultural residues are left on the surface until being ploughed under prior to the next planting. Ploughing is done with oxen. Their dung is also applied to the soil. Fertilizers are not commonly used as flood-associated silt depositions replenish soil fertility.

Earthen bunds constructed from surface soils are used to enclose agricultural fields. Fields enclosed in this manner are called polders. Within the polders, soils are intentionally puddled so as to create an impermeable layer which inhibits drainage and retains water on the surface. In areas where irrigation is practised, the water is traditionally derived from surface sources which are replenished by the floods. Water is conveyed from other fields, surface channels, or hand-dug tanks into these polders via labour-intensive dhunes or swing baskets. Landscaping is commonly undertaken to change the land elevation between polders thereby using gravity to direct water flow across a series of fields.

Fishing provides a livelihood for millions of Bangladeshis and augments the inadequate livelihoods and diets of many more (Adnan, 1991). 80% of Bangladesh's annual fish catch is of inland origin (Adnan, 1991, 71). Many Bangladeshis have access to fish, because while flooded, the floodplain is treated as a common property

Figure 5.1

From Rogers, 1989; FEC II.1-11; Japan, 1989; Shailo, 1992

Table 5.1

RICE PRODUCTION: MORE AND LESS FLOODED DISTRICTS (1980-1985)

DISTRICT	AVERAGE PRODUCTION (1000 tons)				% of PRODUCTION		
	Total	Aus	Aman	Boro	Aus	Aman	Boro
MORE FLOODED							
Bogra	648	115	387	146	18	60	23
Pabna	446	117	214	115	26	48	26
Faridpur	462	136	214	112	29	46	24
Comilla	1015	226	490	299	22	48	29
Tangail	505	100	191	214	20	38	42
Sylhet	1183	199	542	442	17	46	37
Mymensingh	1611	381	678	552	24	42	34
Jessore	568	184	304	80	32	54	14
LESS FLOODED							
Rajshahi	825	160	530	135	19	64	16
Noakhali	692	156	380	156	23	55	23
Barisal	720	176	450	94	24	63	13
Kushtia	222	133	81	8	60	36	4
Khulna	633	55	528	50	9	83	8
Rangpur	1292	297	876	119	23	68	9
Chittagong	917	144	457	316	16	50	34
Patuakhali	428	66	346	16	15	81	4
Dinajpur	703	182	490	31	26	70	4
TOTAL: MORE FLOODED	6438	1458	3020	1960	23	47	30
TOTAL: LESS FLOODED	6432	1369	4138	925	21	64	14

(adapted from Rogers, 1989)

environment. Floods refresh and replenish the supply of water and fish in the tanks. As floodwaters recede, fish are trapped in tanks and later harvested.

Aquatic plants are harvested as food or as materials for mat weaving. Aquatic-resource harvesting accounts for up to 25% of the annual income of landless and marginal farmers (Sadeque, 1991, 53).

The activities outlined here do not represent an exhaustive treatment of the relationships between people, floods, and the floodplain environment. Scant information in the literature relating to indigenous perceptions and understanding of the floods and the floodplain environment suggest that there are additional preparedness strategies and livelihood opportunities not considered here. However, it is clear that floodplain inhabitants have devised systems which protect them from the adverse effects of flooding and enable them to benefit from the flooding.

Agricultural strategies are both intensive and risk reducing to reflect the productive potentials and constraints of the natural environment. Farmers use the fine, flood-deposited sediments for construction and to landscape their fields to direct water flow for irrigation. Excavations are used to store floodwater for dry-season domestic and agricultural use. Floods stock excavations and natural water bodies with fish for later harvesting. The floods create a common-property environment providing livelihoods for many Bangladeshis. Floodplain fishing and aquatic-plant harvesting are particularly important in this respect. Boat builders and boat owners benefit from the floods as demand for transportation by boat increases. People in remote areas are often highly dependant upon the seasonal navigation routes presented by the floods. These

opportunities exist in direct response to the occurrence of flooding. Additional flood-related opportunities are likely to exist but have yet to be identified or adequately considered.

5.2 Floods as Disasters

"A disaster is a natural or human-induced event causing an acute state of crisis to the extent that the affected country, region, or community can no longer rely on its own resources to cope..." (R&R, 1992).

According to this definition, flood episodes in Bangladesh are, increasingly, disasters (Table 5.2). Although the majority of Bangladeshis perceive the annual floods as essential to maintaining a diverse range of agricultural, fishing, and commercial livelihoods, there are indications that the numbers of people adversely affected by the floods are rising annually (ADAB, 1984; Brammer and Khan, 1991). Famine, incidence of disease, population displacement, and economic marginalization are increasingly evident in the wake of flood occurrences in Bangladesh. This likely reflects, at least in part, the fact that population growth exposes more people to the effects of flooding. It is also possible that people's socio-economic and political circumstances preclude them from implementing strategies and activities which protect them from the negative aspects of the floods or which allow them to benefit from the positive. Another possibility is that the floods are becoming physically worse and are now beyond the ability of traditional coping strategies to address them. A further possibility is that human interventions designed to alleviate flooding have aggravated it locally and changed ecosystem behaviour such that traditional coping mechanisms no longer function effectively.

Table 5.2

IMPACT OF THE 100 YEAR FLOOD IN BANGLADESH - 1988

PHYSICAL DAMAGES	
HOUSING	7.2 million houses totally or partially destroyed
RICE	2.5 million tons damaged or destroyed
LIVESTOCK	172,000 cattle and goats 410,000 chicken and other fowl
FLOOD-CONTROL STRUCTURES	2,500 km of embankments 1,900 hydraulic structures
ROADS	3,000 km of national roads 10,000 km of regional roads 913 bridges and culverts
RAILWAYS	1,303 km of track 269 bridges
COMMUNICATIONS	20,400 telephone circuits
ELECTRIC POWER	16 substations 2,000 km of distribution lines 12,000 power poles
INDUSTRY	1,070 small/medium sized factories
PUBLIC HEALTH	1,468 hospitals and health centers
EDUCATION	19,016 schools
WATER SUPPLY	240,000 hand-pump wells
SOCIAL IMPACT	
DEATHS	1,644
REFUGEES	3.8 million
CASES OF DYSENTERY	1.3 million

from Japan, 1989.

5.3 The Changing Nature of the Floods

It is as yet unclear if and in what ways the physical nature of the floods is changing. Annual meteorological and streamflow data indicate no increase in the volume of water entering Bangladesh during the last decade. Despite these findings, some areas report higher flood levels, stronger currents, and longer inundation times than in the past (R&R, 1989; Hossain et al., 1987). This suggests that the time it takes for the normal volume of water to enter the country may be reduced. The more rapid arrival of the water congests the drainage system such that flood levels are raised and more time is required to enable drainage.

5.3.1 Deforestation

One hypothesis put forward to explain these phenomena relates to deforestation within and upstream of Bangladesh (Abbas, 1989, 3). While the influence of natural and anthropogenic change in the Himalayan highlands on lowland flooding remains a controversial issue²⁸, deforestation throughout the foothill and lowland areas is believed to be modifying the time distribution of runoff and aggravating the region's flood hydrology.

Deforestation impacts on soil structure to reduce the amount of water able to infiltrate and travel through the soil as interflow (Talsma, 1975; Schneider, 1989). Increasing amounts of water are forced to travel relatively quickly across the surface as runoff. This more direct contribution of precipitation to streamflow increases the rate at

²⁸See Appendix III.

which water enters and is removed by channels. Higher runoff means that greater amounts of soil material are delivered to channels thus increasing erosion and sedimentation (CSE, 1991).

The Brahmaputra River runs through India's Assam Valley before entering Bangladesh (Figure 5.2). This area receives over 12,000 millimeters of rainfall annually. Due to extensive deforestation and soil erosion, the region's ability to retain water has been greatly reduced (Hossain et al., 1987; Clarke, 1991, 50; CSE, 1991, 77). Vast areas of the Ganges River catchment in northern India and the Terai region of Nepal are also deforested. Within Bangladesh, deforestation has reduced the rate at which water enters the soil such that larger volumes of water remain on the surface until able to be removed by the drainage network.

5.3.2 Seismic Activity

Periods of reduced channel capacity and raised flood levels have been observed to follow the occurrence of earthquakes in the Ganges/Brahmaputra/Meghna watershed. Earthquakes induce a rapid and large contribution of material to the drainage network. This material moves through the drainage system in a pulse-like manner, such that periods of raised flood levels are followed by periods of declining levels (CSE, 1991, 79).

Between 1970 and 1988, 2,500 earthquakes occurred within a radius of 450 kilometers from a seismological observatory in Shillong (Figure 5.4) (CSE, 1991, 77). In 1950, the area experienced one of the worst earthquakes in global history, of magnitude 8.6 on the Richter scale. This earthquake triggered widespread and severe landslides that

Figure 5.4
Political Divisions of South Asia

dramatically changed the topography of Assam and the morphology of the Brahmaputra River. Enormous amounts of material were contributed to the sediment load of the area's rivers. Floods levels were raised, and a more extensive area was affected by floods in the decades that followed (CSE, 1991, 78).

In August 1988, an earthquake of magnitude 7.3 on the Richter scale occurred. Recent declines in high stage of the Brahmaputra River are believed to reflect the removal of a large amount of sediment delivered to the channel following this earthquake.

5.3.3 Structural Flood Control

Higher flood levels and longer inundation times may also reflect the existence of embankments along stretches of the major rivers. International interest in large-scale structural flood prevention in Bangladesh began following the occurrence of severe floods in 1954 and 1955. At that time, a report prepared by a UN Technical Mission recommended researching the feasibility of large-scale embanking (Ministry of Foreign Affairs: Japan, 1989, 15). Although temporarily supplanted as a priority, by 1964, a plan to construct 3,200 kilometers of embankments was in place. By 1968, only 217.4 kilometers of this World Bank financed program was complete, in part, due to problems experienced with channel stability, siltation, drainage, and land acquisition (World Bank, May 1990; Ministry of Foreign Affairs: Japan, 1989).

The earliest embankments were located along the right bank of the Brahmaputra and Tista Rivers in the Northwest of the country. These embankments were equipped with sluice gates to enable rainwater to drain from behind the protective structures. An

early review of these protected areas indicated widespread, severe waterlogging. Sluice gates were commonly found to be inoperative due to siltation and/or lack of operation and maintenance funds. Despite ongoing technical and social constraints, an estimated 6,000 kilometers of embankments have been constructed (Brammer and Khan, 1991, 76).

5.4 Flood Control Structures and River Morphology

Embanking leads to significant changes in river regime that, despite modelling, remain impossible to predict (World Bank, May 1990, 7). In Bangladesh, embankments have increased the velocity and depth of water in the rivers because it is contained and forced to move downstream rather than to spread across a broad expanse of land (Abbas, 1987; Rogers et al., 1989). Increased flow velocities produce more intense erosion thereby aggravating the migratory tendency of channels.

It is unknown if the erosion/accretion ratio of land has changed since the 1950s introduction of structural flood control. It is known that subsequent to the construction of modern embankments, erosion in the Lower Meghna Estuary has intensified, and, between 1973 and 1987, Bangladesh suffered a net loss of land to erosion.

Intense erosion and channel migration increase the potential for embankments to be breached. Embankment breaches cause flash floods whereby large amounts of water are suddenly released onto the floodplain. Although the arrival of flash floods is extremely rapid, water velocity slows quickly resulting in the deposition of a great deal of relatively-coarse material (Hossain et al., 1987, 32). Because the remaining flood-control structures impede drainage, inundation times are long. In particular, the

Brahmaputra Right Embankment, south of the Tista River, is highly vulnerable to erosion-induced breaches such that flash flooding and drainage congestion pose serious problems in protected areas (World Bank, March 1992; Adnan, 1991, S5; Volker, 1983).

Embankments may be strengthened to alleviate the effects of erosion. Such works have successfully halted the migration of meanders along stretches of the Ganges River west of the Gorai River. Downstream of these works, channel migration is erratic and dramatic and flooding is severe (FEC, 1989, II.23.9; World Bank, March 1992).

High volumes of rapidly-flowing water contained within an embanked channel determine that flooding is particularly severe at points along the river where there is relatively less protection or where protection ends and natural banks begin²⁹. Where embankments exist along one side of a river, flood intensities have increased on the other side (Hossain et al. 1987, 17).

The flow velocity of water declines towards the end of the monsoon season increasing the rate of sediment deposition within the embanked channel. Embankments must be periodically heightened to maintain their elevation above that of the channel bed. Over time, accumulated sediments may raise the channel bed above the elevation of the surrounding land. When a breach occurs under these circumstances, the resulting flash flood is particularly catastrophic in terms of both water volume and intensity of arrival. Furthermore, because the flooded land is at an elevation below that of the channel, post-

²⁹ Records of flooding prior to 1954 are sketchy however, since 1954, flow velocity of water downstream of embankments has increased (Abbas, 1989).

flood stage drainage of the flooded area is virtually precluded and the area remains waterlogged. Presently, stretches of the Brahmaputra/Jamuna channel in northern Bangladesh are raised above the floodplain (Rogers et al., 1989).

5.5 The Social Impacts of Changing River Morphology

5.5.1 Land Ownership

Once downstream of embankments, floodwaters flow over the floodplain decreasing the flow velocity of water within the channel and resulting in the accretion of new land. Traditionally, newly-accreted land was distributed to those who lost land to erosion. In recent years however, de facto political and administrative barriers preclude access of displacees to such land (Rogge and Elahi, 1989, 26-32). Powerful elites, supported by their political links, benefit from the unstable riverine environment through their ability to access newly-accreted land (Custers, 1992). As embankment construction has proceeded downstream, protected lands are increasingly concentrated in the hands of the relatively powerful (Elahi and Rogge, 1990).

Flash floods, either normally-occurring or induced by embankment breaches, are primarily responsible for flood-associated deaths and the loss of material assets (Hossain et al., 1987, 32). High-velocity floods frequently bury productive land under less-productive coarse deposits (Brammer and Khan, 1991, 78). The need to rehabilitate their land prior to cropping often forces poor farmers with no access to the necessary resources to sell their material assets or ultimately, to forfeit their land.

In the past, flood-control structures have resulted in extensive and prolonged waterlogging (Adnan, 1991). Pumping to alleviate waterlogging is not cost effective and is not always successful in low-lying areas (World Bank, May 1990). When embankments impede the drainage of floodwaters from their land, poor farmers, lacking the assets to carry them until cropping can resume, have few alternatives that ultimately do not lead to land forfeiture. Because drainage is relatively rapid, unprotected areas, although experiencing flooding, recover more quickly³⁰.

Flood Action Plan studies indicate that subsidence is an unavoidable impact of flood-control due to the preclusion of silt deposits from the delta (Pearce, 1992). Consequently, the difficulties associated with ensuring adequate drainage, the area affected by waterlogging, and the numbers of people displaced from their land as a result are likely to increase with further flood protection.

The construction of embankments requires a great deal of land. NGOs estimate that eight million people may be displaced to enable implementation of the World Bank's long term flood-control program (Custers, 1992). Many people have contested the expropriation of their land in court. FAP Supporting Study 15 was aimed at resolving the delays posed by such court action. The study recommended that the laws be changed to ease land acquisition for the flood-control program (World Bank, March 1992). Recently, the government changed the laws such that people can no longer contest the transfer of their land in court or demonstrate in opposition to development projects (Adams, 1993).

³⁰For a review of India's experience with embankments along the Brahmaputra River north of Bangladesh, see Appendix IV.

5.5.2 Displaced People

People displaced from their land often have no choice but to occupy either newly emerging chars, the area between the river and the embankments, or the embankment itself. High flow velocities and erosion cause these areas to be extremely unstable and dangerous. Flow characteristics become less dangerous as embankment setback from the river increases however, as setback increases so does the amount of land required and the number of people displaced³¹.

Landless displacees squatting on embankments are the most socio-economically vulnerable population group in Bangladesh. Relative to national averages, communities of displaced people located on embankments and chars indicate a higher percentage of female-headed households (Elahi and Rogge, 1990). Communities of displaced people also indicate a higher percentage of nuclear rather than extended families. Nuclear families have less social and economic strength than extended families. Kinship relationships, including those external to the extended family, are vital to survival. Yet, displacement results in people moving further from these connections.

Displacees often have no alternative but to seek sharecropping or wage labour opportunities from powerful people called jotedars (Rosberg and Desroches, 1992). Groups of displaced people align themselves with a jotedar upon whom they are dependant for rights to occupy and work newly-accreted land. In turn, the groups defend their jotedar's claim to the occupied land against the claims of other jotedars.

³¹The Brahmaputra right embankment was originally constructed between 1.6 and 2.4 kilometers from the river. Over half the length of the embankment has been reconstructed at a greater distance from the river. Some stretches have been set back two kilometers from their original location.

Competition for land between groups of displaced people representing different jotedars is often violent. Physical displacement, rape, murder, and crop confiscation are common. Jotedars commonly own up to 2,000 acres of land and collect 50% or more of the harvest from peasants occupying their land in return for the right to sharecrop (Custers, 1992).

5.6 Flood Control and Economics

Since 1973, national development objectives have been based primarily on growth in agricultural productivity achieved via flood control/drainage, irrigation, and non-water inputs. A combination of structural protection and incentives such as agricultural chemical subsidies were expected to increase farmer adoption of modern agricultural methods. Agricultural transformation was expected to enable land taxation based on potential productivity. Such taxation was, in turn, expected to raise domestic capital thereby relieving dependence on foreign investment capital (MPO, 1984, 2-9). These objectives were never realized. Past economic forecasts for returns on flood-control investments were "overly ambitious" (MPO, 1984, 2-11). Farmers did not respond as predicted, and the effects of declining international terms of trade were more severe than anticipated. The gains achieved in exports were offset by the rising agrochemical imports associated with HYV agriculture. Such imports have added significantly to Bangladesh's indebtedness (Environmental Coalition of NGOs, 1992).

Targets for HYV adoption were not achieved as many farmers in protected areas continued to crop less input-intensive, traditional crop varieties (MPO, 1984, 5-39). Some farmers, initially adopting HYVs, abandoned them and resumed cropping traditional

varieties. Poor access to irrigation systems and severe water shortages led many farmers to abandon both HYVs and traditional dry-season varieties in favour of low-yielding drought-resistant varieties³². In other areas, cropping intensities were reduced as waterlogging precluded planting.

Although the majority of existing flood-control projects have not been successful, a number of projects have resulted in more intense cropping and a greater demand for labour. In some cases, the increased demand for labour has raised local wage rates (World Bank, November 1992).

In general, successful projects have benefited landowners more than they have benefited the landless. However, despite evidence suggesting that flood-control projects promote changes in the pattern of landownership, the extent to which this has occurred, either within or external to flood-protected areas, is unknown. Such information is needed to indicate the degree to which increases in wage employment associated with flood control replace the loss of informally-renumerated livelihood opportunities on small, traditional family farms. It is also unknown the extent to which the increased demand for labour following flood protection has offset the loss of flood-dependant livelihood opportunities. It is known that flood-control projects have adversely affected people who depend on fishing (World Bank, November 1992, 19), and it is likely that adverse effects have also been experienced by people relying on other flood-associated resources and opportunities. The World Bank suggests that such livelihood losses may be offset by

³²Irrigation and water supply are discussed in detail in Chapter 6.

opportunities for pump-operators, mechanics, maintenance people, and other labourers associated with the flood-control program.

Reports of staggering flood-associated economic losses have been used to justify the flood-control investment. However, harvests of crops replanted during the late part of the flood-season are not counted as partial compensation in damage or loss statistics. Similarly, dry-season yields following heavy floods are generally higher than otherwise, yet these benefits are not discounted from damage estimates³³ (FEC, 1989, II.2-15&25). Government damage estimates are compiled from sectoral assessments which have been found to be biased and overlapping (FEC, 1989). At times, reported damages relate directly to the failure of existing flood-control structures causing flooding that is more severe than would otherwise occur.

Haque and Zaman (1993), indicate that the damage experienced behind embankments is often higher than the damage experienced in unprotected areas. They suggest that large-scale flood control programs induce a "false sense of security" which leads to inappropriate, infrastructure-intensive development of the floodplain (Haque and Zaman, 1993, 101).

Other damages cited as flood-associated are due to chronically poor general maintenance (Adnan, 1991).

³³ With respect to the severe flood of 1987, the World Bank reported agricultural losses of US\$400 million (World Bank, 1988, 1). However, dry-season harvests following the floods were higher than normal such that total annual production was positively affected (Rogers et al., 1989, 37).

5.7 Summary

Floodplain inhabitants have developed strategies to reduce their vulnerability to, and to enhance their abilities to extract benefit from the annual floods. Despite these strategies, more people have been adversely affected by flooding in recent years.

Perceptions that the floods are becoming worse may reflect the virtually-complete deforestation of the floodplains both within and upstream of Bangladesh. Deforestation has likely modified the time distribution of runoff and aggravated the intensity of flooding, erosion and channel migration. Despite these changes, most Bangladeshis still perceive the floods as beneficial and essential. Regardless, structural flood-control has been widely implemented.

Areas protected by flood-control structures are commonly affected by intense erosion and channel migration, flash floods, waterlogging, and the deposition of relatively unproductive coarse sediments. Areas downstream of protected areas suffer increasingly severe flooding, erosion and channel migration. These conditions contribute to current processes of impoverization as farmers, without the necessary economic reserves, are forced to access unfair credit, sell assets, or forgo planting and harvesting during the post-flood season. All of these options leave people increasingly vulnerable to future flood occurrences. The outcome of this process is generally a loss of land which often represents an irreplaceable loss of livelihood, leads to the break-up of extended families and kinship networks, results in residence in dangerous locations such as on embankments or chars, and increases people's dependency upon exploitive relationships with the socially, politically, and economically powerful.

In general, flood-control initiatives have not led to HYV adoption to the extent predicted and, in areas, have reduced cropping intensities to below pre-project levels. In the few areas where cropping intensities have increased, some landowners have benefited but at the expense of people dependant upon flood-associated resources and opportunities. Although in these areas the demand for wage labourers has increased, it is unknown to what extent this demand has offset the loss of flood-dependant livelihoods, or, because flood-control induces changes in land ownership, the loss of unpaid labour on traditional family farms.

In terms of GNP, the rising costs of agrochemicals needed to sustain HYV agriculture have offset the gains in exports achieved through flood control with the result that Bangladesh's foreign debt has increased.

It is not the natural cycle of flooding, but rather the current socio-economic and political conditions within Bangladesh, coupled with the aggravated nature of flooding due to complete floodplain deforestation that create conditions for disaster. Experience suggests that embankments exacerbate these adverse conditions.

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CHAPTER 6

FLOOD CONTROL, IRRIGATION AND WATER SUPPLY

6.1 Introduction

In Bangladesh, widespread dry-season agriculture is possible because of the high moisture retention capacity of the soils. Agricultural yields are particularly high in response to the exceptionally-good moisture reserves that follow heavy flooding. Maintaining this productivity once flood control is implemented will require widespread and intensive irrigation (FEC, 1989). However, flood control reduces access to traditionally-important water supplies such that increasing demand for alternative supplies accompanies the construction of flood-control structures.

Embankments reduce the access of river water to the floodplains thereby decreasing the amount of water able to be stored in polders, tanks and natural depressions for dry-season use. Direct access to river water is physically impeded by the structures themselves. Water distribution systems provided as components of existing flood-control projects have shown that centrally-controlled water supplies are subject to "capture" by the powerful. The poor are forced to pay unreasonable prices for, or are denied access to, traditionally-communal water resources³⁴ (National Water Plan, 1984, 5-39). For many, groundwater presents the only possibility for irrigation. The effects of increasing groundwater exploitation on the hydrological conditions within Bangladesh are poorly understood.

³⁴See Appendix V.2.3

6.2 Groundwater Recharge

6.2.1 Infiltration

Aquifer recharge, the rate of water entry into the saturated zone, is commonly used to predict a sustainable rate of groundwater exploitation (Freeze and Cherry, 1979, 215). The process of aquifer recharge is initiated with infiltration, the entry of water into the soil at the surface. The rate of infiltration reflects soil textural and structural characteristics, initial soil moisture status, and the intensity of arrival and duration of water on the soil surface. Infiltration rates vary greatly over small distances and with time (Rijtema and Wassink, 1969).

6.2.1.1 Soil Texture and Structure

The textural classification of the floodplain soils tested as part of the field study include silt loams, silty clay loams, and clay loams. Soil texture is indicative of porosity. Fine textured soils, as are characteristic of Bangladesh (see Section 3.1.11 and Table V.1), are very porous and thus have a great deal of space to be occupied by air and water. Bulk density measurements (Table V.1), support suggestions that Bangladeshi soils exhibit poor structural characteristics. Consequently, it can be expected that soil porosity is predominantly associated with a network of small pores. Water located in small pores is less mobile than that located in larger pores (Freeze and Cherry, 1979, 211). Thus, the soils of Bangladesh are likely to have high water-holding capacities, but low rates of water infiltration and transmission relative to coarser materials.

6.2.1.2 Clay Content and Mineralogy

The chemical composition of clay materials influence their behaviour. The northern floodplain of the Ganges River is dominated by montmorillonite clay. Montmorillonite is characterized by its ability to swell significantly upon wetting and to shrink during drying (Freeze and Cherry, 1979; Dixon, 1977). Swelling occurs as water is attracted into small spaces between layers within the crystal structure of clay particles and forces them apart. As the soil dries, shrinkage occurs causing the formation of cracks.

South of the Old Brahmaputra River is the Madhapur Tract. The soils of this area are dominated by kaolinite and, to a lesser degree, illite. Kaolinite, illite, and chlorite are the dominant minerals comprising the soils tested as part of the field study (Table V.2). Kaolinite, illite, and chlorite are clay minerals with non-expanding crystal lattices, therefore swelling, shrinkage, and crack formation occur to a lesser degree than in montmorillonitic soils. Swelling occurs in soils dominated by non-expanding minerals in response to hydration of the exterior of soil particles. In general, the potential for swelling and shrinking becomes greater as the amount of clay increases.

The clay contents of Bangladeshi soils are highly variable. Channel deposits have low clay contents (Table V.1). The clay contents of the floodplain samples tested as part of this thesis ranged between 25.5 and 37.5%. Low-lying soils of the Madhapur tract have clay contents as high as 90% (Ahmed et al., 1971).

At contents in excess of 30%, the water attracting and holding capacities of clay particles dominate soil behaviour. Even when present in lesser amounts, the tendency of

clay particles to coat larger particles enables the clay to influence soil properties (Mitchell, 1976, 171). In general, as clay content increases, soil structure becomes more compact, and the rate of water infiltration into the soil decreases. The low infiltration rates associated with high clay content soils may be increased if the soils are dry enough to exhibit cracking.

6.2.1.3 Initial Moisture Status

Initial moisture characteristics strongly influence the rate of infiltration. In general, water arriving at the surface of a dry soil infiltrates quickly in response to the steep water potential gradient between the dry soil and the wetting front. The rate of infiltration tends to decrease with time as swelling and raindrop impact seal the surface, or as the wetting front reaches a relatively impermeable layer.

Water enters the profile of a dry soil with well-developed cracks particularly rapidly (Dixon, 1977, 701). The rate of water infiltration reflects the width and depth of shrinkage cracks which in turn reflect the clay mineralogy of the soil and the intensity of drying. Upon rewetting, the cracks close as the soil matrix expands in response to hydration, and the rate of infiltration decreases.

Bangladesh's long and hot dry-season favours the development of deep and extensive cracking. Irrigation suppresses crack formation by reducing the length of time when the soil is drying.

The results of tests performed in Bangladesh indicate a range of infiltration rates of more than an order of magnitude for the three test locations. The results suggest that

although highly variable, infiltration rates are low in the areas tested, even in the dry season when water potential gradients are relatively high (Table V.1).

6.2.1.4. Intensity of Water Arrival at the Soil Surface

Intense rainfall may restrict infiltration by breaking down the structural aggregation of soil particles at the surface. This may result in the formation of a crust that seals the surface. Conversely, intense rainfall may increase the amount of water able to infiltrate if the soil is dry enough to exhibit cracking. In this case, a rapid arrival of water results in relatively large amounts entering the soil over a short period of time. A slower arrival of water, although less damaging to surface aggregation, allows time for shrinkage cracks to expand and seal the surface (Dixon, 1977).

The presence of iron and/or aluminum oxides in a soil, may enhance the stability of structural aggregates such that they are less vulnerable to the disintegrating forces of intense rainfall. The percentages of iron and aluminum oxides in the Bangladeshi soils tested in this study are low relative to other tropical soils, and are unlikely to significantly enhance structural stability (Table V.2).

6.2.1.5 Depth to the Aquifer and Duration of Water Supply at the Soil Surface

The downward movement of water to the aquifer occurs only when the supply of infiltrating water exceeds the water-holding capacities of surface layers, the rate of evapotranspiration, and the rate of lateral outflow³⁵. Commonly, the thickness of material

³⁵See Section 6.3.

between the surface and the aquifer is used to represent the distance water must travel to the aquifer (Figure 6.1). In reality, the tortuosity of the pore network defines the distance water must travel per unit thickness of soil. This distance is lengthened in fine soils due to the small size of pores and to the tendency for platelike clay particles to align in an anisotropic manner³⁶. In fine soils, anisotropy generally results in a more rapid flow of water in a horizontal rather than vertical direction. Thus, infiltration is more likely to give rise to recharge the longer water remains available for infiltration at the surface.

6.3 Groundwater Discharge

During the monsoon season, water in streams and in surface depressions or excavations is contributed to the groundwater system. During the dry season, the water levels in streams and surface reservoirs decline to a height lower than the water table with the result that the direction of water flow is reversed. Under these conditions, water stored in the ground contributes to surface water supplies (Freeze and Cherry, 1979).

In Bangladesh, streamflow is augmented by lateral outflow from groundwater storage from October to January (FEC, 1989, II-36). Between February and April, precipitation and groundwater levels are at their lowest, and total river discharge to the Bay of Bengal drops, from a monsoon-season high of 103,900 m³/s, to a dry-season low of 8,780 m³/s.

³⁶Anisotropy is a condition of having different properties in different directions.

FIGURE 6.1 Thickness of the Upper Clay Layer

(adapted from FEC II.1-38, 1989)

6.4 Groundwater Movement

A rapid arrival of water may cause air to become trapped between the water entering at the surface and the water table, resulting in a perched water table³⁷ (Freeze and Cherry, 1979, 232). Although this condition is likely to dissipate with time, it provides an opportunity for evapotranspiration and lateral outflow to dominate water movement at the expense of vertical flow necessary for recharge.

The downward movement of water may also be hindered by an impermeable layer resulting in a perched water table. Bangladesh's soils are widely characterized by a near-surface hard pan which operates to slow the flow of water to the underlying aquifers. When confronting a particularly dense stratum, water will flow parallel to it until intersecting and discharging into a channel, surface depression, or the sea (Freeze and Cherry, 1979, 168).

In most fluvial deposits, the ability of water to travel horizontally is greater than its ability to travel vertically. As a result, lateral flow toward the coast is likely to exceed vertical flow even in the absence of impermeable layers (Freeze and Cherry, 1979, 149). The fluvial nature of Bangladesh's soils, coupled with the characteristically-rapid arrival of water and the presence of impermeable layers, suggest that horizontal flow is favoured over vertical flow. Infiltrating water is more likely to travel laterally through the near surface zone toward the coast until intersecting a channel, than to contribute to recharge.

³⁷A perched water table occurs when a saturated zone overlays an unsaturated zone.

6.4.1 A Groundwater Model for Bangladesh

The delineation of aquiferous zones in highly-variable deposits of braided and meandering rivers, as are characteristic of Bangladesh, often involves much speculation (Freeze and Cherry, 1979). In addition, modelling soil hydrodynamic properties has proved very difficult in Bangladesh (FEC, 1989). Consequently, although a variety of recharge models exist, there is little agreement between them. An adequate comprehensive model of groundwater flow for Bangladesh has yet to be developed.

The current recharge model is untested and based on information of questionable reliability (FEC, 1989, II.1-46). The model assumes that the water table reaches the surface between August and September in all areas and that this indicates complete recharge of the upper aquifer. In reality, the water table does not reach the surface in all areas, and where it does, it is not always indicative of aquifer recharge but rather reflects the presence of a perched water table. In addition, the model assumes that lateral movements of water are insignificant. However, lateral movements through the soils of Bangladesh are likely to account for the bulk of water transmission. To account for errors in these and other respects, the current model is based on recharge estimates that have been reduced by 25% (FEC, 1989, II.1-53). A time series of empirical studies does not exist (FEC, 1989, II.1-53).

6.4.2 The Potential Effects of Flood Control on Groundwater

An important consideration as to the effect of flood control on recharge rates is the reduction in the length of time and amount of water available at the surface for

infiltration. Of importance, it has proved impossible to differentiate between rainfall and river-flooding induced recharge (FEC, 1989). Flood control may also impact on groundwater recharge as the decreased delivery of floodplain sediments, particularly structure-enhancing organic matter, alters the hydraulic characteristics of surface materials. Kock (1985) suggests that flood-associated deposition provides up to 1,000 kilograms of organic matter per hectare in areas of south and south-east Asia where intensive cropping, the use of plant residues and animal dung for purposes other than soil replenishment, and flood-protection are contributing to severe organic matter deficiencies. Organic matter contents were found to be extremely low in all of the field study locations (Table V.2).

In addition, fine materials will no longer be deposited on the floodplains resulting in larger amounts of fine material deposited on riverbeds. Because riverbed sediments are commonly relatively coarse under natural conditions, the deposition of fine sediments associated with flood control may reduce infiltration rates associated with the riverbeds.

6.5 Groundwater Exploitation

The terms aquifers and aquitards are commonly used as relative terms to describe the water transmission characteristics of subsurface layers. Aquifers are layers of coarse materials with higher transmissivities relative to layers of fine materials with lower transmissivities called aquitards. If bounded by impermeable layers of material such that no water flow occurs across the upper and lower boundary of an aquifer, it is referred to as confined (Verruijt, 1982). Unconfined aquifers are those whose upper boundary is the

water table. Aquifers with intermediate characteristics are referred to as semiconfined. Bangladesh is characterized by an interbedded aquifer/aquitard groundwater system (Figure 6.2). The upper aquifer consists of confined, semiconfined, and unconfined formations.

6.5.1 Exploiting Confined Aquifers

Pumping water from a confined aquifer causes a decline in the hydraulic head³⁸ within the aquifer. As hydraulic head is lowered, water pressure within the aquifer is reduced thereby increasing the effects of vertical stress associated with overburden. A relative increase in vertical stress will cause the aquifer materials to compress resulting in aquifer compaction. Although recharge may enable the aquifer to re-expand, compaction will only be partially reversed as expansion values are generally less than compressibility values. Aquifer capacity will be reduced (Freeze and Cherry, 1979, 372).

Bangladesh's monsoonal climate means that drawdown, the lowering of hydraulic head in response to groundwater exploitation, is cumulative throughout the dry-season. Since the potential for recharge is limited to a brief period annually³⁹, the time during which aquifer compaction can occur is relatively long. If recharge does not refill the available space, further compaction of the aquifer can be expected.

Alternatively, pumping from confined aquifers may produce hydraulic gradients that encourage leakage from overlying or adjacent aquitards to the aquifer. While this

³⁸Hydraulic head refers to the water pressure expressed as an equivalence of height.

³⁹Recharge is possible between May and September (FEC, 1989).

FIGURE 6.2

Upper Aquifer Transmissivity

(adapted from FEC. 11.42.1989)

preserves aquifer capacity by restricting compaction, the loss of water from the aquitard may lead to compression of the clay materials and compaction of the aquitard. Because the compressibility of clay is commonly 1-2 orders of magnitude greater than that of sand, the potential for aquitard compaction is very high. Expansion values of clay are often 1/10 of their compressibility values (Freeze and Cherry, 1979, 372). It is under these circumstances that subsidence commonly occurs. The high compressibility and low recharge potential of Ganges floodplain material makes subsidence a particular concern for that area (FEC, 1989, II.1-51). In other areas, the risk of subsidence associated with groundwater exploitation is generally considered low.

In areas where subsidence is not considered a concern, the potential for intrusion of saline water into groundwater aquifers appears high. Due to Bangladesh's low elevation above sea level, most of the groundwater pumped will come from below sea level. This situation creates conditions whereby the natural groundwater flow towards the sea is reversed and seawater flows into inland aquifers.

6.5.2 Exploiting Unconfined Aquifers

Pumping from an unconfined aquifer lowers the water table and reduces the water pressure within the aquifer causing a change in the hydraulic gradients within the groundwater system. Recharge is facilitated at the expense of discharge to streamflow as the system seeks a new dynamic equilibrium. Base streamflow declines. As pumping rates increase, recharge eventually reaches the maximum possible rate. At this point all natural discharge ceases. If the rate of pumping continues to increase, the water table will

reach a depth where the maximum level of recharge can no longer be sustained. At this stage, one particularly dry year may cause an irrecoverable water-table decline (Freeze and Cherry, 1979, 367).

6.5.3 Current Groundwater Exploitation in Bangladesh

Between 1972 and 1984, the number of wells drilled for irrigation increased at a compound rate in excess of 40% annually (MPO, 1984, 9-3). Loans to enable the purchase of irrigation equipment were an integral component of the government's economic plan to raise GNP. However, by 1983, so many wells ran dry that agricultural credit from IDA and from the Bangladesh Bank was suspended throughout the northwest region of the country. Groundwater exploitation significantly lowered the dry-season levels of minor rivers sustained by groundwater flows, and dry-season groundwater levels were markedly lower than a baseline taken in 1978. Since wet season levels remained within their normal range, it was concluded that the decline in water availability reflected poor placement and crowding of wells rather than the limit of the groundwater resource.

Currently, it is estimated that groundwater extraction exceeds annual recharge in 38 of a total of 460 upazilas (Table 6.1). In an additional 11 upazilas, 80% of estimated annual recharge is presently exploited (FEC, 1989, II.1.53). To date, less than 25% of Bangladesh's cultivated area is irrigated (Figure 6.3). The Northwest region is believed to hold the best potential for further groundwater development due to the relatively high transmissivity of the area's aquifers and the relatively coarse nature of the surface soils.

Table 6.1

**GROUNDWATER EXPLOITATION AS A PERCENTAGE
OF ANNUAL RECHARGE FOR 6 UPAZILAS (1983)**

UPAZILA	% of MINIMUM ESTIMATED RECHARGE	% of MAXIMUM ESTIMATED RECHARGE
Bogara	216	91
Singra (south)	388	164
Faridpur	230	103
Ullapara	223	100
Sahjadpur	202	91
Basil (east)	230	109
Basil (west)	207	94

From MPO, 1984

FIGURE 6.3 IRRIGATION IN BANGLADESH

From ROGERS, 1989

6.6 Droughts and Water Shortages

As recently as April, 1992, The Bangladesh Daily Star, reported widespread interruption of economic activities due to prolonged water shortages primarily affecting districts along the embanked Brahmaputra River, Tista Tributary, and Jamuna River from north to central Bangladesh (Bangladesh Daily Star, April 1-19, 1992)⁴⁰. The newspaper reports that poor dry season rain and inadequate soil moisture reserves resulted in widespread crop losses especially of water-intensive high-yield varieties. All major rivers experienced sharp declines in water levels accompanied by heavy siltation. Navigation was hampered or precluded such that essential goods were unable to get through. A total of 15 rivers throughout the northern districts dried up completely. Other surface supplies held in tanks and ponds were spent. Potable water supplies, obtained via 2-3 meter deep wells, were exhausted leading to increases in the incidence of diarrhoea. Violent conflict over irrigation water spread as water levels dropped and even deep wells ceased to produce water. Irrigation represents the greatest draw on a currently-inadequate dry-season water supply (Choudhury and Khan, 1983).

Because water supplies are so seriously limited at times throughout the year, it is necessary to save as much water as possible during the monsoon season for subsequent use. Rather than focusing on reducing the negative impacts of these temporarily surplus supplies of water, structural flood control expedites the removal of water from the

⁴⁰Some of the areas affected by the 1992 water shortages were identified as particularly promising for further groundwater development.

environment thus reducing the amount of time it is of utility as a resource and potentially increasing the length of time water scarcity poses problems.

During the last two decades, water shortages have been of increasing severity in Bangladesh. Such shortages reflect a reduction in water supply associated with water diversions by upper riparians,⁴¹ the increase in demand for water due to the expansion of irrigation, and flood control.

Flood Action Plan research indicates that recharge losses are insignificant for partial flood control but may be problematic once a "large, contiguous area" is protected (World Bank, November 1993). The World Bank suggests that controlled flooding may ameliorate problems associated with groundwater recharge but recognizes that such an approach will exacerbate existing waterlogging problems.

6.7 Economic Implications of Flood-Control-Induced Irrigation

The cost of a shallow tubewell exceeds the annual income of a typical farmer in Bangladesh⁴² (Rogers et al., 1989, 71). However, flood control necessitates the purchase of irrigation equipment by poor farmers who can no longer maintain their livelihoods without it. The lack of access to reasonable credit means that irrigation will intensify the current processes of impoverization and resource concentration.

⁴¹The southwest part of the county experiences water shortages on an annual basis due to operation of India's Farraka Barrage. See Appendix VI for a more detailed discussion.

⁴²Intensive groundwater exploitation is likely to increase the depth of the water table such that more expensive deep tubewells are required.

On a macroeconomic scale, although the sale of irrigation equipment will contribute to GNP, the foreign exchange cost of energy for irrigation currently represents a serious financial burden for Bangladesh⁴³ (Rogers et al., 1989, 71). Beyond this, experience has shown that the result of insufficient water for irrigation is a decrease in cropping intensities and agricultural yields. Thus, if the increasing demand for irrigation water that accompanies flood-control cannot be sustainably satisfied, the country's agricultural base will be undermined with serious social and economic consequences.

The French Engineering Consortium recommends against more widespread or intensive use of groundwater until a time series of empirical observations of groundwater conditions is available (FEC, 1989).

6.8 Summary

The need for irrigation will increase in response to more extensive flood-control. Because surface water supplies are inadequate to meet current levels of demand, groundwater exploitation must increase if current cropping intensities and yields are to be maintained or improved on.

Current information on groundwater processes in Bangladesh are inadequate and unreliable. Soil characteristics and agricultural practices suggest that infiltration rates are generally low and will be further reduced by the implementation of flood-control embankments.

⁴³Most irrigation pumps in Bangladesh rely on diesel fuel.

Current levels of groundwater exploitation exceed or are nearly equal to recharge in areas of central, northwest and southwest Bangladesh. The risks associated with exploiting groundwater at a rate that exceeds the rate of aquifer recharge include: a reduction in aquifer capacity, the compaction of overlying or adjacent aquitards leading to subsidence, the contamination of aquifers by saline water, a reduction in groundwater discharge leading to lower dry-season water levels in rivers, streams, and wetlands, and a possible irreversible decline in the water table.

Currently, water shortages have led to reductions in the base flow of a number of rivers, the complete drying of wetlands and other water bodies, and a temporary lowering of the water table such that even deep tubewells cease to produce water. These conditions have in turn resulted in widespread crop losses, precluded navigation, increased the incidence of diarrhoeal disease, and led to violent conflict over water. Such water shortages are increasingly severe in Bangladesh and reflect both increasing demand for water for irrigation, often induced by flood control, and decreasing supplies due to flood-control, upstream water diversions, poor rainfall and drought.

CHAPTER 7

Is the Flood Action Plan Sustainable?

7.1 Introduction

Development decisions based primarily on economic considerations have adversely affected humanity's bio-physical and social environments. In an effort to address this situation, the tenets of a new decision-making model were defined by international agreement and are embodied in the concept of sustainable development.

The Flood Action Plan is a large and complex program with far-reaching effects that will profoundly impact upon the lives of millions of people. It is therefore important that the Flood Action Plan represent sustainable development. In this chapter, the criteria outlined in Chapter 2 are used as indicators (Table 7.1) against which the sustainability of the Flood Action Plan is evaluated (Tables 7.2 and 7.3).

7.2 The Evaluative Procedure

All the indicators used in this evaluation are treated as equally important to achieving sustainable development: if post-project conditions represent an improvement relative to existing conditions with regard to the indicator, the FAP scores +1; if the change causes a deterioration relative to current conditions, the FAP scores -1; enacting no change to a relevant indicator scores 0. This procedure provides a total score which may be positive, suggesting an improvement of sustainability, or negative, suggesting a deterioration of sustainability.

Table 7.1

THE CRITERIA FOR SUSTAINABLE DEVELOPMENT

BIO-PHYSICAL CRITERIA	
BIO-DIVERSITY	The integrity of ecosystems must be maintained.
	Existing species diversity must be maintained via in-situ conservation.
LAND	The extent and severity of erosion must decrease.
	Land loss to waterlogging must be halted.
	Land fertility must be maintained with minimal reliance on chemical fertilizers
	Tree cover must be increased.
FRESH WATER	Sources of fresh water must be protected.
ATMOSPHERE	The efficiency of non-renewable fuel consumption must be improved.
SOCIO-ECONOMIC CRITERIA	
POVERTY	Economic growth must be achieved.
	Distribution of the benefits of growth must become more equitable.
	The foreign debt of developing countries must be substantially reduced.
	Economic dependence on primary commodities must be reduced.
	Universal access to sufficient food and other basic requirements must be assured.
	The value of informally-paid work must be accounted for.
	The range of livelihood options must be widened.
	Additional sustainable livelihoods must be generated.
POPULATION	Livelihood security must be promoted.
PUBLIC PARTICIPATION	People must be empowered to contribute to the development process.
	The knowledge and opinion of affected populations must be reflected in program design.

Table 7.2

**EVALUATION OF THE SUSTAINABILITY OF THE FLOOD ACTION PLAN:
BIO-PHYSICAL ASPECTS**

CRITERIA	PRE-PROJECT CONDITIONS	POST-PROJECT CONDITIONS	SCORE
The integrity of ecosystems must be maintained.	An extensive area of the country is affected by annual flooding. The interactions between the rivers and their floodplains give rise to a diverse range of ecosystems.	Embankments will confine water flow to a relatively narrow channel. River/floodplain interactions will be restricted over an extensive area.	Existing floodplain ecosystems will be dramatically altered. Score: -1
Existing species diversity must be maintained via in-situ conservation.	The river/floodplain complex supports many species of fish.	Existing flood-control structures have decreased bio-diversity. More extensive embanking will further interrupt fish migration routes and destroy breeding grounds.	Existing bio-diversity will be decreased. Score: -1
	Indigenous varieties of rice are adapted to variable floodplain conditions.	The habitats of traditional varieties of rice will be altered. HYV rice will replace indigenous varieties.	
The extent and severity of erosion must decrease.	River erosion and migration are rapid and intense. Bangladesh has suffered a net loss of land to erosion in recent years.	Structural efforts to control erosion have not generally been successful and in some areas have intensified erosion in adjacent or unprotected areas. Further embankments will lead to increased flow depth and flow velocity during flood episodes.	Erosion will be intensified. Score: -1

Evaluation of the Sustainability of the Flood Action Plan: Bio-physical Aspects continued

CRITERIA	PRE-PROJECT CONDITIONS	POST-PROJECT CONDITIONS	SCORE
Land loss to waterlogging must be halted.	Wetlands form in depressions where the natural drainage system is unable to remove water from the floodplain.	Waterlogging is currently widespread and severe as water cannot drain from behind existing embankments. Additional embankments will further inhibit drainage. Existing drainage options are neither reliable nor cost-effective.	Waterlogging will increase in extent and duration. Score: -1
	Flood-associated silt depositions contribute to floodplain height, thereby offsetting subsidence and minimizing waterlogging.	Flood-control will eliminate silt deposits from the floodplain such that the effects of subsidence will be experienced. Drainage of the affected areas will become more difficult.	
Land fertility must be maintained with minimal reliance on chemical fertilizers.		The loss of nutrient replenishment associated with existing embankments has forced farmers to increase the amount of chemical fertilizers used. Additional embankments will eliminate the delivery of fresh minerals and organic matter to a more extensive area of land.	The natural replenishment of soil fertility will be reduced and reliance on chemical fertilizers will increase. Score: -1

Evaluation of the Sustainability of the Flood Action Plan: Bio-physical Aspects continued

CRITERIA	PRE-PROJECT CONDITIONS	POST-PROJECT CONDITIONS	SCORE
Tree cover must be increased.	The near-complete removal of floodplain forests has eliminated their ameliorative influence on flood and drought events and their stabilizing influence against erosion.	No change	Current levels of deforestation will not be addressed. Score: 0
Sources of fresh water must be protected.	Flooding facilitates the recharge of dry-season water supplies to surface and ground stores. At current rates of recharge, water is in short supply during the dry season. In some areas, groundwater is being exploited at unsustainable rates.	As flood extent is reduced, the amount of water recharging to surface, soil and groundwater stores will decrease. The rising demand for water associated with hyv agriculture will lead to an increasing over-exploitation of water supplies.	Sources of fresh water are threatened. Score: -1
The efficiency of non-renewable fuel consumption must be improved.	The traditional mix of crops in Bangladesh provide for a varied diet that is produced domestically and does not require long-distance transportation.	The cultivation of HYV rice for export leads to the displacement of alternative food crops. These foods must then be imported which often requires long-distance transportation.	The efficiency of fuel consumption is adversely affected. Score: -1
CRITERIA EVALUATED: 8			

Table 7.3

**EVALUATION OF THE SUSTAINABILITY OF THE FLOOD ACTION PLAN:
SOCIO-ECONOMIC ASPECTS**

CRITERIA	PRE-PROJECT CONDITIONS	POST-PROJECT CONDITIONS	SCORE
Economic growth must be achieved.	The majority of Bangladeshis live in conditions of increasing poverty. Economic growth has been ineffectual at alleviating poverty as existing social and institutional structures promote inequities. Past foreign assistance has largely supported the status-quo.	Planning and implementation of the Flood Action Plan and the adoption of HYV agriculture will stimulate economic growth. No mechanisms to ensure an improvement in the distribution of the benefits of economic growth have been adopted.	Economic growth will be facilitated. Score: +1
Distribution of the benefits of growth must become more equitable.			The benefits of growth will be distributed as per the status quo. Score: 0
The foreign debt of developing countries must be substantially reduced.	Bangladesh has a large foreign debt. The economic pressures associated with servicing the debt have reduced Bangladesh's economic and political autonomy.	Long-term loans will enable the planning and implementation of the FAP.	Bangladesh' foreign debt will increase substantially. Score: -1

Evaluation of the Sustainability of the Flood Action Plan:
Socio-economic Aspects continued

CRITERIA	PRE-PROJECT CONDITIONS	POST-PROJECT CONDITIONS	SCORE
Economic dependence on primary commodities must be reduced.	Development programs aimed at facilitating debt repayment, have left the country vulnerable to unfavourable global commodity markets in recent years.	Economic projections associated with the Flood Action Plan rely heavily on increasing commodity, primarily rice, exports	Bangladesh's economic dependency on primary commodities will increase. Score: -1
Universal access to food and other basic requirements must be assured	A large number of people rely on subsistence farming and fishing. Many people cannot afford to purchase the available food that is available on the market. Malnutrition is endemic.	HYV agriculture for export has led to the displacement of locally-important subsistence crops which are now imported at greater expense. The input-intensive nature of HYV agriculture will lead to higher production costs for farmers. This will adversely affect the ability of poor farmers to meet their subsistence needs.	Universal access to sufficient food will be undermined. Score: -1
The value of unpaid work must be accounted for.	Millions of existing livelihoods are informally remunerated and therefore not reflected in national accounting.	Millions of informal livelihoods will be eliminated as a result of the FAP but because they do not contribute directly to GNP, this loss is not considered.	The value of unpaid work is not accounted for. Score: 0

Evaluation of the Sustainability of the Flood Action Plan:
Socio-economic Aspects continued

CRITERIA	PRE-PROJECT CONDITIONS	POST-PROJECT CONDITIONS	SCORE
The range of livelihood options must be widened.	There is a critical shortage of livelihood options in Bangladesh.	The FAP will generate a variety of new employment opportunities. The Plan will also generate wage-paying opportunities. It is unlikely that these newly-generated opportunities will offset the loss of previously-existing livelihoods.	The range of livelihood options will be broadened Score: +1
Additional sustainable livelihoods must be generated.			The FAP is likely to result in an overall decrease in livelihood opportunities. Score: -1
Livelihood security must be promoted.	Traditional social relationships and treatment of the floodplain environment as a common-property resource may ensure many Bangladeshis a relatively secure livelihood.	As traditional relationships between people and between people and their environment change in response to flood control, the livelihood security of many people will be reduced.	The security of livelihoods will be undermined. Score: -1

Evaluation of the Sustainability of the Flood Action Plan:
Socio-economic Aspects continued

CRITERIA	PRE-PROJECT CONDITIONS	POST-PROJECT CONDITIONS	SCORE
People must be empowered to contribute to the development process	People have few means to effectively voice their opinions. Access to information is highly restricted.	Educational components aimed at overcoming and changing public sentiment are planned.	People are not empowered to contribute to the development process. Score: -1
The knowledge and opinion of affected populations must be reflected in program design.	The public were not consulted during the initial stages of the program as to objectives and options.	The main aspects of the FAP are being designed and implemented regardless of public opinion.	The knowledge and opinion of the affected population is not reflected in program design. Score: -1
CRITERIA EVALUATED: 11			

7.3 The Envisioned Outcome of the Flood Action Plan

Nineteen indicators were selected as appropriate to evaluating the sustainability of the Flood Action Plan from Agenda 21 and the Alternative Treaties. Assigning a weight to each indicator based on its relative importance in a particular situation is a necessary, but difficult, task marked by a great deal of controversy. In absence of an agreed upon weighting system, equitable treatment of all indicators, as undertaken in this evaluation, yields significant information as to program sustainability.

The concept of sustainable development embodies an imperative to consider a much broader range of possible project impacts and to achieve a broader range of objectives than has generally been the case in the past. If these imperatives are respected throughout the program cycle, an evaluation of sustainability would indicate that many of the relevant indicators are positively affected or unchanged. Alternatively, if there is poor commitment to the concept of sustainable, an evaluation of sustainability is likely to expose a large number of adversely-affected indicators.

Of the nineteen indicators considered with respect to the Flood Action Plan, it is likely that fourteen will be adversely affected, three will remain unchanged, and only two will be positively affected. This outcome suggests that, despite a high level of World Bank involvement in defining the criteria for sustainable development, the objectives of sustainable development were not central to the planning of the Flood Action Plan. In failing to meet the criteria for sustainable development, the potential for unintended impacts is high.

Proponents of the Flood Action Plan predict that the program will produce an environment where economic activity is no longer interrupted by flooding. They predict that without flooding, the floodplains will be sufficiently risk-free to induce a shift from traditional wet-season rice varieties to HYV rice. They expect that this shift to HYV agriculture will reduce unemployment and increase the country's GNP such that poverty will be alleviated.

The nature of rural society and economy in Bangladesh suggest that, at best, the employment opportunities generated by the Flood Action Plan will not offset the livelihood opportunities lost as a result of the Plan's implementation. Furthermore, the program's effect on economic risk associated with water shortages, and the potential for the flood-control program to exacerbate such shortages remain ill considered. These factors reduce the likelihood that the envisioned benefits of the Flood Action Plan will be achieved or sustained over the long term.

7.4 An Alternative Vision of Development in Bangladesh

The risks associated with economic activity on the floodplain could be significantly reduced by supporting the strategies, developed through centuries of experience by Bangladeshis, to prepare for, cope with, and recover from floods. Based on what is currently known of the perspectives of flood-affected Bangladeshis, it is possible to outline such an alternative to the Flood Action Plan and the longer-term program it supports. However, for traditional approaches to appear feasible in the global economic context, existing livelihoods must be accounted for as is demanded by the

internationally-defined criteria for sustainable development. By doing so, it is likely to become evident that, socio-economically, Bangladesh is less adversely affected by flooding than is currently suggested, and that the potential exists for more livelihoods to be generated through careful management and exploitation of the floodplain environment.

Flood-affected Bangladeshis stress that an important approach to flood "control" in Bangladesh is the use of earthen homestead mounds. Homestead mounds support the socially and economically important extended-family structure. A well-maintained homestead mound of sufficient height and area provides refuge for people, animals and other assets, and provides space to undertake economic activities during the flood season. Unfortunately, people are increasingly unable to access the resources necessary to build and maintain mounds of an adequate height and area to serve these purposes.

The most common alternative for people without access to homestead mounds is to seek refuge on embankments. However, while access to a homestead mound supports extended family structures and all the associated social and economic benefits, seeking refuge on an embankment is more often associated with abject poverty, family break-up and exposure to violence and increased exploitation. In addition, because they raise flow depth and velocity, and induce more intense erosion, embankments are dangerous and volatile locations. Earthen mounds function as islands and therefore are less restrictive of water movement across the floodplain than are embankments. As a result, mounds are also less likely cause a significant increase in flow depth and velocity, and are therefore safer and less volatile locations.

Because water is able to spread across the floodplain, a mound-centered flood-control program supports the integrity of the floodplain ecosystems. Sediment deposition, water recharge, drainage, and fish access to the floodplain are significantly less impeded. Floodplain habitats are conserved. In turn, the livelihoods that are dependant upon existing floodplain ecosystems are maintained.

A mound-centered program also offers potential to increase livelihood opportunities. Firstly, the removal of existing embankments as required by a mound-centered program, would enhance ecosystem functioning with positive effects on fish populations and other resources. By providing assistance to poor landowners towards building, repairing, or enlarging of homestead mounds, their vulnerability to the damaging effects of flooding are reduced, and their capacities to maintain productive activities during floods are enhanced. The program could include components designed to enhance local livestock and poultry industries, and to enhance homestead forestry in support of increasing the stability of mounds, balancing the flood/drought hydrology, and supporting local industry (fruit-growing, brick-making, sawmilling...) Dry-season water supply shortages could be addressed by encouraging the use of traditional tanks and landscaping techniques.

Village mounds could provide refuge for landless people during the floods. To overcome the current "refugee camp" atmosphere that prevails within populations seeking refuge on embankments, the village mound program could support a strong community focus on health care/nutrition, and education/economic diversification, cooperative/group formation, and recreation while other activities are suspended during the floods. Land for

village mounds could be obtained from landowners who currently own more land than the legal ceiling in Bangladesh.

The demand for labour created by moving earth to build embankments along the major rivers could as easily be generated by a program aimed at building, repairing or enlarging homestead and village mounds, tank excavation and landscaping across the floodplain. Local people with knowledge of mound building and landscaping techniques, could largely replace foreign engineers and consultants during project planning and implementation. Agricultural extension could focus on transmitting traditional knowledge of crop varieties and farming techniques that are best-suited to particular hydrological conditions.

The engineering and technical expertise in existence in Bangladesh could be used to design structural approaches to protect urban populations and infrastructure. Embankments offer the most feasible form of protection for urban areas. Such a less-extensive use of embankments would significantly reduce the negative effects associated with the current program. Flood forecasting, modelling and early warning systems would still be useful program components upon which the existing technical expertise in Bangladesh could focus.

Reduced reliance on foreign consultants and technologies would likely lessen the costs associated with the flood-control program, and more of the money invested would remain in Bangladesh.

Because mounds are of direct benefit to particular landowners, financing of at least part of the program could be based on the highly-successful Grameen Bank approach to providing fair credit to poor Bangladeshis (IFAD, 1988).

The design and implementation of such a program would require a level of active public involvement as yet untried in Bangladesh. Such participation would rely heavily on cooperation and collaboration among the many NGOs representing flood-associated populations in Bangladesh. Although clearly a difficult undertaking, such cooperation represents a shift from the use of scarce resources to organize foreign officials and experts around the problem of how to address poverty in Bangladesh, to the use of resources in a manner that empowers Bangladeshis to respond to their own predicament in ways that are bio-physically and socio-economically more sustainable than the program currently underway.

7.5 Conclusions

This evaluation suggests that embankment-centered schemes are not the best option to achieving sustainable development in Bangladesh. It purports that the manner in which the Flood Action Plan has been conceived, designed and is being implemented does not represent sustainable development. The Flood Action Plan ignores the bio-physical and socio-economic capacities and potentials that exist in Bangladesh and, in doing so, undermines them. In addition, the program does not adequately consider Bangladesh's vulnerabilities beyond those directly related to flooding. In not addressing

these vulnerabilities, the actions currently underway are likely to aggravate many of the existing adverse socio-economic and bio-physical conditions within Bangladesh.

The potential adverse impacts of the Flood Action Plan are significant. Reconsideration of the program is warranted. Redesigning the program such that it builds on the existing capacities of Bangladeshis to respond effectively to the advantages and disadvantages of their situation, remains a major challenge to achieving sustainable development in Bangladesh.

APPENDIX I

Homestead Forestry

In 1979, the FAO conducted a Village Forest Inventory, which provided data on the standing volumes and species composition of Bangladesh forests. In 1980, an FAO-coordinated survey of 5,600 rural households provided information on the pattern of wood consumption in rural areas (Byron, 1985).

These studies indicate that, in many areas, forest resources are insufficient to maintain current levels of domestic and industrial demand. In these areas, homestead forests of mango, jackfruit, date palms and other trees are being exploited at unsustainable rates to supply local industries with wood.

Bangladeshi farmers have an extensive knowledge of silviculture. Trees are highly valued for the food and other products they provide, their land stabilizing influence, and for their ameliorative effects on flooding and drought. Most farmers expressed a desire to increase the numbers of trees on their land. However, poverty is currently forcing many farmers to cut their homestead trees to meet short-term needs, a process that leaves them increasingly physically and economically vulnerable. Others are motivated to cut their trees by the relatively-high prices offered for wood in response to the growing shortage.

The FAO concluded that there is little need to educate people as to the benefits of trees or to motivate people to plant them. Most farmers in a position to do so are planting trees. However, many others are economically-constrained from doing so.

APPENDIX II

A Comparison of Traditional Bangladeshi and HYV Rice Varieties

Traditional varieties of rice generally have long, flexible stalks. Intensive applications of nitrogen fertilizer, necessary to increase yields, weaken plant stalks, therefore, HYVs are bred to have shorter stiffer stalks (Barker et al., 1985). Plant stalks provide material that is used for weaving, as fuel, fodder, or returned as organic matter to the soil. Although yields of rice may be higher, HYVs generally produce less plant material than traditional varieties.

The success of HYVs is highly correlated to fertilizer use. Nitrogen is the most important nutrient affecting rice yields. Most nitrogen fertilizers are produced using fossil fuels, therefore price and supply are insecure. The intensive cropping enabled by nitrogen applications can lead to other nutrient deficiencies. Throughout Asia, the natural availability of phosphorus and trace elements such as zinc is not keeping pace with their use by plants (Barker et al., 1985).

Traditional varieties of rice are genetically diverse, and while not immune to pests and diseases, they are less vulnerable than are genetically-uniform HYVs. Pests and diseases are a major constraint to the success of HYVs, and generally require the use of chemical controls. The elimination of natural predators through chemical herbicides and pesticides may cause a rise in populations of previously insignificant pests or may lead to chemical immunities by the pest. For example, until 1973, crop damage associated with the brown planthopper was considered insignificant. Since then, the use of

chemicals to treat for more troublesome pests has led to dramatic rises in crop damages associated with the brown planthopper (Barker et al., 1985). Beyond this, the use of chemicals reduces the demand for labour traditionally employed to manually control weeds and pests.

Traditional varieties of rice are highly adapted to the vagaries of water supply characteristic of the floodplain environment. Traditional wet-season varieties are generally able to tolerate being submerged, or are able to grow sufficiently rapidly to maintain a height above the flood level. Even when flood-damaged, traditional varieties of rice will resprout if their stems are broken at an internode. Harvests may be only slightly less abundant than if no flood damage had occurred (Cuny, 1990, 66). Traditional dry-season varieties are able to tolerate inconsistent applications of water. Drought-resistant varieties, though very low-yielding, are able to tolerate periodic water shortages.

HYVs are not able to withstand submergence by floodwater. Because of their relatively short height, they are at higher risk of flood damage than are traditional varieties. Once damaged by flooding, HYVs must be replanted (Cuny, 1990). Beyond this, HYVs require intensive and consistent applications of water which necessitate reliable supplies of irrigation water.

Farmers usually save a portion of their rice harvest for use as seed for planting the following season. However, under field conditions, HYVs generally do not produce sufficient amounts of germinating seed. Farmers must purchase additional seeds,

produced under carefully-controlled conditions, from seed companies.

The need for commercial inputs makes cropping HYVs significantly more expensive than cropping traditional varieties. This precludes the adoption of HYV agriculture by many poor farmers. Uncertainty as to the timely availability of the required inputs, and the relative vulnerability of HYV crops to floods and drought, deter other Bangladeshi farmers from adopting HVYs.

HYVs contribute more to GNP than do traditional varieties, in part because of their higher yields, and also because their input-intensive nature generates a significant value-added contribution. These additions to GNP are partially offset by the need for imported agricultural inputs.

APPENDIX III

Himalayan Deforestation: A Controversial Issue

The relationship between upstream deforestation and flooding in Bangladesh has become a politically-sensitive and controversial issue. In particular, the effects of deforestation in the highland areas of the Himalayas have been debated. Deforestation in the foothill and floodplain areas of the Ganges/Brahmaputra/Meghna watershed is generally accepted as aggravating the regional flood regime.

Ives (1989), argues that as agriculture has become more extensive in highland areas of the Himalayas, although deforestation has occurred, the natural rates of soil erosion and runoff tend to decline in response to the terracing, intercropping and other sound agricultural practices of Himalayan farmers. It is further indicated that many highland areas are more heavily forested today than in previous decades. Beyond these considerations, it is stated that human interference is insignificant given the natural rates of sediment transfer associated with the highly dynamic Himalayan environment.

Others argue that highland farmers are increasingly responsive to market forces that compel them to abandon their sound traditional practices in favour of monocropping and other modern practices (Jacobson, 1988; Postel and Heise, 1988; CSE, 1985). While modern approaches yield quick economic returns, they also promote erosion and induce higher rates of runoff. In the last four decades, deforestation throughout the Himalayan environment has become so extensive that runoff has increased and aggravated flooding downstream (Jacobson, 1988).

APPENDIX IV

India's Experience with Embankments in the Assam Valley

In excess of 4,000 kilometers of river, rail, and road embankments have been constructed throughout India's Assam Valley. Despite these flood-control efforts, annual flooding continues to pose serious problems for the area's population. Channel-bed aggradation, flash floods, waterlogging, and increasing social conflict are so commonly associated with embankments in the area that the local people believe they would be better off without them (CSE, 1991, 85). Police regularly patrol the embankments to protect them from intentional damaging by the affected population.

At the national level, there is debate over whether stronger and higher embankments and other structural solutions should be adopted, or whether support should be directed towards helping the population develop lifestyles and production systems more in harmony with the natural environment. In 1986, a government-appointed committee found that existing embankments had exacerbated the region's hydrological problems. The committee concluded that, "(n)o more embankments should be constructed to avoid a deterioration of the situation" (CSE, 1991, 87).

The Indian government is currently leaning towards the implementation of an intensive program of dam construction throughout the highland areas surrounding the Assam Valley. The dams would control the flow to be contained by the embankments downstream. Research in support of the program is underway although opposition to the plan is widespread. Of particular concern are the dangers associated with storing huge

amounts of water in seismically-active areas upstream of the densely-populated Assam Valley, and the loss of vast tracts of forest, which would be submerged should such a plan be implemented.

Although in support of the aforementioned plan, the government of Assam has also proposed a variety of flood adaptive strategies. One such strategy is the building of earthen platforms large enough to afford protection to entire villages. Such platforms would provide an alternative for people forced to seek refuge on embankments¹. The strategy would also involve modifying agriculture by encouraging a return to flood-resistant rice varieties and other crops whose planting and harvesting can be timed in accordance with the hydrological cycle (CSE, 1991, 93).

¹Several platforms have been constructed by the government recently. The platforms were less well received than expected. Beneficiaries complained that the earth used to construct the platforms was too sandy.

APPENDIX V

The Field Study

V.1 Introduction

Field examinations provided an indication of soil structural and permeability characteristics at four locations in Bangladesh. Soil samples were collected and tested upon return to Canada. The calculation of particle size distributions enabled soils to be assigned to a textural class and facilitated a preliminary appraisal of the capacity of the soils to hold and transmit water. Particle size distributions were calculated using a sedimentation procedure (Gee and Bauder, 1986).

The water holding and transmission capacities of soils are also affected by soil structure. Bulk density is indicative of the level of soil compaction. Bulk density measurements were based on a constant-volume core procedure (Sheldrick, 1984). Resistance to penetration also provides information about structure by indicating the presence of relatively impermeable soil layers. Resistance to penetration was measured with a pocket penetrometer according to the procedure outlined in Bradford (1986).

Soil pH indicates the amount of hydrogen in the soil solution, providing a rough measure of the bases present on the soil exchange complex. The structural stability of a soil is influenced by the amount and type of bases present. A pH meter was used to determine the pH of the soil in a calcium chloride solution (Sheldrick, 1984).

Iron and aluminum oxides may also enhance structural stability. Iron and aluminum oxides were extracted from the soils using dithionite citrate, and measured using an atomic absorption spectrometer (Olson and Ellis, 1982; Sheldrick, 1984).

Organic matter in soils encourages particle aggregation thereby encouraging good soil structure. Organic matter contents were estimated by measuring the amount of total carbon released during a combustion procedure. The absence of inorganic carbonates was determined by testing the samples with hydrochloric acid.

A simple infiltration test was designed for on-site testing. Metal cylinders were inserted into the soil at the surface and at a depth of between 20-30 centimeters and then filled with water. The decline in water height from the top of the cylinder was measured at an initial interval of 1/2 hour and again after an additional 1 1/2 hours².

Surface cracking greatly influences the rate of water infiltration into the soil profile. Clay mineralogy suggests the degree to which cracking may occur as a soil dries. Clay mineralogy was determined by X-ray diffraction (Barnhisel and Bertsch, 1982).

Informal discussion with farmers, fishermen, teachers, members of women's groups, and other community members provided insights into agricultural practices, flooding, flood control, and the natural environment.

The study was undertaken in mid-February, 1992, as Bangladesh entered the driest four month period of the year. Unusually heavy rainfall was experienced throughout the central and southeastern parts of the country during the study period. Drought and severe water shortages were experienced throughout the northwest regions of the country during the same period. NGO project sites comprised the sampling locations (Figure V.1).

²The cylinders were 5.5 centimeters in radius and 9 centimeters in height.

FIGURE V.1 FIELD STUDY LOCATIONS

V.2 The Test Locations

V.2.1 Boakhali

In Boakhali Upazila, an agricultural community, comprised of people displaced from elsewhere in the country, was visited. The area is regularly flooded by rivers emerging from the Chittagong Hills. Floodwaters generally drain within several days and rarely interfere with cropping. Farmers stated that flood-associated silt deposits were agriculturally important and that only occasionally did excessive flooding cause problems. Dry-season irrigation enables farmers to transplant three crops of traditional varieties of rice annually. Diesel-fuelled pumps are used to move water from a small river into the area's polders. Fertilizers are not used, but pesticides are used regularly. Ploughing is done with bullocks. Hand-dug tanks are used extensively in the area to store floodwaters for dry-season use and for fishing. Farmers estimated that the water table declined to about ten meters from the surface during the dry-season. Samples were taken from a poldered field of recently-harvested rice. Agricultural residues remained on the surface.

Soil testing (Tables V.1 and V.2), revealed a moderately compacted silty clay loam with a low organic matter content. The soil is acid. Iron and aluminum oxide contents were low. The dominant clay mineralogy was chlorite and illite. Infiltration rates were low but within the range expected for soils of similar texture. No particularly dense layers were observed.

Table V.1 **PHYSICAL PROPERTIES OF BANGLADESH SOILS**

LOCATION/ TEXTURAL CLASS	DEPTH (cm)	PARTICLE SIZE DIST. (%)			BULK DENSITY (g/cm ³)	INFILTRATION ¹ (m/s)	RELATIVE PENETROMETER RESISTANCE
		CLAY	SILT	SAND			
BOAKHALI/ SILTY CLAY LOAM	2-5	31.5	54	14.5	1.34	1.25 X 10 ⁻⁵	2
	20-30	---	---	---	1.38	0.35 X 10 ⁻⁵	2
	60	---	---	---	1.54	----	3
ANWARA/ SILT LOAM	2-5	25.5	50	24.5	1.26 ²	0.97 X 10 ⁻⁵	1
	20-30	---	---	---	1.80	0.14 x 10 ⁻⁵	5
	60	---	---	---	1.74	----	5
NARAYANGONJ/ CLAY LOAM	2-5	37.5	32	30.5	1.62	0.07 X 10 ⁻⁵	7
	20-30	---	---	---	1.72	0.04 X 10 ⁻⁵	10
	60	---	---	---	1.70	----	10
DAULATPUR/ LOAMYSAND	2-5	5.5	22	72.5	1.36	----	---
	20-30	---	---	---	1.30	----	---
	60	---	---	---	1.42	----	---

¹Initial soil moisture status was not controlled for. At Boakhal, it rained 5 days prior to testing. At Anwara, testing following a short, moderately intense rainfall. Narayangonj received several hours of very light rain prior to soil testing.

²The low bulk density of this sample likely reflects that, unlike the other sites, this field was plowed following the rice harvest.

Table V.2 CHEMICAL PROPERTIES OF BANGLADESH SOILS

LOCATION/ TEXTURAL CLASS	DEPTH (cm)	pH	MINERALOGY	Fe ₂ O ₃ (%)	Al ₂ O ₃ (%)	ORGANIC MATTER (%)
BOAKHALI/ SILTY CLAY LOAM	2-5	4.8	Chlorite, Illite	.83	.07	1.08
	20-30	5.3	-----	1.06	.10	.51
	60	5.6	-----	2.66	.19	.25
ANWARA/ SILT LOAM	2-5	5.5	Chlorite, Illite	1.01	.09	1.05
	20-30	5.3	-----	.95	.08	.94
	60	5.4	-----	.77	.07	.26
NARAYANGONJI/ CLAY LOAM	2-5	3.8	Illite, Kaolinite	.35	.07	.56
	20-30	3.9	-----	.58	.08	.43
	60	4.3	-----	.74	.07	.47
DAULATPUR/ LOAMY SAND	2-5	5.8	Chlorite, Illite	.59	.07	.55
	20-30	5.8	-----	.54	.07	.58
	60	6.0	-----	.54	.07	.64

V.2.2 Anwara

Communities of farmers and fishermen were visited along the coast of the Bay of Bengal in Anwara Upazila. This area is highly-vulnerable to cyclones and storm surges. Farmers in this area transplant two consecutive rice crops followed by a crop of broadcast, less-water-intensive oilseeds. Although rice generates higher economic returns, oilseeds provide a more assured dry-season harvest because the area is not irrigated. Only when exceptionally-heavy flooding ensures good soil moisture reserves is a third crop of rice planted. Normally, floodwaters drain from this area in less than a week. Farmers expressed their dependence upon the river floods for productive agriculture. Fertilizers are not used in the area, but pesticides are used regularly. Samples were taken from a poldered field of recently-harvested rice. Bullocks had been used to plough agricultural residues under in preparation for oilseed planting.

The testing of samples obtained in Anwara (Tables V.1 and V.2), revealed a highly compacted silt loam of low organic matter content. The soil is acid. Iron and aluminum oxide contents were low. The dominant clay mineralogy was found to be chlorite and illite. The coarse texture of the Anwara silt loam relative to the Boakhali silty clay loam suggested that infiltration rates would be higher in Anwara than in Boakhali, but testing revealed the opposite. At the surface, recent ploughing of the Anwara site had reduced bulk density to below the densities measured in Boakhali but recent rainfall in Anwara had likely reduced the rate of infiltration such that it was lower

than the rate measured for the finer textured and more compacted Boakhali soil surface. Below the furrow slice, the low infiltration rates measured for the Anwara soil likely reflect a high level of soil compaction at depth.

V.2.3 Narayangong

A flood-protected community was visited in Narayangonj, along an embanked stretch of the Old Brahmaputra River. Farmers in this area generally transplant three rice crops. Bullocks and diesel-fuelled ploughs are used to prepare the soil for planting. Fertilizers and pesticides are used regularly. Farmers complained of the lack of new silt due to flood-control. Despite the loss of fresh silt deposits, some farmers realized net benefits from the flood protection. Others complained that water, essential to enable cropping during the dry-season, was unavailable to them. Although large irrigation canals service the area, the operators of the system control who has access to the water. Some farmers have access to shallow tubewells, exploiting water at depths of 30 to 40 feet, but these consistently fail to produce water early in the dry-season. For farmers without assured water supplies, planting a second rice crop was risky and planting a third crop was precluded in most cases. Embankments have been illegally cut to allow flooding in instances. Samples were taken from a poldered field from which rice had been recently harvested. Agricultural residues remained on the surface.

The samples from Narayangong (Tables V.1 and V.2), indicated a clay loam, of predominantly illite and kaolinite mineralogy. Organic matter content, and iron and

aluminum oxide contents were low. The soil pH is very acid. Bulk densities were high suggesting a well-compacted structure. Penetrometer resistance increased significantly below plough depth. Infiltration rates were roughly an order of magnitude lower than the rates measured at the other two sites. Lower infiltration rates reflect the finer soil texture, poor structural characteristics, and relatively wet soil moisture status of the soil during testing.

V.2.4 Manikgonj

The village visited in Daulatpur Upazila is located on a char in the Padma River. Village residents are landless displacees. The population was primarily composed of women and children. Evidence of the immense power of the Padma River was abundant and clearly pointed to the continuing vulnerability of the char population. Groins are rebuilt each year in an effort to afford some protection from erosion to the village. Although the banks of the char rise about 20 feet above the dry season water level, the entire village has been built on a mound of about 8 feet in height. Despite this, water levels rise sufficiently each flood season to refill a large depression in the center of the village which acts as a communal fish tank following the flood season. Cropping was not undertaken in the area visited. The char was essentially unvegetated except for small bushes and trees planted by the villagers in an effort to stabilize the mound. Samples were taken several hundred meters away from the village.

Samples obtained from Daulatpur (Tables V.1 and V.2), were of a sandy loam textural class. The dominant clay mineralogy of the soil was chlorite and illite. As elsewhere, organic matter content, and iron and aluminum oxide contents were low. The soil is acid. The soil was not compacted, bulk densities were moderate, and resistance to penetration was negligible. Infiltration rates were not tested at this site.

APPENDIX VI

India's Farakka Barrage

The Farakka barrage on the Ganges River, is located in India, 11 kilometers upstream of Bangladesh (Figure 5.1). The barrage is a 1 1/2 mile long structure designed to divert flow from the Ganges River, through a feeder canal to the Bhagirathi-Hooghley River in an effort to reduce siltation in the harbour at Calcutta.

Throughout the dry season of 1975, Farakka's first year of operation, a water-sharing agreement ensured that an agreed upon amount of Ganges flow entered Bangladesh. During subsequent dry seasons, India diverted increasing amounts of water, causing ecological damage and intensifying economic hardship throughout southwest Bangladesh (Crow, 1981). An average of 50% of the river's flow is currently diverted during the driest months, resulting in flow reductions in Ganges distributaries in particular, the Gorai River. The reduced dry-season output of rivers as they reach the Bangladesh coast facilitates the movement of saline water upstream and into coastal aquifers.

Appeals for assistance to the United Nations have resulted in little change. Rather than define a sharing agreement, the United Nations proposed that the needs of both countries be met by designing a plan for augmenting dry season flow. To this end, India has been proposing the construction of a 200 mile long canal crossing Bangladesh to link the Brahmaputra River with the Ganges. Bangladesh has consistently opposed this solution. It has been suggested that monsoon water be stored in Nepal for release during

the dry season via a series of dams. This is not feasible due to tectonic instability (Rogers et al., 1989; Ives, 1989).

Although temporary agreements apportioned flow between the countries until 1987, the long-term water-sharing arrangement demanded by Bangladesh has not been negotiated. Furthermore, there is speculation that India is planning to construct a canal to divert Brahmaputra water from the Assam Valley to the Ganges river. If implemented, such action would further reduce dry-season water availability in Bangladesh.

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