

THESIS

WATER RESOURCES PLANNING FOR REGIONAL
DEVELOPMENT OF BANGLADESH



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BY

LIAQUAT HOSSAIN

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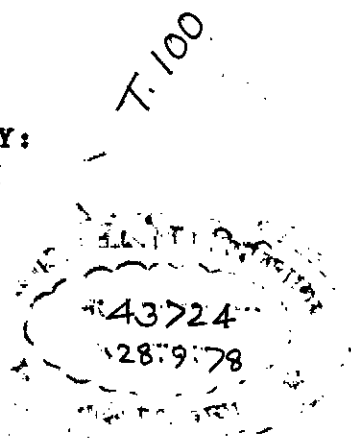
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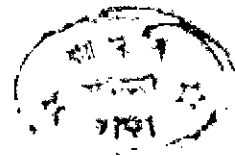


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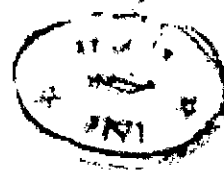
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ABSTRACT

WATER RESOURCES PLANNING FOR REGIONAL DEVELOPMENT
OF BANGLADESH.

Bangladesh has got tremendous possibilities to develop its limited land and enormous water resources on the basis of regional planning. One of the most urgent problems facing Bangladesh is to produce enough food for its people. Bangladesh is subjected every year to droughts as well as floods and periodic cyclones and tidal surges. There is an intense pressure of population on the land. The production of foodgrains has lagged behind the population growth and the requirements of food have to be met by increasingly large imports from abroad annually.

The economy of Bangladesh is predominantly agricultural. About 90% of the countries population is rural, and about 80% of these are engaged in agriculture. Cereals constitute the main national diet of which 95% is rice. Again rice yields per acre is very low. Since it is not feasible to appreciably expand the cultivated area, a more intensive use of the available land must be achieved. Most of Bangladesh is a network of rivers and streams, constituting the delta of three of the world's biggest rivers-the Brahmaputra, the Ganges and the Meghna. The over all gradient of the flood plains is less than a foot per mile. In the monsoon season, lasting for four to five months, the rivers rise to high levels causing extensive flooding by direct overbank spill and

impeded natural drainage and inflicting heavy damage to lives, properties and standing crops. The remainder of the year is characterised by little rainfall and low river levels.

The main crops are grown during the monsoon and depend on rainfall. Only a part of the cultivated area is sown during the dry months taking advantage of the residual moisture in the soil. Perennial irrigation is, therefore, essential to enable a second and if possible a third crop to be grown. Of course organized irrigation has started in recent years.

At present attempt has been made to increase food production in Bangladesh through quick-yielding projects utilizing tube wells and low lift pumps to supply irrigation water and expanding the use of the new high yielding rice varieties. However, these have limited ceilings and all studies of future increases of population and agricultural production in Bangladesh indicates that better water control is essential to meet the long-term needs of food of the people.

The major programmes in the field of water control in Bangladesh may be summarised as follows;

- a) Water control;
- b) Estuary closures;
- d) Land Reclamation, drainage and irrigation.

For the regional development of water resources in Bangladesh

urban protection, development of water fronts in urban centres, development ports and harbours, development of fisheries both inland and marine, development of forest, development of national parks, preservation of wildlife, development and reclamation of bils and haors have been incorporated in the plan. For recreational uses of water, marina, sea world, aquarium, tourist resort, etc. may be developed. Domestic, industrial and agricultural uses of water may be assured by salinity and pollution control. Measures may be taken against cyclone and tidal surges. Ecological balance must be maintained by proper water control. Multiple & inter cropping may be introduced in Bangladesh like China; Taiwan to accelerate food production. Research stations should be established with trained personnels in the field of agriculture and hydraulics.

According to hydrological unit and divisions made by major rivers, Bangladesh is divided into four region:

- a) Northwest Region;
- b) Northeast Region;
- c) Southwest Region;
- d) Southeast Region.

Each region is again divided into Sub-Regions: Northwest into two, Northeast into three, Southwest into four and Southeast Region into three Sub-Regions. As thana is an administrative unit, a big thana may be taken as smallest unit for regional development.

For small thanas two or more of them may be integrated into one for regional development. Public should be encouraged to participate in the development work. From now local water right may be established by public hearing to avoid dispute in future.

In Bangladesh major problem arises in the development of major rivers. All the major rivers have their head waters outside the country. Any developments in the upper reaches of the rivers which flow from India affect Bangladesh. Further, best results would be obtained only if the river basins are developed on a comprehensive and co-ordinated basis. India and Bangladesh have, therefore, set up a Joint Rivers Commission to make joint studies and take joint action in the field of flood control, river basin development and the development of hydroelectric power and irrigation on the common rivers between the two countries.

For the implementation of the Regional Plan it is proposed to establish a number of departments such as:

- a) Park and Recreation service;
- b) Wildlife Preservation;
- c) Land Reclamation;
- d) Marine Fisheries;
- e) Environmental Protection Agency;

The Regional Plan may be implemented with local and foreign

assistance. Local manpower and materials should be used as far as possible to save foreign exchange. Proper economic and financial analysis should be made before taking up any work. Cost Benefits ratio should also be determined and viable regional plans should be implemented. In short it may be concluded that Water Resources Planning for Regional Development of Bangladesh is essential for the economic emancipation of the country.

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CHAPTER I

INTRODUCTION

General

Since the beginning of history and even before, the availability of water has determined the course of civilization. The necessity of life itself, the abundance or scarcity of fresh water has dictated where and how the man will live as well as how far he will progress economically and culturally.

Rapid population growth and ever increasing living standards have resulted in a rapid rise in mankind's needs and greater demands for water resources. As water use has gone up, there has generally been a concurrent degradation in water quality. At the same time, because the most readily available supplies were developed and utilized first, there has been an ever increasing complexity in the system and management organizations required to develop new supplies. Consequently, problems associated with meeting new demand have multiplied in some sort of geometric progression and are becoming more acute with each passing year.

Because of these trends and the ever-growing recognition of the importance of water resources to the mankind, planning for the utilization and management of water and related land resources has been in an almost constant state of flux. We have seen the concepts of water resource planning to advance from the single purpose project concept through the multiple purpose basin approach, to regional, national and even now the international approach.

In spite of the failure in the past to make significant advance in water resource planning for regional development of Bangladesh (Map 1) it is generally agreed among those concerned that future development of water resource should follow the concept of integrated regional development. Water resources of Bangladesh should be planned in the following three manners for the regional development of the country:

- a) Controlling;
- b) Conserving;
- c) Utilizing;

Flood control, irrigation, drainage, channel improvement, river training, protection of urban and commercial centres, dredging, construction of embankment, power generation and use, fish culture, wild life preservation, control of water pollution, recreational facilities, urban and rural water supply for domestic and industrial purposes etc. are all affect each others. In this thesis an attempt has been made to present a plan for development and utilization of water resources for regional development of Bangladesh for achieving maximum benefit as far as practicable.

Because of the vital relationship between water resources and the lives of seventy five million people, Bangladesh is very much concerned with the problems relating to water resources planning. The recurring need for import of food grains in huge quantities is a constant reminder of the importance of finding a workable solution. An adequate and assured indigenous food supply

for Bangladesh depends upon improved water control and uses. It may be that use of water in the dry months through irrigation rather than flood prevention would prove the speediest way of securing adequate food production. No single solution can possibly be depended upon in the long run for this problem, however, only a comprehensive effort joining dry season water use with the improvement of proper protection for high flows can achieve the desired result.

Elements Of Integrated Development

The term "integrated" applies largely to three associated ideas. These ideas are: multiple purpose storage project, basin wide programme, and comprehensive regional development.¹ The idea of the multiple purpose storage project is simple. If a dam is to be built for any purpose it is usually advantageous to use it for more than one purpose.

Multiple-purpose storage projects gradually came to be favoured over single purpose dams, after it was repeatedly shown that the total benefits of public expenditure could be considerably increased. Multiple purpose storage is now a widely accepted part of integrated river basin development and has been practiced in Bangladesh in Karnafuli Multipurpose Project.

¹Dr. Ian Burton, "River Basin Development in India" Indian Journal of Power and River Valley Development, December, 1965, P.59.

The second idea i.e. the basin wide programme is still not fully accepted in Bangladesh. It can be shown that just as a Master Plan for a city enables developers to fit their projects into a meaningful frame-work, so also in river basin development it makes more sense to plan for a whole basin in broad terms. If the series of individual projects are co-ordinated, each one of them is able to contribute more in the way of benefits. The benefits from an integrated basin wide plan can be much greater than the sum of the benefits from a series of unrelated projects.¹

Although most storage projects are built on multiple-purpose lines, there are still only a small number of basin wide plans for development. The Tennessee Valley Authority plan for the development of the Tennessee River is one famous example. Other examples include the Rhone in France, the Kitakami in Japan, the Tigris-Euphrates in Iraq, the Volga-Don in U.S.S.R and the Damodar Valley Corporations Plan for Damodar River in India.

The third idea in integrated river basin development is that of comprehensive regional development. If storage projects are to be multipurpose, then it makes a lot more sense to attempt a basin wide approach to development. If a basin wide approach is to be adopted then it soon follows that the approach should be comprehensive. There is a distinction here which is crucial. As long as projects are considered as engineering works to be

¹ Gilbert F. White, "A Perspective of River Basin Development", Law and Contemporary problem, Vol. 22. No. 2. Springs, 1957, P.158.

carried out for their direct benefits i.e. flood control, Irrigation, power generation, etc. there is no emergence of the comprehensive development idea. One such engineering works are seen as a means to an end, however, they become comparable with any other means of achieving the same end. For example, as flood control and irrigation are to promote the well-being of the agricultural community in the basin, so also are soil erosion control, fertilizer programme, subsidised seeds and the like. It is at this point that river basin development becomes a form of regional planning. It is a form of regional planning in a river basin context and centered round water resources.

Power Development

Power development is essential for water resources planning for regional development of Bangladesh. One of the essential keys to adequate adaptation of water resources to man's purposes is electric power. Power is essential for irrigation and drainage and by extending its magic outside of the cities, it will also serve to electrify the farm villages and give a new and mighty impetus to developing rural and village industry and commerce (Map 2). So power and water should be developed jointly.¹

Co-operation Of Bangladesh, India And Other Countries Of The Region

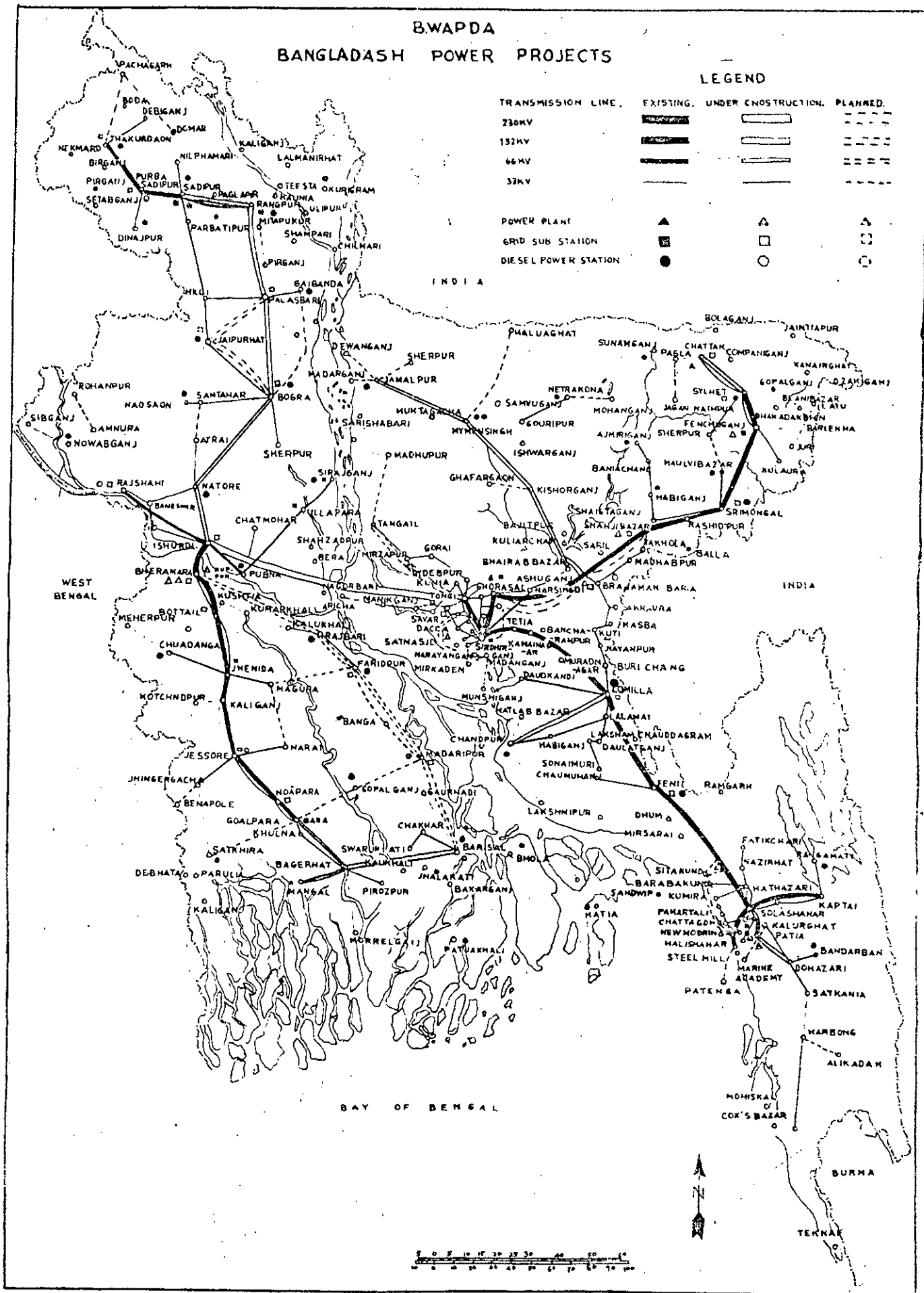
The main rivers of Bangladesh are all international in character, originating in the Himalayan Plateau and flowing

¹ EPWAPDA, "Master Plan - Supplement D - Power" International Engineering Company, Inc, Sanfrancisco, California, U.S.A., December, 1964, P.1.

BWAPDA BANGLADASH POWER PROJECTS

LEGEND

TRANSMISSION LINE.	EXISTING.	UNDER CONSTRUCTION.	PLANNED.
230KV			
132KV			
66KV			
33KV			
POWER PLANT			
GRID SUB STATION			
DIESEL POWER STATION			



MAP 2. TRANSMISSION LINES IN BANGLADESH

through long reaches in India before crossing the boundaries of Bangladesh. To obtain the best total result, these mighty rivers should be developed on a comprehensive plan, taking full advantage of all the opportunities afforded, regardless of location. It should be possible to develop benefits through such an approach which would pay off handsomely for all of the countries (Bangladesh, India, Nepal, Bhutan, Sikkim and China) involved. Of utmost importance, therefore, is that Bangladesh and India find an effective way of working together, as only in this way both the countries can secure the maximum benefits at minimum cost, and this will cause minimum dislocation of densely populated areas. Accurate knowledge of the river characteristics and their effects on the economy of Bangladesh is a prime prerequisite to effective co-operation. Hence the job of accumulating and maintaining necessary records is of most urgent importance. It should be the first step, not only in Bangladesh's own programme, but also in any joint action with India and other countries of this region.

Possible Effects Of Indian Development On Bangladesh.

Indian developments in the Ganges Basin will seriously reduce the amount of dry season flow entering Bangladesh. Quite apart from the matter of Farakka Barrage, where-from it is proposed to divert upto 40,000 cusec down the Bhagirathi-Hoogly, there will be strong pressures within India to permit greater use of the dry season flows for irrigation. This pressure will come particularly from farmers in the new project areas in course of construction on the northern tributaries, notably the Gandak,

Gogra and Kosi. The proposed Farakka diversion alone represent a potential difficulty for the successful operation and development of the Ganges-Kobadak Project (Kushtia Unit), if India is to abstract 40,000 cusecs regardless of the residual flow. In some years during April and May this would leave only a negligible flow in the Ganges and even if sufficient to supply the G-K Pumping units, there would be problems of maintaining water depth at the pump intakes. Further expansion of irrigation from the Ganges in Bangladesh should, therefore, be linked with a resolution of the Ganges water dispute.

The reduction of flows of the Ganges into Bangladesh would have a number of major consequences: (1) there would be a distinct seasonal limitation to the development of irrigation in the southwestern region of Bangladesh by gravity flow or by pumping from the natural distributaries, (2) there would be further encroachment inland of the margins of saline water intrusion, (3) navigations would be affected on the Ganges and on the Gorai, (4) it is claimed that the forestry of the western part of Khulna district would be adversely affected, (5) it is claimed that fisheries would suffer, (6) it is possible that certain method of operation adopted by India for Ganges control works (barrages and dams) might change the sediment discharge and regime of the Ganges.

Multiple Purposes Of Water Resource Planning.

While the primary objective of water control in Bangladesh is to increase crop production through flood protection, irrigation

and drainage, other important objectives include navigation, conservation, improvement of fisheries, water power and land reclamation in the coastal regions.

Flood Protection And Control.

Flood protection is the pre-requisite to the development of our country, as full land capability cannot be achieved without it. The various methods of flood protection and control as applicable to Bangladesh are briefly discussed below:

Catchment Conservancy

Forest and vegetation in the catchment of the rivers where precipitation is very high helps to retard the flow of water over the surface and increase percolation into the soil. This reduces the quantity and intensity of the flood run-off. This also checks soil erosion and formation of gullies on hillslopes and consequently lower the sediment loads in the river. The conservancy works comprise of afforestation, soil management, stream control and checking landslides. Conservancy of the catchment constitutes therefore, a very important means of flood control. In the hilly regions of Bangladesh conservancy of catchment can be practiced.

Storage And Diversions

There is no significant storage sites in Bangladesh. Many sites exist upstream in the Ganges, Brahmaputra and Meghna basins; hence the feasibility of developing sufficient storage there, to have an appreciable effect on flood stages in Bangladesh,

remains to be examined. Diversion solely for flood control are generally uneconomic. In Bangladesh there is however a possibility, of diversion of a part of flow of big rivers through old channels.

Embankments

Embankments constitute the most practical method of flood protection in Bangladesh. A well designed and properly aligned system of embankments can exclude exterior flood waters from protected areas. Flood waters resulting from blocked drainage and interior run-off can be removed through sluices and regulators and in some cases through interior drainage channels and major pumping plants. As a next step the protected area should be given irrigation facilities by means of tube-wells and low lift pumps.

Channel Rectification And Bank Stabilisation

A comprehensive channel rectification and bank stabilisations and dredging programme can materially increase the hydraulic efficiency and hence the channel capacity of the rivers. But these increases would not be sufficient to eliminate flooding at times of peak flow. However, these works would have significant flood control benefits through reduction in the required embankment heights and probable reduction in the duration of flooding in unprotected areas. Channel rectification works consists of rock dikes and groins to close secondary channels and induce sediment deposit and short spur dikes or groins.

constructed normal to the bank line and spaced, sufficiently close together to reduce the current against the bank thus eliminating caving and encouraging silt deposit.

Bank stabilisation structures consists of articulated concrete mattress or rock rip-rap revetment. A channel rectification and bank stabilisation programme to control reasonably the big rivers of Bangladesh will require large quantities of stones. These are not available within easy reach of the rivers in Bangladesh and have to be imported. A number of bank protective works to check erosion by the rivers of important towns and business centres have either been completed or are in progress in Bangladesh.

Dredging

Dredging alone have little chance of being effective in alluvial valleys or even small streams in increasing their hydraulic efficiency because of their very nature which are in the process of aggrading and which still depend on rivers to provide the sediment needed to raise the elevation of the land.

A further point that precludes using dredgers along to effect flood control is the fact that the heavy silt carrying streams of Bangladesh will fill the dredging cuts almost as fast as they are constructed. The rivers of Bangladesh are perhaps the heaviest silt carriers in the world. Therefore, dredging cuts would have no chance of remaining open for any appreciable time.

On the otherhand, dredging strategically located and excavated at the proper time can aid materially in the development of a central channel, the closure of secondary channels and the removal of clay plug from the central channel that are retarding development. The planning and execution of dredging is largely a case of trial and error and has to be carried out after keeping careful records at the initial stages of the condition under which each cut is made and analysing the results obtained therein.

Irrigation

Most of the agricultural land in Bangladesh is cropped only once taking advantage of the rainfall during the monsoon season and the land remains fallow for a considerable part of the year corresponding to the dry season for lack of water. Even during the monsoons, failure of rain at critical periods of the crop growth affects the standing crops. All the year irrigation is, therefore, essential for raising two or three crops and to safeguard the monsoon crop. Irrigation development will be done with both surface and ground water, surface water being distributed by gravity diversion by means of barrage or pumping the water from the rivers.

Two principal agencies have been active in the field of water control in Bangladesh. The principal agency for small scale irrigation is the Agricultural Development Corporation (ADC), while for large-scale water control (including flood control, drainage as well as irrigation) the agency is the Water Development Board (WDB) (Previously the Water and Power Development Authority).

The Inland Water Transport Authority looks after the development and maintenance of navigation channels.

Saline Water Intrusion

The lands of Bangladesh because of heavy rainfall do not have the problem of the rise of salts and their concentration in the upper layers of the soil. However, the coastal saline lands occupy an area of about 6,000 square miles bordering the Bay of Bengal including the Sundarban forests. The soils are generally silty clay loam and the topography is flat with occasional coverage with sea water. The cultivable areas are being reclaimed for rice cultivation through the construction of embankments which protect the lands from flooding by saline tidal water.

Navigation

The waterways of Bangladesh are transport routes ranking in importance with the railways and highways. In addition to established steamer and barge routes for freight and passengers, sail and hand powered craft in great numbers serve thousand of villages. The major rivers serve as the main arteries of communication and the secondary rivers and smaller channels as the connecting route to reach the cities, towns, commercial centres and villages. Irrigation canals wherever feasible will also be utilised as waterways for transport by boat.

Hydro Power

The scope of hydro power in Bangladesh is limited on account of the generally flat terrain of the country. There is only one

hydro power station on the Karnafuli river in the Chittagong Hill. Two other hill streams in this region, the Sangu and Matamuhuri, have potential for generation of hydro power. Prospect of tidal power is not so good on account of the fluctuation in tidal range being small. There is prospect of power generation through the construction of barrages across the Brahmaputra and Tista rivers..

Basic Approach Of Water Resource Planning

The planning of water resources development has to consider the benefits to be derived not only immediately or in the near future, but also in the long run through the development of the entire basin or the region. Therefore, whatever development is executed today should be considered to be part of the future ultimate development and it should be integrated to the planning for the future. Within Bangladesh, the country is naturally divided into four regions by the major river systems viz North-West, North-East, South-West and South-East. Water Resources Planning Studies have been made for the regional development of Bangladesh on the basis of this four divisions. Each region has again been divided into sub-region to evaluate its development potential.

The long-term water resource development plan has the following objectives:

- a) to confine the river flows to stable and fixed bank at all stages of discharge, requiring embankment and river training;
- b) to control water flow from river to land;

- c) to ensure drainage of water from the land into the river;
- d) to expand irrigation by surface and ground water on a co-ordinated basis to cover as much land as possible;
- e) to prevent flooding from the sea which would require besides coastal embankments, estuary closure;
- f) to generate hydro-power where feasible;
- g) to improve river channels for navigation and provide regulated navigation canals where feasible;
- h) to relate the Water Resource Planning Studies for regional Development of Bangladesh to a comprehensive programme for the water resource planning studies for the entire Ganges-Brahmaputra-Meghna river system.

Inter Relationship Of Various Aspects Of Water Use

In most river basins, there exists at one time or other during the year a period of water deficiency related to the potential demand of that water. The question of priority of use, therefore arises. Such uses include irrigation, navigation, pollution control, checking salinity intrusion and recreation facilities. Similar relationship exists between water and other natural resources and where conflicts of interest arise, these have to be solved taking into consideration their economic and ecological impact.

Fishery

Fisheries hold a unique position in the economy of Bangladesh second only to agriculture. Fish forms the second

staple diet of the people. Also, roughly 15 million people depend directly or indirectly for their livelihood on trades connected with fishery. Attempt should therefore, be made while planning development to ensure that water control measures do not interfere in the natural movement of fish or their breeding.

Water Pollution and Its Control

There is problem of dispersal of domestic waste and as communities grow, this problem will increase both in magnitude and in complexity. With the development of manufacturing and other industries, the disposal of industrial wastes frequently becomes a serious and complex pollution problems. The problem of water pollution in Bangladesh is not however, acute as yet. Nevertheless, attention is being given to the proper treatment of sewerage and industrial wastes prior to their discharge into public waters.

Problem Of Water Resource Planning In Bangladesh

Major problem arises in connection with the planning of the water resources of international rivers. For instance, upstream storage of a sufficient capacity could decrease the flood peaks downstream. On the other hand, flood embankments built along the rivers in the upper reaches increase the flood flow downstream. Any irrigation withdrawal in the upper reaches decreases the low flows in the lower reaches during the dry season. Thus, the potential uses of water in India affect the planning and design of water projects in Bangladesh.

The fundamental problem of land and water resource development in the Ganges - Brahmaputra - Meghna basins arise from the highly seasonal flow of these rivers and their tributaries. Nearly 84% of the rainfall in the Ganges plain occurs from June to September, and 80% of the rivers annual flow takes place, during the four months of July to October. The season of high flow on the Brahmaputra begins a little earlier and lasts upto October. But two thirds of its annual flow occurs in the four months from June to September, and only one-third during the remaining eight months of the year. The average annual precipitation in Meghna valley is exceptionally heavy. It varies from 80 inches to 250 inches. About 82% of the rainfall occurs from April to September.

Even at present the dry season flow of the rivers is barely sufficient for the needs of India and Bangladesh. In order to develop the irrigation potential of agricultural land in both countries it is essential to store a portion of the monsoon water for irrigation. Such storage will also render other benefits of which the most important is the generation of hydro-power. In the lower Ganges-Brahmaputra-Meghna Basins, there are four major approaches to water resources Planning for regional development.

- 1) Surface storage on the Ganges, Brahmaputra and Meghna tributaries for river regulation;
- 2) Exploitation of the Groundwater potential;
- 3) Estuary closures and downstream channel storage;
- 4) Inter-river transfer of water to adjust shortages between river basins;

Joint Rivers Commission

India and Bangladesh have agreed to make joint studies and take joint action in the field of flood control, river basin development and the development of hydro-electric power and irrigation. For this purpose the Indo-Bangladesh Joint Rivers Commission has been set up. The constitution of such rivers commission was recommended in 1941 by Mr. S. C. Majumder, Chief Engineer, Department of Communication and Works (Irrigation Branch), Bengal.¹ The Commission has already started functioning. It has been considering an approach to long-term planning as well as medium and small projects which could render benefits to the people in comparatively shorter period of time. The Commission is investigating the flood problems of certain areas through joint study groups consisting of water resources experts of both the countries. The Commission has already instituted an integrated flood forecasting and flood and cyclone warning system between the two countries by means of wireless net works. Special studies and surveys will be taken up in the upper reaches of the common rivers for the location of suitable sites for storage reservoirs. A comprehensive programme of work is being drawn up for this purpose.

¹ S. C. Majumdar, "Rivers of Bengal Delta" Government of Bengal, Department of Communication and Works, Irrigation Branch. Superintendent, Government Printing, Bengal Government Press, Alipore, Bengal, 1941, P.11.

Mathodology

For data collection for this thesis, the writer undertook an extensive field trips both by land and air throughout Bangladesh. Extensive field survey was undertaken and data were collected from the existing water resources project areas of Bangladesh by taking interview of the local people. Moreover, the writer got the opportunity of discussing the various aspects of water resources development plans and its problems with a number of experts in this field. Further, the writer had a chance to visit important water resources projects of U.S.A. and Holland during 1971 and 1972. The materials and experiences thus gathered helped greatly in preparing this thesis.

Moreover, several useful sources have been utilized - books, periodicals, public documents, daily papers, office files and maps. These were procured from the various libraries in Bangladesh and the Unites States of America. Materials were also procured from the Government Agencies and Autonomous Organizations of Bangladesh. Planometer and rotameter were used in finding out the areas and lengths respectively from maps.

CHAPTER II

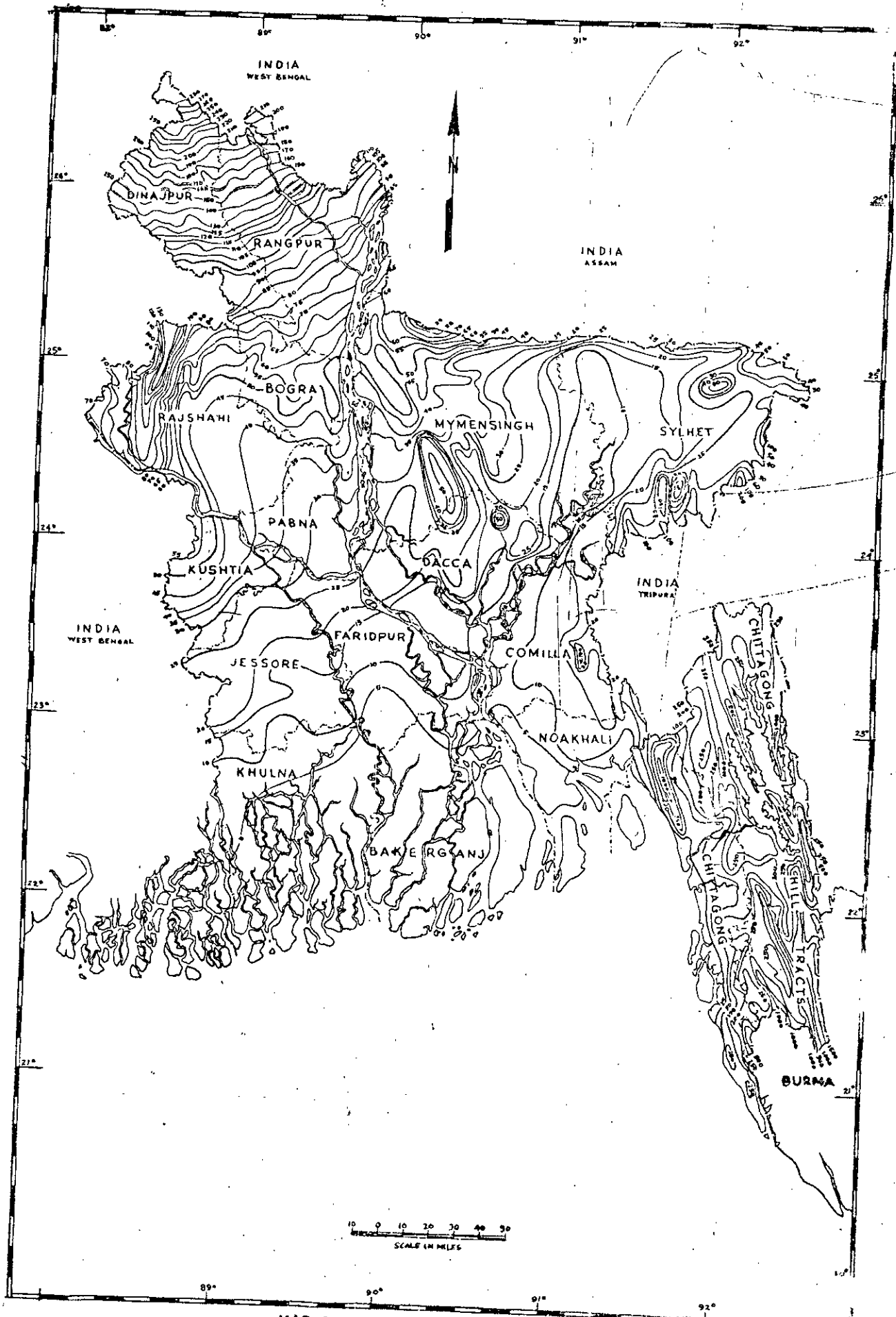
GEOMORPHOLOGIC DESCRIPTION OF BANGLADESH

Origin and Formation Of Delta

The origin of the land of Bangladesh (excluding Chittagong District and the Chittagong Hill Tracts) was the deposition of materials transported by the rivers. The contour map shown in Map 3 shows how the river plain have been built up from the west and south, and to a much smaller extent from the north-east. Millions of tons of silt from the Himalaya, Chotangagpur plateau, Sauthal Pargana and Assam hills are carried every year by the Ganges, Brahmaputra, Meghna and their tributaries which eventually form the Ganges - Brahmaputra-Meghna delta on the region once occupied by the Bengal gulf.

Along with the progress of building, a delta also gradually extends towards the sea. The seaward movement is facilitated by the deposition of load within the sea during the flood times when the silt laden water is carried considerably to the sea.

Delta building activities are also facilitated by the tidal activities of the sea. Tides flow in and ebb out nearly twice a day (the average period being between 12 to 13 hours per tide) and the duration of flow tide is between $1/2$ to $5/9$ th of that of the ebb tide. Now the flow tide enters into these rivers twice daily throughout the year, and as there is a vast reservoir of unconsolidated silt at their mouths, deposited there by the upland flood during the monsoon months, the flow tide picks up this silt on their way inland. This flow tide, as has already been pointed out, has a lesser duration than the ebb.



MAP 3. CONTOUR MAP OF BANGLADESH

But due to upland flow a greater quantity of water runs back in the ebb tide than it is in the flow tide, the velocity of water in the ebb will be less than that in the flow. As the silt carrying capacity of water of a river varies directly with its velocity in these tidal rivers, the ebb tide cannot carry the same amount of silt as the flow tide. The net result is that the tidal water, while coming back in ebb tide, cannot carry back the same amount of silt that the flow tide took inland, and hence the quantity the former cannot carry on account of its low velocity has to be dropped somewhere on the river bed.

So long as the bank of these tidal rivers lie below the high tide level and the river are free to spill over their banks into the adjacent lands, the tides perform the same function as the upland floods, i.e. raising the delta already built. After depositing the silt on the banks and on the delta lands, the tides ebb back with much less quantity of silt in it.

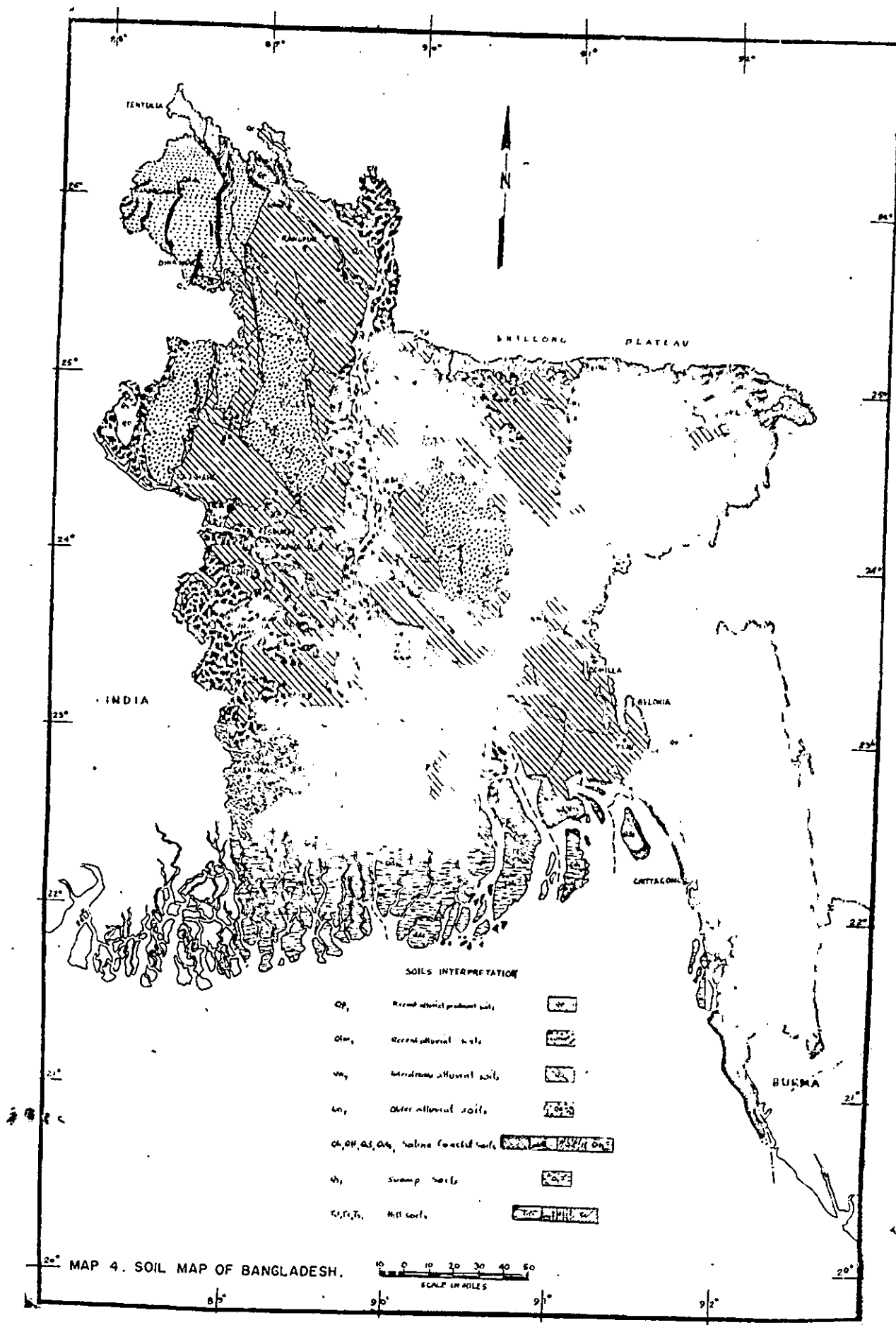
It has already been mentioned that when the silt laden water from flood or spring tide spills over the bank of a river channel, the velocity suddenly drops due to sudden increase of cross-section of flow and the major part of the silt gets deposited on and near the banks. This water, then with lesser silt load, passes over the rest of the adjoining area in the delta, depositing silt in lesser quantity there. The thickness of the silt deposit is thus lower and lesser, the further the area is away from the bank.

This makes the bank relatively higher than the adjoining areas which are raised with a slope away from the banks making the central part

of the delta quite low. Finally, a time is reached when the banks of the river channels become too high to allow normal flood or tide to spill over them, thus slowing the process of land formation. The final stage of the raising of a delta, however, is a very slow process. Here, to expedite the process of raising of the delta lands, specially for the low lying central zones, nature takes the help of these zones. These central zones form, in all probability, into creeks through which the tides could play inland and picks up silt on their way in and, generally raise their beds and banks until they are raised up to the same level with other portions already raised or being raised by the main diverging channels running by the sides of the delta.

Thus, both upland floods or upland water supply and the tides help in building up and raising the delta. The process of raising and extension of the delta towards the sea has been going on from time immemorial and it will in all probability, continue for many more years to come.

The soil map shown in Map 4 shows the approximate spread of the alluvium of the several large river groups. The red earth areas are higher lands, and evidently belong to much older alluvial deposit. The relatively high land in the north-west and west was probably laid down by the Tista, Karatoya, Atrai and Mohananda rivers. The land bordering the present course of the Brahmaputra and that of south Mymensingh, north Dacca and west Comilla districts was formed by the alternating course of the Brahmaputra. The land bordering and south of the Ganges was formed by that river, which has steadily moved east



during the past few centuries. The low-lying land in north Mymensingh and Sylhet districts was formed by the rivers devouching from the hills in Assam, adjoining the area to the north-east and south.

Mention has been made of the very marked depression in the east Mymensingh and west Sylhet area, considerably below the level of the banks of the Brahmaputra at Bhadurabad. A probable explanation of this difference in elevation is that the Brahmaputra has carried a considerable sediment load, due to the easily erodible rock of the Himalayas. The tributaries of the Meghna carry less sediment, since they rise in the Garo, Khasi, Jaintia and Naga hills of Assam, formed of relatively hard rock. The Brahmaputra has therefore been quite active plain builder, and the flood plain of the Meghna group has remained low and gets submerged due to the rising levels of the outfall to the sea.

The advance of the delta into the sea has apparantly been very slow during the last two centuries, despite the vast volume of silt brought down by the combined rivers. This may be due to the steep continental shelf (swatch of no ground) bordering the coast, and the strong tides which distribute the silt. Just to the south of the middle of the developed part of the delta there exists a sub-marine canyon around which sounderings from 30 to 60 feet abrouptly dropdown to 1,200 to 2,000 feet below mean sea level in the form of a long narrow estuary to the deep sea. This remarkable depression lies north-east to north-west.

Fergusson has assigned the cause of the existance of this great canyon to the scouring of the bed of the Bay of the sediment-laden

under currents produced by the meeting of the tides from both the east and west coasts. A similar canyon exists near the mouth of the Mississippi and it is suggested that a turbid current carrying coarse granied material during glacial stage eroded the Mississippi submarrine canyon and supplied the material for the submarine delta off the canyon's mouth¹.

In the case of the Ganges delta, the coarse scouring materials may be associated with the shingles and coarse pebbles found at 481 feet depth, in Boaring operation in Fort William, Calcutta, from 1835 to 1840. These materials instead of being carried during glacial stages as in the erosion of the Mississippi submarine canyon, might have been deposited during a devastating flood some 4,000 years ago, and later on eroded by under current to form the "Swatch of no Ground" in the Bay of Bengal.

The formation of swatch of no ground has also been ascribed to local sinking, but this depression may also be the remainder of some prehistoric valley. The formation of these submarine canyons is very controversial. Actually their effects upon shore evolutions are of more immediate concern in development planning for the area than their origins.

Much additional study must be made on the nature and type of deposits of this vast delta and the coastal and submarine morphology,

¹ James Fergusson, On Recent Changes in the Delta of the Ganges. (London: Quarterly Journal of Geological Society, Vol. XIX. Pl. XII, April, 1863, P.352).

so that conclusions can be drawn regarding its formation, growth and development.

History Of The River

The formation of the delta lands indicates that the Brahmaputra has favoured alternatively the two channels now known as the Jamuna, leading due south, and as the old Brahmaputra, leading south-east. It is known that from 1864 to 1787 the channel was in the Old Brahmaputra. Then the Tista, which had flowed south to the Ganges via the Purnabhaha and into the lower Jamuna via the Atrai and Karatoya, in the floods of 1787 suddenly swung east down an old channel to join the Brahmaputra at Chilmari.¹ Thereafter the Brahmaputra slowly favoured the Jamuna Channel at the expense of the old Brahmaputra Channel. By 1830 the Jamuna was the main Channel and was pushing the Ganges south.² Suppositions of earth movement raising the Modhupur red soil area on the east and north, might have caused these changes but this has not been substantiated. The Tista has a history of being very unstable, and from the configuration of the ground has apparently swung to and from between its Ganges and Brahmaputra-Jamuna outfalls. Following the river protection and embankment work recently constructed in India, the Tista is now likely to remain flowing into the Brahmaputra.

Prior to the sixteenth Century, the Ganges passed most of its discharge to the sea via the Bhagirathi-Hoogly, Jalangi and Mathabhanga

¹ S.C. Majumder, Rivers of the Bengal Delta.
Op. Cit., P. 30.

² Ibid, P. 32.

into the Brahmaputra tributaries. This so glutted the Brahmaputra with debris that the river at Dibrugarh, which had been previously observed to raise about one-tenth of a foot yearly, rose ten feet in five years. Vast areas in the lower Himalayas and in the Assam hills appear to be literally torn apart and millions of tons of earth and gravel exposed to rapid erosion into the river valleys. Decades will pass before this loose material finds a resting place.

The river levels at Dibrugarh are still rising slowly, but the excess charge seemed to have passed downstream by 1956. It therefore appears that, although much of this excess burden may still be deposited in the Assam Valley, some part of it will be carried downstream into Bangladesh. Unfortunately, no data is available to show the passage of this unusually heavy load down the Brahmaputra in Assam other than the effect on the navigability of the river, which has become obstructed for a distance of forty miles downstream from Dibrugarh. Although it is suspected that there has been changes in river level of Brahmaputra in Bangladesh, there is limited data available to prove or disprove any such specific river level changes. The general report from navigation source in Bangladesh is that dry weather navigation has been more difficult in the past few years on the Brahmaputra and Padma.

CHAPTER III

PHYSIOGRAPHIC DESCRIPTION OF BANGLADESH

Relief

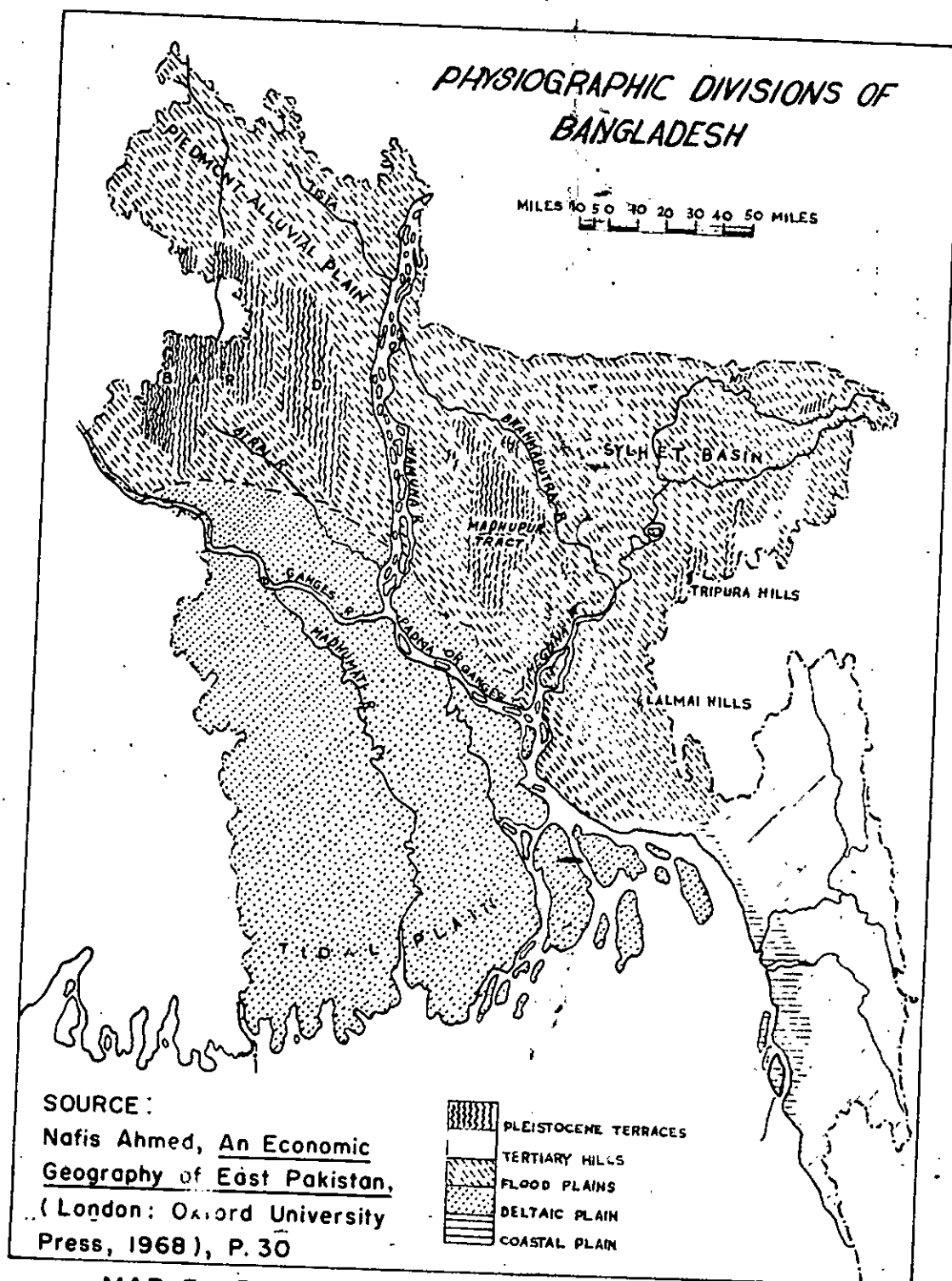
Physiographically Bangladesh can be divided into a number of divisions (Map 5) with their own characteristics on the basis of physical feature and drainage patterns. It can be divided into three major physiographic units, namely, the Tertiary Hills, the Pleistocene Terraces, and the Recent Flood Plains. Each one of these can be further subdivided into smaller units.

Tertiary Hills

The hills of Bangladesh are the continuation of the Assam hills and the Burmese arc and are of the Tertiary age. They have been folded by thrusts coming from the Burma side, so they have a convex face towards the west. The political boundaries have divided the hills into three units belonging to the Burma, India and Bangladesh. Those of Bangladesh are divided into three groups: Chittagong Hills, Tripura Hill and the Northern foot-hills.

Chittagong Hills

This is the only extensive hill area in Bangladesh and lends a welcome geographical variety to the scene, which is dominated by wide plains and large rivers. In the area of the Chittagong Hill Tracts, a number of hill ranges run from north to south, enclosing longitudinal river valleys. The hills rise in tapering masses and are generally no wider than about 120 feet at the top. Their elongated summits fall away at the two extremities, and it is only here and there along the



MAP 5. PHYSIOGRAPHIC DIVISIONS OF BANGLADESH

range that there is any material difference in height. In general, the ranges gain in elevation to the east. The highest peak in all Bangladesh is Keokradong (4,034 feet) at the south-eastern extremity of the area, and others are Mowdok Mual (3,292 feet), Reng Tiang (3,141 feet) and the Pyramid Hill (3,016 feet) formed nearby. In all, there are ten ranges i.e. Basi Tang, Maranga, Tyambang, Bilaisari, Sachchel, Bhanga-mura, Batimain, Barkal, Sitapahar and Fatikchari. Except on the borders of the Lushai Hills and the Arakan division of Burma, these hills do not rise beyond 2,000 feet. Chimbock, about 50 miles south of Rangamati and about 2,000 feet in elevation, is a suitable choice as a hill station in Bangladesh. Near Kaptai, at the western extremity of the hills, on the Karnafuli river less than 30 miles from Chittagong, the Karnafuli hydro-electric project has been brought into existence with the construction of the Karnafuli dam.

Many of the valleys, particularly in the west, are flat and broad, while others are a mixture of laterite and sandstone hillocks. Most of the valleys are covered with dense virgin forest, interspersed with small watercourses, called "Chara" and "Chari"¹, and swamps of various sizes. Generally, the configuration is erratic and not easy to follow.

To the west of this main mass of hills, a few low ranges run in a south easterly direction, parallel with each other along the Bay Coast line of the Chittagong district. In the north, the Sitakund and Chandranath hills run close to the coast, with the highest elevation of

¹ "Chara" and "Chari" mean small hilly streams.

1,155 feet in the centre of the range. Part of the town of Chittagong lies on the outlying "Tilas"¹ of this range. In the south, near Cox's Bazar and Teknaf, the hills form precipitous cliffs along the sea. These low range enclose three or four wide valleys of exceeding fertility and contain dense population in Chittagong district.

Tripura Hills

South of the Kushiya river, six hill ranges of small elevation project into Sylhet district from the Tripura range. The maximum elevation of these hills hardly exceeds 800 feet above sea level, and they enclose between them river valleys opening, out to the north into the depressions or "haors"² in the plain. From east to west, they are: the Patharia range, Hararganj or Langla hills, Bhanugach or Rajkandi hills, Balisara hills, Satgaon hills, and Raghunandan hills. Of these, the Patharia hills, the eastern-most, lie on the boundary of India and Bangladesh. They are the highest in elevation, with a maximum of about 800 feet. Traces of oil were found several years ago, but recently in spite of prospecting on a modern scale, no further trace has been found. The Rajkandi, or Ita hills penetrate farthest north, reaching Fenchuganj on the Kushiya. These hills contain no prominent peak and their hills degenerate into mere tilas. In their natural state, they are covered with forest, bomboo and scrub. But the topography, climate and soils are suitable for tea cultivation and they are Bangladesh's most important tea area.

¹ "Tilas" mean small hillocks.

² "Haor" means depressed area specially of Sylhet and Mymensingh districts.

Northern Foot-Hills

The Northern Foot-Hills occupy small isolated areas north of the Surma River in Sylhet district and the northern border of Mymensingh district. The Jainliapur, the Jaflong, the Sylhet and the Chhatak Hills of Sylhet district and the Susang Hills of Mymensingh district represent the Northern Hills.

Around Sylhet town, particularly to the north and northeast, there are many low hills and "tilas" covered with trees and turf. These isolated elevations are from 100 to 200 feet in height. Near Chiknagul, on the Sylhet-Shillong road, the hillocks run in small ranges which cover an area of several square miles. The prominent elevations are Charragong (300 feet), Chiknagul (260 feet) and Khadimnagar (180 feet). A few "tilas" are also found between the Surma and the Kushiara rivers, near Gopalganj and Madhuganj. Tea is cultivated on these elevations.

The Susang Hills and the hillocks of this region extends in a thin line of some 100 miles length from the north of Jamalpur sub-division to the north of Sunamganj sub-division. It includes the hillocks at the base of the Meghalaya Plateau, which are within Bangladesh and the land in between and around them, which is high and sloping.

Beds and outcrops of rocks of the Jaintia Series occur. They are mainly sandstones and shales: recently a layer of limestone has been found in north Sunamganj sub-division. These are small quarries of nummulitic limestone in the north of Jamalpur sub-division. Large deposits of white clay have also been found here. The highest of the

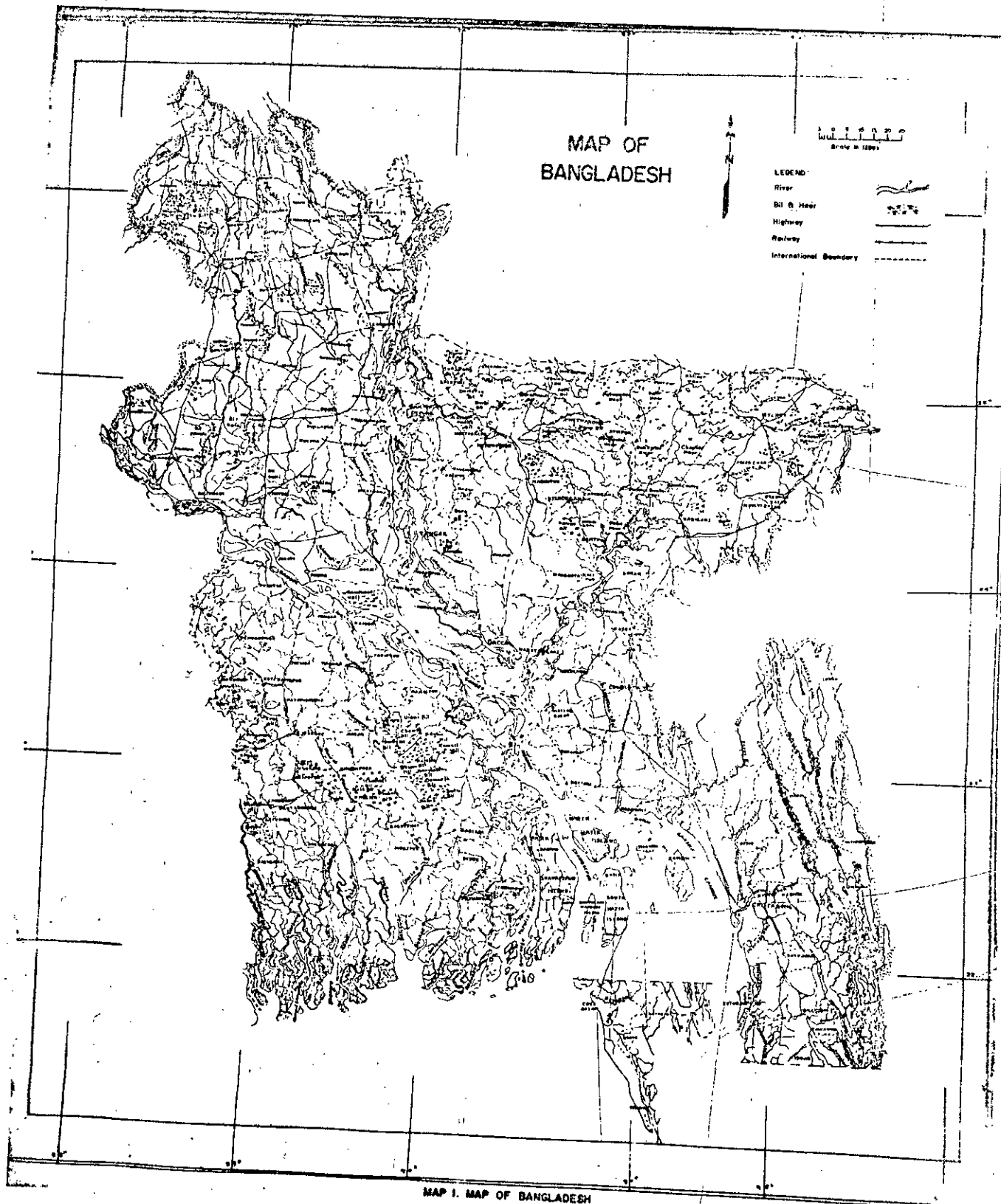
hillocks within Bangladesh are over 300 feet. The valleys are at a height of over 100 feet. Many entrenched mountain streams cut through this region, depositing sand plentifully. Over much of its length this narrow belt give way very rapidly to low waterlogged land. In the eastern part of this region, the Meghalaya Plateau ends abruptly in a series of gigantic faults over 2,000 feet in length, and the narrow gravelly ledge at its base sinks down to the very low Haor Basin.

Pleistocene Terraces

The monotony of the low Bangladesh plains is relieved somewhat by the occurrence of pleistocene terraces, the Modhupur Tract, Barind, Lalmai Hills and Piedmont Terrace. These older deposits occur in the middle of the plain in Dacca-Mymensingh district, North Bengal, south-west of Comilla town, eastern border of Bangladesh in Comilla district extending northward into the adjoining parts of Sylhet district and southward into Noakhali district. The maximum elevation of the deposits is every where below 100 feet above sea level and the outline of the ridges is smooth. These terraces stand above the monsoonal floods and are drained by a relatively few, small deeply entrenched streams with meandering courses. Their higher relief is due not only to the more resistant nature of their materials, but also to the uplift to which they have been subjected.

Madhupur Tract

The Madhupur Tract covers an area 1,600 square miles and is roughly 70 miles long and 35 miles wide, extending from the central part of Mymensingh district to the northern part of Dacca. This tract



of old alluvium, with its typical reddish soil, underlies every thana of the Sadar sub-division of the Dacca district except Keraniganj between the Buriganga and Dhaleswari rivers. In fact, the first-named river skirts the edge of these formations. The old alluvium extends north into the Mymensingh district, bending slightly towards the west as it crosses the district boundary.

On the old alluvium, the top of the uplands, grow crops of mustard and jute, for one or two seasons, but the soil is poor and the cultivators mainly depend on the "baid"¹ lands which grow good crops of aman rice. In the northern part of the tract, in Mymensingh and in the thana of Jaydebpur, Sripur and Kaliakoir in Dacca, there are forested stretches of the tall and sturdy Gajari trees, which are excellent timber material.

In spite of the smallness of its area and slight elevation (50 to 100 feet), the Madhupur Tract has undoubtedly exercised an influence upon the drainage of this area out of all proportion to its size. The hard, tenacious, red clays have directed the great rivers, the Jamuna, old Brahmaputra and Dhaleswari, to skirt along its edges.

A remarkable characteristic of the Madhupur is the abrupt western margin separating the low, flat, flood plain from the uneven, highly dissected Pleistocene surface. The entire, irregular western margin is formed by a series of six echelon faults ranging from 6 to 13 miles long. The eastern side of each fault is upthrown, and surface relief indicates a minimum throw of 20 to 60 feet. The flood plain is on the way,

¹ "Baid" means depression.

and the highly dissected Pleistocene of the uplift block is on the east. The dendritic stream pattern of the Madhupur is emphasized by the dense jungle cover on the ridges and artificially flattened paddied stream valleys.¹

Barind

The Pleistocene area called the Barind is the largest of the Bengal Basin units, it covers about 3,600 square miles. It is a tract of comparatively higher land consisting of old alluviums and rising above the surface of the North Bengal plain. It has been mapped as four distinct Pleistocene bodies separated by long, narrow Recent alluvial river valleys. The flood plain of the Mahananda River flanks the west side, the Karatoya River delineates the eastern margin. The Purnabhaha, Atrai, and the Jamuna rivers with headwaters in the Himalaya foot-hills have cut across the Pleistocene, and their flood plains delineate the four units. These and numerous other streams have deposited a broad Piedmont alluvial plain which overlaps the northern flank of the Barind.

In the Barind, three distinctive stream-pattern types are evident. North of the Pleistocene Barind are many small braiding streams which have build a broad piedmont alluvial plain along the foothills of the Himalaya. Major streams of this alluvial plain (including the Atrai and Purnabhaha) have entrenched valleys across the Barind surface.

¹ James P. Morgan and William G. McIntire, "Quaternary Geology of the Bengal Basin, East Pakistan and India" (Bulletin of the Geological Society of American, Vol. 70. (Coastal Studies Institute. Contribution No. 59-2) March, 1959, pp. 329-330).

Numerous small, tightly meandering streams on the Pleistocene have developed and over-all dendritic pattern and flow into the more important north-south rivers. Flanking the remainder of the Pleistocene are low-gradient, sluggish, meandering and braiding streams of the Recent flood plain.

Bounding the northeast flank of the Barind is a northeast-southeast fault 40 miles long, upthrown to the southwest. This fault has controlled the course of the Karotoya river. All minor streams draining the eastern portion of the Barind flow southwest into the Jamuna River suggesting southwest tilting of the up-lifted block.¹

Topographically, Barind is a slightly elevated tract, not exceeding 20 to 40 feet in elevation. It is undulating with large, level plains and gentle, gradual slopes. The soil are yellowish to red in colour. Winter rice (aman) is the only crop which thrives well. The fields do not stretch to the horizon, as in the typical scenery of the Bangladesh plains, but there are intervening patches of waste land and scrub. Large trees, with massive branches and much foliage, abound here and there.

The southern part of the Barind and adjacent flood plain has recently been surveyed by field parties of the Standard Vacuum Oil Company. Contouring of the surveyed portion of the Barind suggests that two terrace levels may be present. One level occurs at 130 feet above sea level; a second, less definite surface is at 65 to 75 feet above

¹ Morgan and McIntire, Op. Cit., P. 325...

sea level. Available data permit only a suggestion that two terraces may be present. It is not known whether the surfaces are in indication of multiple terraces in Bengal or if they reflect structural activity¹.

Lalmai Hills

The Lalmai Hills covers an area of 13 square miles. This range, a couple of miles west of Comilla Town, is 9 miles in length and from half to one and a half miles wide. Its highest peaks are over 150 feet. It is bounded by faults on the western and eastern sides. The faults scarp on the east is up-thrown to the west and considerably dissected by drainage channels. On the west there are two parallel faults about a mile apart. Both are upthrown on the east. The inner fault forms a well-defined valley. The outer (western-most) fault has a surface throw in excess of 100 feet at several places. Structurally this range is a horst, tilted to the east. The upper part of this horst is composed of oxidised clays and sands of Pleistocene age, which rest upon beds of sandy shales, coarse ferruginous sand stones and molted clays and sands, probably of the Tipan Series. Fragments of fossil wood are plentiful. The eastward dip of the upper deposits is slight, but of the lower deposits quite steep.

Piedmont Terrace

The Piedmont terrace is a narrow fringe along the eastern border of Bangladesh in Comilla district extending northward into the adjoining parts of Sylhet district and southward into Noakhali district. Its maximum width is two to three miles and at places it narrows down

¹Morgan and McIntire, Op. Cit., P.329.

to a few yards only. The entrenched and tightly meandering streams have developed a dendritic pattern. In some areas the terrace have been badly dissected resulting in the emergence of eroded hillocks. The Piedmont terrace is also of considerable agricultural importance.

The Recent Flood Plains

An overwhelming proportion of the surface of Bangladesh is a vast, flat, even, alluvial plain, intersected by numerous rivers, their distributaries, "Khals"¹ and backwaters and dotted with "Bil"² and marshes.

It is true that fewer dominating physiographic contrasts are found than elsewhere, but there are local variations of contour and minor physiographic features which lend colour to local geography, and at times are an important factor in human adjustment to environment.

The remarkable evenness of the plain can be judged from the fact that many places, though about 100 miles away from the sea, are less than thirty feet above sea level and the slope is less than five inches per mile.

Thus if the level of the sea were to rise by 30 feet, most of Bangladesh's surface would be under water, except the isolated "islands" of old alluvium and the hills of Sylhet and the Chittagong Hill Tracts.

The Plain can be roughly divided into: (a) The Mahananda and Jabuneshwari Rivers Plain; (b) the Upper Tista, Dharla and Dudhkumar River Flood Plains; (c) The Mahananda Flood Plain Between the Barind

¹ "Khal" means small channel.

² "Bil" means low depression.

and the Ganges Flood Plain; (d) The Ganges Flood Plain; (e) The Brahmaputra-Jamuna Flood Plain; (f) The Old Brahmaputra Flood Plains (g) The Meghna Flood Plain; (h) The Tippera Surface; (i) The Sylhet Basin; (j) The Moribound Delta Plain; (k) The Central Delta Basin; (l) The Mature Delta Plain; (m) Immature Delta Plain; (n) The Active Delta Plain; and (o) The Chittagong Plains.

The Mahananda And Jabuneshwari River Plain

This sub-region is bounded by the Mahananda river in the west and Jabuneshwari in the east. In the north, it merges with the submontance terai, known here as the Duars. The rivers in this sub-region are entrenched in the recent alluvial deposits, mostly sandy silt. They flow towards the south, for the land slopes from a height of 317 feet in Tetulia Thana to 109 feet at Dinajpur. The gradient is considerable, being 3 feet per mile. In the south, deposits overlie the pleistocene clays of the Barind Tract. The plain is undulating in parts, being most marked on either bank of the Kulik river.

The Upper Tista, Dharla And Dudhkumar River Flood Plains

This part extends from the high sandy fields of the Jabuneshwari-Dinajpur Karatoya interfluves to Kaunia. The Tista river dominates this area, which is cut up by its many abandoned channels. The line of drainage is towards the south-east. The streams are not so entrenched as in the Western Sub-region.

The Mahananda Flood Plain Between The Barind And The Ganges Flood Plain

The Mahananda river forms the western boundary of Bangladesh in two places along the Piedmont Plain. Further south, it flows along the

northern side of Bholahat Thana and enters Bangladesh in Gomastapur Thana and winding through Chapai-Nawabganj sub-division, it falls into the Ganges south of Chapai-Nawabganj Town. The course below Chapai-Nawabganj is in the Ganges Flood Plain. Above it, the Mahananda flood-plain varies in breadth from 5 to 7 miles west of the river and 1 to 3 miles east of it. This 250 square mile flood-plain lies between the Barind and the Ganges flood-plain. The river is slightly entrenched.

The Ganges Flood Plains

The Ganges flood plains are composed of "Diaras"¹, "Chars"² & broad levee stretches of the Premtali in Godagari Thana to Shujanagar Thana where it slopes into the Jamuna flood-plain. In such a large river as the Ganges, Diaras and Chars are plentiful. These are generally the accretions of the rivers. These accretions are, however, very rarely permanent, for courses of rivers in low alluvial plains are very liable to shift across their flood-plains. These Diaras and Chars often first appear as thin slivers of sand. On this is deposited layers of silt till a low bank is consolidated. Tamarisk bushes and spiny grasses establish a flood-hold and accelerate deposition. The people from either bank settle these accretions as soon as the river recedes in winter, the river flows being considerably seasonal. For several years the Diara or Char may be cultivable only in winter, till with a fresh flood either the level is raised above the normal flood water level or the accretion is diluvated completely.

¹ "Diaras" means low bank of a river

² "Chars" means sand bars.

Certain Chars and Diaras appear very substantial while others appear to be mere sand or mud-banks. Some are very flat, while others are undulating. There are three types of these accretions, according to the principal composition of their soil. The clay or mud chars and Diaras are not easily cultivated, so they are generally used as pastures during winter. The sandy chars and Diaras are unfertile, but landless cultivators often try to raise a millet or pulse crop on them. These are also favoured for pastures. Those with silty soils are obviously the most prized as on some of them crops can be grown without any tillage. As a general rule, the accretions in the upper courses of the rivers within Bangladesh are sandy, those in the middle courses are silty, and those in the lower courses have a high proportion of clay. The Ganges Diaras and Chars within Bangladesh stretch from the south-west of Shibganj Thana to the south of Bera Thana, a distance of 165 miles. The Ganges here fluctuates between its high levees on either side, which are from three to twelve miles apart. There are large Diaras south-west and south-east of Shibpur Thana north of Daulatpur Thana and south of Charghat, Ishurdi, Pabna and Shujanagar Thanas. Chars are numerous and shifting very often. The principal ones are south of Rajshahi and Shujanagar Thanas.

Because of the shifting of the course of the Ganges, the levee is not everywhere besides the river. In the south of Charghat Thana, the levee is far from the present course of the river, the intervening ground containing point bars, swales, and Diara accretions. Formerly the Northern Region rivers used to flow directly south into the Ganges,

but during the eighteenth and nineteenth centuries the levee has built itself up rapidly. It varies in width from two to twelve miles, and its total area is about 170 square miles. Heights varies from 70 to 90 feet.

The Brahmaputra-Jamuna Flood-Plain

The dual name is used for the mighty Brahmaputra river, because the Jamuna channel is comparatively new and its course must be clearly distinguished from that of the old Brahmaputra.

The western flood-plain of the Brahmaputra-Jamuna, within Bangladesh stretches from Bhurungamari Thana to Bera Thana. In breadth it varies from 10 to 20 miles. The portion between Moribund Ghaghat and the very active Dharla rivers is in some respects the valley of the Tista river. It has been included in this flood-plain because the broad levee and the slight backswamp found in this region is essentially due to the Brahmaputra. The course of the Tista here is a new one and it has not yet beilt up appreciable levees of its own. In the north, the land slopes up from the Ghaghat depression to the broad levees. Within the levee, there are in places, two or three narrow, parallel depressions. The height of the levee is such that it is not normally flooded by the Brahmaputra-Jamuna. Further south, the levee is somewhat lower, but is traceable right to the confluence with the Ganges. This corner has been diluvated and beilt up in turn by the Atrai, the Ganges and the Brahmaputra-Jamuna, so that the land is more of a Diara than the levee of any river. There are several point bars and swales. The levee is fairly high at Serajganj, Kamarkhand and Kazipur Thana. The height above sea level obviously varies a lot, since this sub-region stretches

from the Piedmont Plains to the Delta. At Boladanga the height is 54 feet.

Along the Brahmaputra-Jamuna, as along the Ganges, there are many Diars and Chars. In fact there are more of them along this channel than in any other river in Bangladesh. There is a continuous line of chars from where this river enters Bangladesh to the off-take point of the Dhaleshwari river. Both banks are punctuated by a profusion of Diars. The largest of these are in Rahumari Thana where they form most of the land between the river and the abrupt faulted western end of the Meghalaya Plateau. There are other large Diars on the opposite bank in Chilmari Thana. Chars are profusely studded. There are so many of them where the river turns past the Meghalaya Plateau that the banks are 10 miles apart with several dozen shifting semi-permanent chars in between. This extremely braided course of the river is about 50 miles long. Below Fulchari-Ghat there are several stretches with no Chars. There are, however, considerable Chars between Serajganj and Jagannathganj-Ghat. As in the Ganges, the soil and topography of the Chars and Diaras varies considerably. Some of the larger ones have point bars and swales. The elevation between the lowest and highest points of these accretions may be as much as 15 feet. The difference between them and the higher levees on either bank can be up to 20 feet.

The eastern limit of this sub-region is roughly a line drawn from Bakshiganj (Dewanganj Thana) to Kendua Kalibari (Jamalpur Thana) and along the western side of the Madhupur tract to a point on the Buriganga branch of the Dhaleswari river. This river limits the flood-

plain in the south, for the land to the south is deltaic in nature. This levee along this eastern side of the river is high as far south as Pingua. South of it, the land gets progressively lower. At the southeastern corner, near Mirzapur, the land is below normal flood water level.

The Old Brahmaputra Flood Plain

When the Brahmaputra turned south and adopted the Jamuna as its main channel, the old course between Bahadurabad and Bhairab shrank through silting into a small seasonal channel only a quarter of a mile broad. The old river had already built up fairly high levees on either side over which the present river rarely spills. The levees slope away to lower ground; in the north there is a long depression parallel to the alignment of the Meghalaya Plateau, and only a few miles from it; in the south the plain is more uniform in level possibly because the Madhupur tract dips beneath it just where a backswamp would have been. There is, however, a very conspicuous depression in the south of Ghaffargaon Thana between the old Brahmaputra river and the Madhupur tract.

Sherpur depression is large enough to be made a sub-region. It extends from the east of Sherpur Thana across Nalitabari and Nakla Thanas to Kalmakanda Thana where it slopes down to the Haor Basin. The line of swamps along it, and numerous river scars extending to the Haor Basin, make it possible that was the course of the main channel of the Brahmaputra before it shifted to the course past Mymensingh Town.

The northern part of this flood-plain is crescent shaped; it extends from about Diwanganj to Bhairab, a distance along the curve of 110 miles. In breadth it varies from 2 miles at Bhairab to 30 miles at

Kishorganj. North of Sherpur it encompasses the western half of the Sherpur depression. The levee on this left side of the river begins after a short stretch of "Diara" and slopes down gradually. The level of the land is fairly high.

The southern part is also crescent shaped. It extends from Narundi to the south of Ghaffargaon Thana which is a distance of 60 miles in a direct line. The plain is fairly broad, averaging 14 miles. Most of this plain is lower than the northern one, and has a large low basin (Bil) at Moshakhali, at the southern end. The levee immediately beside the old Brahmaputra is, however, at a height of 50 feet, which makes it a couple of feet higher than the levee on the other side. The lower course of the river contains several Chars, of which one near Ghaffargaon is large and apparently permanent.

The Meghna Flood-Plain

Much of the flood-plain of the Meghna was built up by the old Brahmaputra river, when that carried the main streams. The Meghna continues to fill in the depressions left since then but is not building up any more north of its confluence with the Dholeswari.

Meghna-Sitalakhya Doab is a large piece of land includes part of the Sitalakhya-Bangshi Doab to the west. In its north there are several large outliers of the Madhupur Tract, which, of course, are part of that region. This Doab is low and very fertile.

Titas Low Plain is encircled by the Titas distributary of the Meghna, which leave it near Chatlapur and re-joins it near Nabinagar. The lowground is in a sense the continuation of the Haor Basin Rim, but

it does not slope towards the centre of that Basin. It is studded with point-bars.

Tripura Diaras and Chars along the large Meghna river, is to be expected, there are many large Chars and Diaras separated from those to the south because the latter are part of the Delta, while the former are not. There are several very big Chars between Bhairab Bazar and Daudkandi which is opposite the Dhaleswari confluence. Whereas the Chars in the lower course of the Meghna river are liable to sudden change, most of those in its upper course are fairly stable.

The Tripura Surface

In the eastern part of the Bengal Basin, flanking the Tripura Hills and surrounding the Lalmai Hills is a distinctive alluvial physiographic unit. This unit, 3000 square miles in area, has been named the Tripura surface, because it covers most of the district of Tripura and small parts of the adjoining districts.¹

The drainage system of the Tripura surface displays a well-developed rectangular pattern in contrast to the braiding and meandering patterns of the Recent flood plain and the dendritic pattern of the hill regions. In addition to the rectangular system are a few small meandering streams which form the drainage system for the adjacent hills. In contrast to meandering streams of Barind Pleistocene surface, however, these exhibit numerous cutoff and oxbow lakes, indicating that the deposits are less consolidated. The rectangular pattern upon detailed examination proved to be due entirely to man's activity.

¹ Morgan and McIntire, Op. Cit., P.333.

Because of its flat surface, relatively low elevation, and heavy seasonal rainfall, the entire Tripura area is uniformly inundated. For agricultural purposes a series of low dikes has been constructed throughout the area. The ditches resulting from excavation for dike material have subsequently become the rectangular drainage network. Through continuous use, the artificial canals have been expanded, and natural drainage has declined in importance. High land values, coupled with the need for flat rice paddies, have resulted in artificial filling in the most of the abandoned natural drainage channels. Although the Tripura surface exhibits a high degree of cultural modification, its alluvial origin is still evident. Traces and remnants of curved meander scars and loops are emphasized by concentrations of trees and houses along former natural levees. However, intensive agriculture for countless generations has nearly erased such evidences of origin and has led to formation of the rectangular drainage net.

The Tripura surface is delineated on the north by an important northeast-southwest trending fault. It is uplifted to the southeast a few feet higher than the adjacent flood plain of the Meghna River. A branch of the Meghna impinging against the Tripura surface along the fault scarp has caused appreciable local erosion. Most of the western limit of the Tripura likewise is being eroded by the Meghna or its branches. Along the southwest and southern margin the Tripura is flanked by a narrow band of Recent river deposits. The eastern limit of the Tripura surface is the abrupt boundary with Pleistocene hills.

The sediments of the Tripura surface correspond physically with the Recent flood-plain sediments, except that they are more compacted and are slightly oxidized. The sediments display higher oxidation than Recent flood-plain deposits but are not comparable with the reddish brown Pleistocene terrace materials.

Surveyed elevations are scarce on available maps of the Tripura surface and adjacent flood plain, but all available elevation have been averaged. Based on 65 elevations, the Tripura surface averaged about 21 feet above sea level in contrast to an average of less than 15 feet for 45 elevations on the near-by flood plain.¹

All evidence suggests slight uplift of the entire Tripura surface. Cultural modifications of the natural drainage system, displacement along the bordering fault to the north, and oxidation of sediments all indicate that the Tripura surface has been uplifted during Recent time. Though the surface is uplifted, yet it has a low relief and is inundated during the monsoon months.²

The Sylhet Basin

The Sylhet Basin is a subsidiary part of the Bengal Basin, bounded on the north by the Shillong Plateau and on the east and south by the plunging, anticlinically folded Tripura Hills. The south flank of the Shillong Plateau is delineated in part by a major fault scarp which is dissected by numerous steep valleys. The northern part of the

¹ Morgan and McIntire, Op. Cit., P.333.

² F. Karim Khan. An Introduction to Economic Geography. (Dacca: Green Book House Limited, 1970, P.634).

basin is less than 10 feet above sea level, for example the vicinity of Matian-Sanir Haor. In the same immediate area are meander scars left by an old course of the Brahmaputra River which antedates the recently abandoned course past Mymensingh. Maximum elevations on the residual levees of this old stream course average about 15 feet above sea level. At a comparable distance from base level (the Bay of Bengal), the other Brahmaputra River courses have elevations in excess of 50 feet above sea level. This suggests that the Sylhet Basin has subsided about 30-40 feet within the last several hundred years.

Information furnished by personnel of Geophysical Services International indicates that stumps and wood were encountered in at least three shallow holes at depths of 60-65 feet, 60 feet, and 50-55 feet in the northern part of the Sylhet Basin. Rapid subsidence, probably still occurring, has exceeded the rate of sedimentary fill of the basin. A calculated gradient for the Brahmaputra river course passing through the low part of the basin is about 0.11 feet per mile. This gradient is much flatter than that of the old Brahmaputra past Mymensingh (0.25 feet per mile), the Jamuna (0.26 feet per mile), the Ganges (0.26 feet per mile), the Mississippi (0.25 feet per mile), or any other known major river.¹

Although sediments are probably undergoing compaction, the subsidence of the Sylhet Basin is probably primarily tectonic and is undoubtedly related to the major fault system bounding the northern side of the basin. The many lake (haors) immediately adjacent to the fault

¹ Morgan and McIntire, Op. Cit. P.395.

scarp suggest that the downthrown block has been rotated, carrying the Sylhet Basin down more rapidly than it is being alluviated.

The major part of the Sylhet Basin is flooded during the rainy season. In its southern part there are a number of lakes, for example Hail Haor, Hakaluki Haor etc.

The Moribound Delta Plain

If an imaginary line is drawn from north of Faridpur town in a south-westerly direction to south of Satkhira, then, in general, all the area north and west of this line would lie in the so-called moribound part of the delta - an area of dead and decaying rivers. The moribound part is somewhat higher, and free from regular annual inundations.

No tidal water reaches the rivers, and they generally remain confined within their high banks, except during the height of the rainy season. Little Ganges water flows into the rivers. Their channels have deteriorated and become choked with vegetation and weeds. From the air they present a fantastic picture of dirty, green bands, creeping into the country side. Between the rivers, the land is depressed.¹

The Central Delta Basin

This extensive basin in the heart of the delta cannot be satisfactorily explained by Strickland's hypothesis of a sea-ward ledge and its blocking of inland deposition. This large basin (also known as the Faridpur Bil Area) is about 900 square miles in area. The most satisfactory explanation to date has been advanced by Morgan and McIntire,

¹As seen by the writer in the course of air trip with World Bank Team.

whose hypothesis about the structural forces affecting the Bengal Basin is explained. Their theory that part of the Delta is subsiding as a compensation to the elevation of the Tripura surface and the Barind Tract is plausible. The origin of the Central Delta Basin, with its extensive Bils, lies probably in the absence of rapid deposition by the active distributaries (which flow towards its east) coupled with steady subsidence due to warping by torsional forces.¹

The Mature Delta Plain

The Mature Delta is the region where the distributaries have completed that work of raising the level of the land above the high tides of the Bay of Bengal, and are not depositing extensively.

This region is cut through by a line of Bils from west to east. The associated slightly higher land to the south of these Bils has been explained by many as the zone where the rise of the tide (above 18 feet) has led to rapid deposition of the silt carried by the once active rivers. The formation of this ledge has proceeded with compaction of the deposits, which made the depression along the east-west line to the north of it. The findings of Morgan and McIntire seem, however, to indicate a tectonic origin for these Bils.

Immature Delta Plain

South of the Mature Delta, there is a broad belt of land, barely above sea level. Whereas the height of the southern edge of the Mature Delta is about 8 feet, the height a few miles to its south is only 3

¹Haroun Er Rashid. East Pakistan - A Systematic Regional Geography and its Development Planning Aspects (Lahore: Sh. Ghulam Ali and Sons, 1967, P.25).

feet. This very lowland area, contains the Sunderbans forest and the Sunderbans reclaimed estates (cultivated land). There are two possible causes for the existence of such a large very low estuarine area - insufficient deposition by the Ganges distributaries or subsidence. It seems that the main distributaries of the Ganges never flowed through this region, and the small ones that did lasted a few centuries at most. The building up of this estuarine area is consequently not complete. The tides may have also contributed to the retardation by forcing the major part of the silt to be deposited along the ledge.

It is also possible that subsidence has played a major part in depressing this area. There are many evidence of it, such as large ruins in the heart of the swampy estuarine areas. It seems that both the absence of adequate deposition and subsidence are responsible for incomplete build-up of this area.

The sea-ward face of this region is a network of branching streams around roughly oblong shaped islands. When silt laden streams reach the sea, their velocity is checked and their sediment load is flocculated. Bars form at the mouths, and the streams branch off to either side. In time these branches too form their bars and are also divided. As this process goes on the branches unite and re-divide and the bars coalesce into islands, which are sometimes cut apart. This process forms a network of channels.

The high tide ponds back the estuarine rivers and force them to break their banks and open out cross-channels. These are a marked features of the low areas much affected by tides, for as the delta is

elevated out of tidal influence, the cross-channels disappear. The sea-face is in places marked by old breachridges, of peculiar formation. The sandy beach usually facing south-west is backed by a ridge of sand dunes twenty to thirty feet high; behind this is a grassy plain, of about half-a-mile width and parallel to the beach; this plain is bordered by a belt of mud, usually with a stream and forest trees. Behind this mud-flat there is again a succession of sandy shelf (an old beach), sand dunes, grassy plain and mud flat. Some beach-ridge are as much as two miles inland. Their mode of formation depends upon the tide, which in this area ebbs towards the south-west. This makes the estuarine rivers build as south-west facing bar on the eastern side of their mouth since there the water is stiller. The summer tides and storms build up the sand dune ridges. The channel between the ridge and the mainland gradually fills up into the mud-flat and diverts the rivers silting further down.¹

There are extensive shoals, extending ten or more miles out to sea, between the larger rivers. At the mouth of the Raimangal river, the shoals extend twenty miles from the land. Between the Haringhata and Marjata estuaries, shoals cover more than 300 square miles. A notable feature is that they are higher on their seaward sides than on their land-ward sides by two to three fathoms.² This stretch of the coast contains Patni and Dubla inslands.

¹ Harun Er Rashid, Op. Cit., P.27.

² Ibid.,

The Active Delta

The Active Delta extends from Pussur river in the west to the island of Sandwip in the east. In the south-west, its sea-ward reach is limited by the Sunderbans. In the north, it is bounded by the Central Delta Basin, the Mature Delta, the old Brahmaputra flood-plain, the Tippera "Diaras" and the Tippera Surface. The extension of the delta right upto the Buriganga has been made in consideration of the essentially deltaic nature of the Dhaleswari-Padma interfluence. The rivers completely inundate the entire land during the monsoon. There are hardly any roads, and in these natural settings every household has its own boats and water transport is a common feature. People and crops have adjusted themselves to their surroundings. Paddy sown before the rains set in grows a long stem of eighteen to twenty feet or more to keep pace with the rising level of water.

The Chittagong Plain

The Chittagong Plains occupy a narrow margin along the sea in Chittagong district. They extend from the Feni River in the north to a little south of Cox's Bazar. The average width is 5-6 miles, widening to 16 miles at the Karnafuli mouth. The area is covered with Recent materials brought by the Karnafuli, the Sangu, the Matamuhuri, the Bagkhali and other rivers. In places, narrow strips of mud flats, coastal marshes, sand beaches or sand dunes are found. Isolated patches of mangrove swamps are also found. Inland, the usual levee and bill topography of Bangladesh flood plains are found.

CHAPTER IV
DESCRIPTION AND ANALYSIS OF WATER BODIES IN
BANGLADESH

Classification Of Water Bodies

Water bodies (Map-C) in Bangladesh can be grouped primarily into the following three categories:

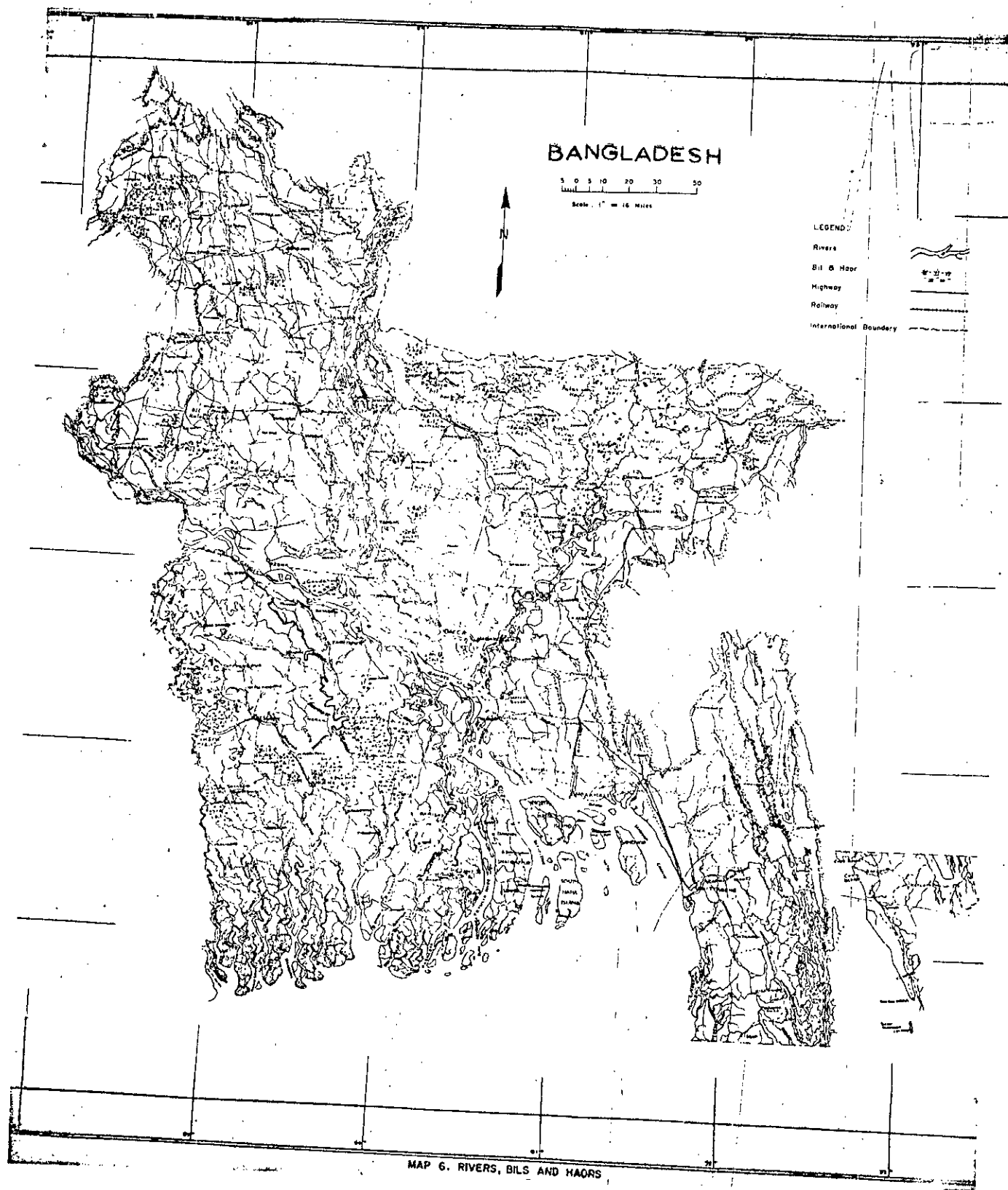
- a. Major Rivers
- b. Minor Rivers
- c. Bils and Haors

Major Rivers

The major rivers have built up different types of soils in their respective areas and have, in the process, left innumerable low pockets of varying sizes and depths scattered all over the country, which present varying drainage problems. The constant physiographic and hydrographic changes caused by the active deltaic rivers inundating adjacent lands and depositing fertilizing silt on these have a great bearing on the cropping systems and agricultural practices and duration of the seasonal flood determine the type of rice crop grown in the flooded plains.

But in the process of delta building, the major rivers have oscillated within wide limits and naturally or through some tectonic activity, have changed courses at different periods in the past¹. In consequence, some regions have suffered and their spill channels, being

¹ S. C. Majumder, Op. Cit., P.32.



MAP 6. RIVERS, BILS AND HAORS

cut off from the parent rivers, have decayed resulting in water-logging in the areas and gradual improvement of the soil. The areas which have been affected by major changes in the course of the major rivers are the Kushtia and Jessore areas, due to the diversion of the Ganges through the Padma sometime towards the beginning of the 16th century; the North Bengal zone due to the diversion of the Tista towards the end of the 18th Century (1787) and portions of Mymensingh and Dacca districts due to the diversion of the main Brahmaputra through the Jamuna in the earlier part of the 19th Century (Map 7).

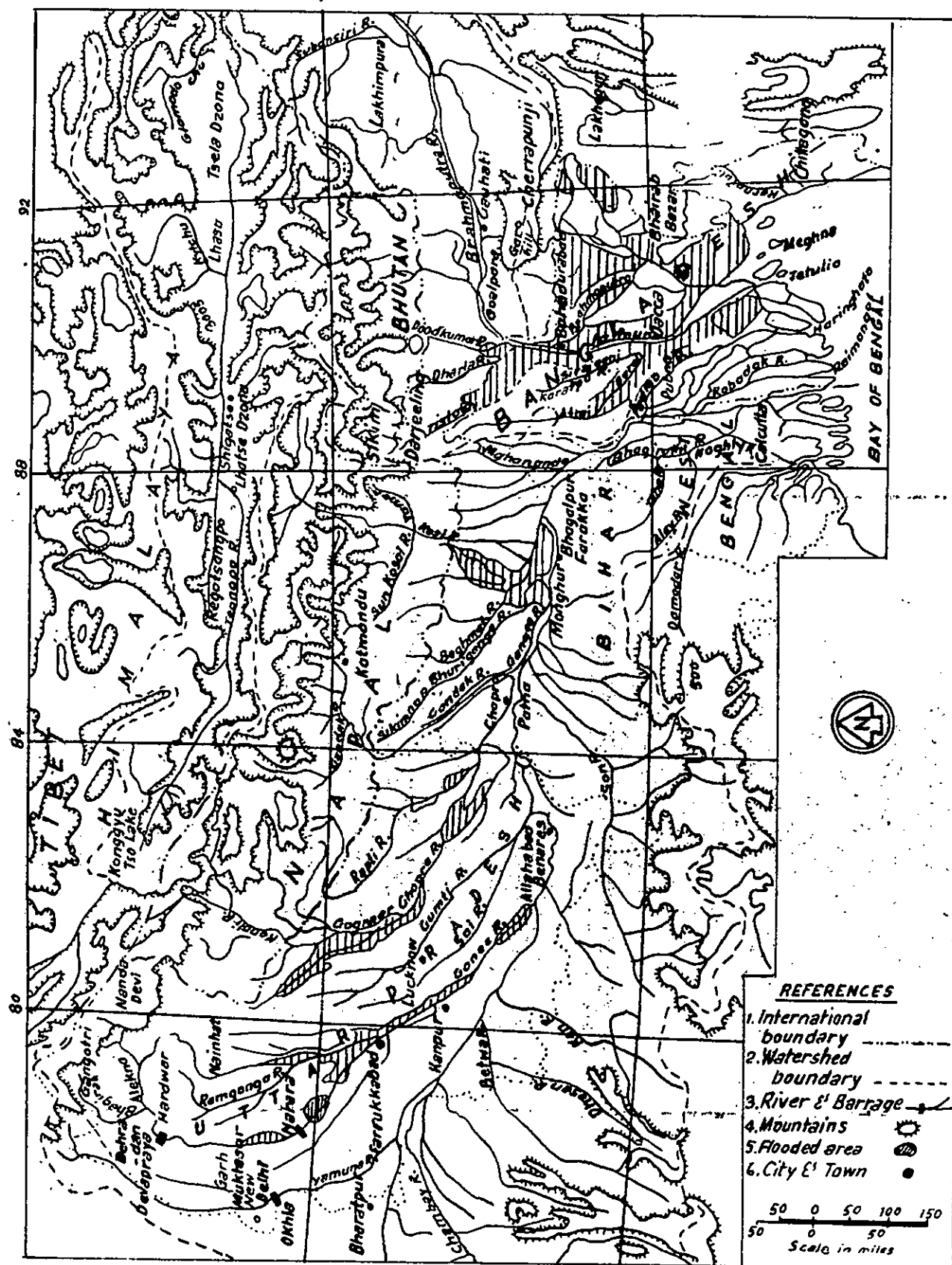
The Catchment of these three major rivers namely, the Brahmaputra, the Ganges and the Meghna are shown in Map 8. The name of major rivers and their spill channels sometimes overlap with others and generally change in different reaches or through various districts. This partly explains the change in the rivers course which continue to retain their old name.

The Ganges

The Ganges, rises in the Gangotri Glacier of the Himalayas at an elevation of 23,000 ft. west of the Nanda Devi Range, and quite close to the sources of the Indus and the Tsangpo. It has a length of 1370 miles upto Goalundo, and 1570 miles to the mouth of the Meghna and a drainage area of 377,400 sq. miles upto Goalundo.¹ Its average discharge in Winter is 80,000 cusecs and in the rainy season 6,40,800

¹ A Latif, "Water Resources Development in East Pakistan" Proceedings of the Fifth Regional Conference on Water Resources Development in Asia and the Far East. (New York: United Nations Water Resources Series No. 23, 1963, P.103).





MAP 8. GANGES-BRAHMAPUTRA AND MEGHNA RIVER BASINS

cusecs. The average annual discharge at Paksey bridge is 410,000 cusecs, as compared to 678,000 cusecs of Brahmaputra at Bahadurabad. It has a maximum recorded discharge of 2,585,000 cusecs and a minimum of 41,421 cusecs on the 29th April, 1953 at the Hardinge Bridge.¹ The annual flow of the river varies from 202 million acre-feet to 433 million acre-feet. In the middle Ganges Valley, nine large tributaries joint it. From Patna downstream it is as large as when it first forms the border of Bangladesh at Shibganj. Just west of that place it sends south its first distributary, the Bhagirathi, which becomes the Hoogly further south. Just west of Godagari Town the Mahananda, a large river in the rainy season, falls into it. The Baral joins the Atrai-Gumani System. The Jalangi Channel of Bhairab and the Bhagirathi-Hoogly are entirely in West Bengal. India is building a barrage at Farakka on the Ganges, a few miles to the west of the Bangladesh border. India and Bangladesh has agreed in a Ministerial level meeting that the barrage would not be put into operation by India, without consultation with Bangladesh. Then in the Prime Ministers meeting in April, 1974, it was decided that the Joint River Commission would study the possibility of augmentation of the Ganges dry season flow by constructing reservoir upstream in India.

The Ganges is fed mainly by rivers rising in the high Himalayas where much of the precipitation is in the form of snow. There is comparatively little winter rainfall, and the lowest river level is usually recorded in April, after which melting snow increases the flow.

¹ Harvard University. Bangladesh Land, Water and Power Studies: Final Report. (Harvard, U.S.A: Center for Population Studies, June, 1972, P.VII.5).

Rainfall in the foothills of the Himalayas and in the plains is abundant during the monsoon months, June to September, and the river rises to its maximum usually in July or August.

The Ganges flows parallel to the Himalaya range and is fed mainly by rivers rising in the southern slopes of these mountains. Of these, the Kosi, which carries a considerable volume of flood water, joins the Ganges within a short distance of the Bangladesh border. Another important affluent of the Ganges is the Gorai, taking off near Kushtia and flowing to the sea via Madhumati and Baleswar. The Ganges joins the Brahmaputra to form the Padma at Goalundo.

The Ganges delta, an area of 23,000 sq. miles, is bounded on west by the Bhagirathi-Hoogly and on the east by the Padma and the Meghna. It consists of very fertile lands in the northern part, in the districts of Murshidabad, Nadia in India and Khulna, Jessore, Barisal and Faridpur in Bangladesh. The Southern part from the coast to about 60 miles inland, the area known as the Sundarbans, is interwoven with a complex network of channels. This area is covered with dense jungle full of mangroves.

The Ganges basin extends from latitude $22^{\circ}26'$ N to $31^{\circ}26'$ N and from longitude $73^{\circ}35'$ E to 90° E. It is bordered in the north by about 700 miles of the Himalaya range and in the south by the Vindhya mountains. Its area of about 374,000 sq miles is one of the most densely populated river plains in the world.¹

¹ Economic Commission for Asia and the Far East. A Compendium of Major International Rivers in the ECAFE Region, (New York: United Nations Water Resources Series No. 29, 1966, P.34).

The average gradients of the river are as follows: from Allahabad to Benaras 1: 10,500, from Farakka to Rampur Boalia 1: 18,700, from Rampur Boalia to Hardinge Bridge 1: 22,200 and from there to Goalundo 1: 28,000.¹ The river, since ancient times, has meandered extensively. Often, it leaves the old bed and seeks a new channel. New islands are washed away or attach themselves to the mainland. Many ruins of old towns and cities are evidence of such changes. There is difference of opinion regarding the main course of the Ganges downstream. Some say that, until about beginning of the sixteenth century the main course of the Ganges was through the Bhagirathi-Hoogly. Then gradually it swung eastward across the plain till it met the Jamuna or Brahmaputra and drained into it, leaving the Bhagirathi-Hoogly as a spill channel which is fed only during the high water season by the Ganges and supplemented by the Mor, the Ajay and the Damodar. Others consider that the Padma Channel has always been the main and major channel of the Ganges.²

The maximum silt content measured at Hardinge Bridge is 2,950 ppm, whereas the annual average is about 1,310 ppm.³

The Brahmaputra

The Brahmaputra is the second largest river in Bangladesh. In size it is gigantic. In the rainy season the river is nowhere less than two miles broad, and often four miles or more. It is, through

¹ Economic Commission for Asia and the Far East. A Compendium of Major International Rivers in the ECAFE Region. Op. Cit., P. 34.

² Ibid. P. 34.

³ ppm means Pound per million parts.

most of its course through Bangladesh, studded with island (Chars) many of which go under water during the rainy season. One such braided portion is to the east of Kurigram Thana¹, where the four main channels and three islands are together seven miles in breadth. North of Sirajganj is another braided stretch, six miles in breadth. The greatest breadth of a clear stretch is four miles. Thus by breadth alone this river qualifies as one of the largest in the world. The maximum and minimum discharges of the river recorded at Bahadurabad are 2,700,000 cusecs and 101,000 cusecs respectively.² And the average annual discharge at Bahadurabad is 678,000 cusec. The average annual flow is about 540 million acre feet.

The Brahmaputra is a great river passing through Tibet, Bhutan, India and Bangladesh, with a total length from source to Goalundo of about 1,600 miles. It rises in a great glacier mass in the Kailas range of the Himalayas at a latitude $30^{\circ}31'N$ and longitude $82^{\circ}10'E$, just south of a lake called Konggyu Tso. Many tributaries join the infant river from near the Mariam La pass (elevation 16,900 feet) which separates the Brahmaputra's basin from those of other great rivers, the Indus and the Sutlej. The river under its Tibetan name of Tsangpo, flows through southern Tibet for about 700 miles, keeping a course parallel to, and about 110 miles from the main chain of the Himalayas. It receives many

¹ Thana is an Administrative Unit of a Sub-division of Bangladesh.

² Kh. Mazidul Islam, "Hydrology and Water Resources Development in Brahmaputra Basin in Bangladesh" Seminar on Flood Control and Water Resources Development in Bangladesh, Ministry of Flood Control and Water Resources, Peoples Republic of Bangladesh, August, 1972, P.98.

tributaries of which the larger ones are: on the left bank, the Raja Tsangpo, which meets the main river west of Shigatse town, and the Kyi Chu which passes close to Lhasa; on the right bank, the Ngang Chu, which flows by the trade center of Gyantse and joins the main river at Shigatse, the second town of Tibet.

From Lhatse Dzong at $87^{\circ}37'E$ for about 400 miles downstream, the Tsangpo has a wide channel and is one of the most unique inland waterways of the world, for boats navigate it an elevation of 12,000 feet and more above mean sea level.

Along the greater part of its course in Assam, the Brahmaputra is bounded on either side by stretches of marshy land covered with thick grassy jungle interspersed occasionally with patches of cultivated land. Further behind, however, where the ground level is higher, the area is covered with paddy fields.

Sweeping round the Western spurs of the Assam range, the Garo hills, near Goalpara, the Brahmaputra enters the alluvial plains of Bangladesh, through which it flows southwardly for another 170 miles until it joins the Ganges at Goalundo. Major tributaries joining it from the north are the Dudkumar, Dharla, Tista, Karotoya, Baral and Hurasagar. Below the confluence of the Tista, the old channel of the Brahmaputra branches off from the left bank. From here to Goalundo, the river is called the Jamuna.

Till the end of the eighteenth century, the Brahmaputra flowed in its old channel through the center of Mymensingh district to join the Ganges near Bhairab Bazar. Because the channel became choked up

with silt, the stream moved westward and cut a new channel along the western edge of Mymensingh.¹

The United stream of the Brahmaputra and the Ganges flows south-east under a new name, Padma. At Chandpur, 65 miles below Goalundo, the Padma is again joined on the left bank by another large river, the Meghna, whose source is in high mountains subjected to intense rainfall in Assam. From the confluence downward, the river, now known as the Meghna, becomes a very broad estuary making its exit into the Bay of Bengal.

The Brahmaputra has a total drainage area from its source to Goalundo, of 224,000 sq miles,² viz:

In Tibet	113,000 sq. miles
In India	93,000 " "
In Bangladesh	18,000 " "
Total	224,000 sq. miles

The average slope of the whole river is approximately 1:11,400, but the actual gradients in different localities vary considerably from this average value. In Bangladesh, the average slope is 1:11,340 for the 37 miles reach between Nunkkawa to Kamarjani. From there to Serajganj 66 miles, the slope flattens down to 1:12,360. Between Serajganj and Goalundo, a distance of 57 miles, the gradient is 1:27,200 and from Goalundo to Chandpur, 65 miles, the slope is 1:37,700.³

¹ S. C. Majumder, Op. Cit., P.32.

² United Nations, Report of a Technical Assistance Mission, "Water and Power Development in East Pakistan", Vol. 1, Report No.Pak.15, June 3, 1957, P.5.

³ United Nations Water Resources Series No. 29. Op. Cit., P.21.

Every year the river spills its banks and a vast sheet of water spreads over the plains damaging standing crops, destroying properties of urban and rural areas and depositing fertile silt on the land. For this latter reason, the river is called "the plain builder".

The Brahmaputra is the most important commercial route between Assam and Bangladesh and also provides an important outlet from Assam to West Bengal, India, by means of connecting channels. Steamers can navigate up as far as Dibrugarh, 800 miles from the sea. There is only one bridge crossing the river at Pandu near Gauhati in India.

The average maximum sediment concentration observed at Bahadurabad is 1,180 ppm. During peak flood it brings down something like 7,000,000 tons of sediment daily. The annual silt runoff at the same station has been estimated at 735 tons.¹

The Meghna

East of the Brahmaputra river is the Meghna river. The Barak river, the headstream of the Meghna, rises in the hills of Assam in Manipur district of India about the longitude $94^{\circ}10'E$ and latitude $25^{\circ}35'N$, at an elevation of about 9,500 feet. It flows south-westerly winding its way along hill ranges for about 155 miles, before it turns around a hill to flow north. At Lakhipur, where it emerges from the hills, it changes direction to run west in a meandering course till it enters Bangladesh at latitude $24^{\circ}53'N$ and longitude $92^{\circ}32'E$. Near the

¹ James M. Coleman, "Brahmaputra River Channel Processes and Sedimentation" Sedimentary Geology, International Journal of Applied and Regional Sedimentology. Special Issue, (Amsterdam, The Netherlands: Elsevier Publishing Company, August 1969, P.155)

border and Amalshid town, the Barak bifurcates into two rivers, the Surma and Kushiya¹.

Many tributaries join the Barak. The more important ones are the Makra, the Irang, Juri, Sonai, Rakni and Dhaleswari.

The Surma, while flowing along the northern part of Sylhet district of Bangladesh receives discharges from a number of tributaries flowing south from the hills, of which the Lubha, Piyan and Jadukata are the main ones. The Kushiya, on the other hand, receives supply flowing north from the Singla, Langai, Manu and Khowai.

The Surma and Kushiya again join together at Markuli and the united stream takes the name of Kalni river and flows in a southerly direction. Near Kuliarchar (latitude $24^{\circ}10'N$ and longitude $90^{\circ}59'E$), the united stream of Somerwari, Kangsa, Baulai and Mogra called Ghorautia river meets the Kalni and the combined course takes the name of Meghna. From there the Meghna flows in a southwesterly direction to meet the Padma which carries the combined flow of the Ganges and Brahmaputra at Chandpur. Between Kuliarchar and Chandpur, main tributaries joining the Meghna from the left are the Titas and Gumti. Those joining from the right are the old course of the Brahmaputra, the Lakhya and the Buriganga. In fact the Lakhya and Buriganga join each other only a short distance before the combined stream enters the Meghna.

¹ United Nation Water Resources Series No. 29, Op. Cit., P.28.

Below Chandpur the combined river, also known as the Meghna, becomes a very wide and deep estuary. It enters the Bay of Bengal by four principal mouths - Tetulia river, Shahbazpur river, Hatia Channel and Bamni of Sandwip Channel. The distance between Chandpur and the sea is about 80 miles.

The Meghna is about 590 miles long, of which 340 miles including the estuary from Chandpur to the sea lies in Bangladesh. The drainage area of the Meghna at Bhairab Bazar where the Old Brahmaputra meets the river is about 25,000 sq. miles. At Chandpur, its drainage area is 31,000 sq. miles of which about 14,000 sq. miles are in Bangladesh.

The width of the river at Bhairab Bazar is about half a mile and there is a railway bridge at this point over the river. The mean discharge at that point, from late May to mid October, is about 250,000 cusecs with a recorded maximum of 431,500 cusecs in 1960. In the Piedmont tract from Durgapur to Jaintiapur, most of the network of streams and channels overflow in the rainy season and create vast sheets of water which connect the Haors¹ with the rivers. In the Haor Basin, too, the rivers overflow and fill the Haors in the early part of the rainy season, and receive back much of the water as soon as the monsoon rains slacken.

Several small channels separate from the Meghna and meandering through the lowland bordering the Tripura surface receive the flow

¹ Haor is a depressed area usually remain full of water during monsoon season. These are generally found in Sylhet and Mymensingh districts of Bangladesh.

of a number of hill streams and re-join the main river downstream. The most important of these offshoots is the Titas, which takes off south of Chatalpar and after meandering through two long S-bends, extending over 150 miles, re-joins the Meghna through two channels, in Nabinagar Thana. It receives the Howrah hill stream near Akhaura. Brahmanbaria and Akhaura are both on the banks of this river. Other offshoots of the Meghna are Pagli, Katalia, Dhonagoda, Matlab and Udhamdi. The Meghna and these offshoots receive the waters of a number of hill stream from the Tripura Hills. The important hill streams are the Gumti, Howrah, Kagri, Senai Buri, Hari Mangal, Kakri, Pagli, Kurulia, Balujuri, Sonaichari, Handachara, Jangalia and Durduria. All of these are liable to flash floods. The Gumti, Kakri, and Howrah are the main culprits. They have silted their beds to the extent that they now flow above the mean level of the land when brimful. Embankments have been built to contain them. Most of these are looked after by the farmers and are, therefore, not sufficiently strong. Every other year one or the other of these streams overflow and cause considerable damage to crops, live stocks and villages in the rural area and properties in the urban areas.

The river has a steep slope while flowing in the hills in India. After it enters Bangladesh at the north-east corner, it travels through the low lying alluvial basin of Sylhet district. When the Meghna flood meets with of the Padma at Chandpur, flood level is backed up into the Meghna and the basin acts as a gigantic detention reservoir, more or less similar to the Tonle-Sap of the Mekong river in Combodia, without which the area between Goalundo and Chandpur

would be under water at a much greater depth. At flood stages the slope of the Meghna downstream of Bhairab Bazar is only about 1:88,000, which certainly reflects the influence of backwater from the Ganges-Padma.

Minor Rivers

The pride of Bangladesh is her net work of minor waterways. Minor rivers, streams and channel totals about fifteen thousand miles. They consist of tiny mountain streams, winding seasonal creeks, muddy channels, and tributaries and distributaries of major rivers. In some places, such as south Barisal, the waterways are so plentiful that even on a map it is difficult to find a pattern to them. They are obviously not evenly distributed; the increase in numbers and size from the north-west of the Northern Region to the south-east of the Southern Region. All of them, except those of the Chittagong Region, belong to one or the other of the three major river systems, those of the Ganges, the Brahmaputra and the Meghna, (Map 8).

The Tista

The Tista was the most important river of the Northern Region till 1787. Before that year, it used to be the principal source of supply for the Karatoya, Atrai, Jabuneshwari and other rivers. Considerable structural changes in the Barind Region (See Map 7) affected the Karatoya, which rapidly dwindled. This led to the Tista having a considerable amount of water left over, which it could not pass down the Atrai without causing flood. The excessive rains of 1787 brought down a vast flood of sand which choked the Atrai Channel, with the result that the Tista burst into the Ghaghat river, which is a very

small one, and not finding sufficient outlet, overflowed and swept nearly the whole of Rangpur district. The flood, or rather deluge, happened in a single day on August 27th. Nearly a sixth of the population of Rangpur died in 1787, mainly due to this flood. The Tista found a new outlet for itself, and it has kept more or less to this channel since then. The frequent changes of its course has left a legacy in the shape of numerous stagnant cut-off channels in the west of Rangpur, most of which are known as Buri (Old) Tista. The Tista is the major tributary of the Brahmaputra river in Bangladesh and it joins the mighty Brahmaputra just south of Chilmari. It rises in Sikkim Himalaya, not far from Darjeeling. It has a catchment area of 4,600 sq miles.¹ The river recorded a maximum discharge of 3,64,000 cusecs and a minimum discharge of 2,590 cusecs at Kaunia in Bangladesh.² The annual flow at the site varies from 10 to 18 million acre-feet. The present channel within Bangladesh, is about 110 miles long, and varies from three to six hundred yards in width.

The Ghaghat is a distributary of the Tista. It flows past Rangpur and Gaibandha Towns and joins the Brahmaputra a few miles north of Fulchari Ghat. A distributary known as the Bangali, flows south from Gaibandha. The Ghaghat, is for the most part, a sluggish stream, choked with weed. Its flow varies from 4 to 11,000 cusecs.³ The Bangali has a larger flow, which varies from 400 to 21,000 cusecs.

¹ A Latif. United Nation Water Resources Series No. 23. Op. Cit., P.103.

² Kh. Majidul Islam, Op. Cit. P.98.

³ Ibid.

The Dharla

Flowing somewhat parallel to the Tista, and to its north, is the Dharla river. It flows into the Brahmaputra. The Dharla (white) is a swift river in the rainy season, but a braided clear stream in winter. In its upper course, it is known as the Jaldhaka or Singimari. In Rangpur district, it has a small tributary in the Nilkumar, formerly a larger river.

The Dharla has low and shelving banks and is particularly liable to change its course. In 1947, it completely diluviated the old site of Kurigram Town.

The Dudkumar

Flowing parallel to Dharla and to its north, is the Dudkumar. The Dudkumar, known in its upper course as Sankosh, is a small river. It also flows in a south easterly direction and falls into the Brahmaputra. Right on the eastern border is the Sankosh river of the Bhutan Duars. Most of it is in India.

The Ghaghat

West of the Tista river is the Ghaghat river. It is a distributary of the Tista. It flows past Rangpur and Gaibandha Town and joins the Brahmaputra a few miles north of Fulchari Ghat. The Ghaghat is, for the most part, a sluggish stream, choked with weed. Its flow from 50 to 2,500 cusecs.

The Karatoya

The Karatoya river has got four distinct parts i.e. the Dinajpur Karatoya, the Rangpur Karatoya, the Bogra Karatoya and the Pabna Kara-

toya. The Dinajpur Karatoya is the northern part of the river Karatoya, is the main source of the Atrai. It rises in a marsh in Baikanthapur in Jalpaiguri Thana in India, but also receives water from underground streams. From Khansama Thana its name changes to Atrai. The Dinajpur Karatoya was connected with the Rangpur Karatoya north of Khansama, but very little water passes down that channel at present.

The Rangpur Karatoya rises in Saidpur Thana and flows in light meanders south-south-eastward to Gobindoganj Thana where the main stream turns eastward through the Katakhalī and falls into the Bengali. The portion of the former river through Shibganj Thana is dry most of the year; it effectively separates the Rangpur Karatoya from the Bogra Karatoya. The latter river flows past Bogra Town and southward, till it joins the Bangali to make the Phuljhor river, which falls into the Hurasagar. The maximum discharge of the Bogra Karatoya is below 3,000 cusecs. The fourth part, the Pabna Karatoya is a moribund river-bed near Handial. Various other channels are also pointed out as those of the old Karatoya. The ancient Karatoya must have been a large river. In Van den Broucke's map of Bengal, prepared in 1660, it is shown as such, and in Major Rennell's map, prepared in 1781, it is still large. As late as 1810, Buchanan-Hamilton writes of it as "a very considerable river"¹. The decline, however, came so rapidly after the 1820 flood that the old banks of the river are distinctly traceable, nearly a mile apart.

¹ F. Buchanan - Hamilton, "A Geographical, Statistical and Historical Description of the district of Dinajpur", 1833.

The Jamuna

West of the Rangpur and Bogra Karatoyas is the Jamuna, hereafter called the Western Jamuna, to distinguish it from its giant namesake (Brahmaputra). The Western Jamuna rises in Jalpaiguri district in India and flows more or less southward through eastern Dinajpur and western Bogra district and falls into the Atrai in Rajshahi district. The Tulsiganga and Chhiri Nadi, both of which drain the Eastern Barind, are its principal tributaries. The western Jamuna, as has been mentioned earlier, has carved out its own valley in the Barind, which separates the eastern from the east-central Barind.

The Atrai

The Atrai is west of the western Jamuna. It is the western-most tributary of the Brahmaputra. Its main source is the Dinajpur Karatoya, which changes its name in Khansama Thana to Atrai. This channel bifurcates north-west of Chirirbandar and unites south-west of it. The western arm is called Gabura and the eastern is called Kankra. The rewritten river is once again the Atrai, which flows almost due south to Manda Thana separating the east-central and west-central Barinds. It receives many small streams while passing through the Barind, but its flood-plain there, is only a couple of miles wide. From the Manda Thana, the river flows south-east. At Shuktigachha, the Western Jamuna joins it. A few miles further down, near Atrai Railway Station, the river bifurcates into Gur and the Old Atrai Channels. The old Atrai, the southern channel, flows south and then east. The Baranai, which drains the southern Bhar Basin, joins it at this second bend. The course of the river is henceforth difficult to follow since in the very

lowland of the low Bhar, rivers bifurcates and unite a number of times. The Narad and the Nandakuja join the old Atrai from the south by a number of channels. The northern channel - the Gur, receives the main flow of the Nagar, which drains the southern part of the eastern Barind near Singra. The Gur too bifurcates and each of its arms bifurcates in turn. The Old Atrai is called the Gumani after it joined by the Nadakuja. The Gur joins it near Bahadurabad, near the eastern end of the Chalan Bil. The confluence in the rainy season is a very large sheet of water, known as Gumani till the Baral joins it east of Chatmohar, from where it is known by the latter name. Thirty miles downstream from there, the Atrai-Baral is joined by the Phuljhor; the combined stream is known as the Hurasagar will be referred to as Atrai for simplicity's sake, unless a specific reference to one of the component parts is made. The Atrai formerly flowed into the Padma near Ratanganj in Bera Thana. After the changes of 1787, no water flows down that way.

The Purnabhaha

The Purnabhaha is a tributary of the Ganges. The upper course of the Purnabhaha is just a few miles west of the Atrai. The main source of the river is the Brahmapur Barind. It is joined by the Dhepa which also rises in a bill. The Dhepa is also known as the Purnabhaha. From just south of Dinajpur Town this river flows between the western and west-central Barinds, and drains the west of the west-central part. Its valley is from two to five miles broad.

The Mahananda

The Purnabhaha joins the Mahananda just south of Rohanpur. Be-

tween the Purnabhaha and the Mahananda rivers there are three other tributaries of the latter river, the Tangon, Kulik and Nagar. The Tangon has an entrenched valley, even in the Piedmont Plain. Along the Kulik the land is markedly undulating. The Nagar forms the western border of Dinajpur district for many miles. The Mahananda, a major tributary of the Ganges, rises near Mahaldiram in Darjeeling district in India. It forms the western boundary of Bangladesh at Tetulia Thana and then again at Ranishankoil Thana. Flowing through India, it again forms the boundary of Bangladesh near Bhadahat, then flows through Chapai Nawabganj sub-division and joins the Ganges south of Nawabganj Town. The banks of the last portions of the Mahananda are alternately sheer and sloping and the river is 300 to 600 yards wide, and deep. Rise of water can be 20 ft or more within a short time during the rainy season. The average maximum flow is about 80,000 cusecs; flood discharge can be over 100,000 cusecs. The winter flow as can be expected, is only a few hundred cusecs.

The Bangali

The Bangali river is a continuation of the Ghaghat river of Rangpur. It has a connection with the Brahmaputra in the east, and with the Karatoya (through the Katakhal) from the west at Ramnagar. Flowing south, it receives the Belai distributary from the Brahmaputra and further on bifurcates: the western arm being called Halhalia, while the eastern retains the original name. The Bangali arm receives the Manash Madhulkhal distributary of the Brahmaputra in Kazipur Thana. The combined stream falls into the Phuljhor at Nalka.

The Simla Khal, an offshoot of the Brahmaputra flows east of Sirajganj Town and joins the Dhanbandi, another Brahmaputra offshoot, which flows through that town. The Dhanbandi falls into the Hurasagar at Manpur. The Hurasagar itself is an offshoot of the Jamuan. It flows south-west then south, and finally south-east to rejoin the Jamuna north of Bera Town. Its mean discharge from June to September is probably about 100,000 cusecs.

The Old Brahmaputra

The Old Brahmaputra takes off from the left bank of the Brahmaputra to the north of Bahadurabad. Flowing more or less to the south-east, it passes by Jamalpur and Mymensingh Towns and falls into the Meghna at Bhairab Bazar. Its average gradient is 0.25 feet per mile. Over most of its course, the right (southern) bank is higher than the left. Before the 1787 changes, the river was a mile wide; the left side levee can still be traced, more than half a mile from the present left bank. The flow in a river of that size and with the given gradient could have reached a maximum of two million cusecs.

The mean discharge from the middle of May to middle of October at Mymensingh is about 50,000 cusecs. The river is a quarter of a mile wide at Mymensingh Town. It has two main off-shoots, the Jinai and Banar. The Jinai takes off north-west of Jamalpur Town, joins the Chatlai Channel of the Brahmaputra and falls into that river just north of Sharishabari. The Banar is joined to the Old Brahmaputra at Nandina, and receives quite a lot of water from it in the rainy season. After passing the main volume of its water down the Lakha river, the Banar

falls into the Old Brahmaputra at Egaro Shindur and the latter river joins the Meghna at Bhairab Bazar. Formerly the Kangsha was an important left bank distributary of the latter river, but its head has silted up leaving it an attenuated seasonal stream. It flows north-east, east and then east-south-south-east to join the Dhanu. Its discharge varies from 500 to over 40,000 cusecs. The Nitai and Balach are tributary to the Kangsha. The Balach is a channel of the Someswari, which comes down from the Garo Hills and joins the Surma south-east of Kalma-kanda. A large number of streams come down from the Garo Hills, of which the western Somesari, Malejhi, Tharua, Tolongs, Bhoyai and Dursha are the main ones. They drain into the Kangsha.

The Dhaleswari

The Dhaleswari, along with its distributary, the Buriganga, is a river of great importance to the economy of the western and southern part of Dacca district and is of considerable size. It takes off from the Brahmaputra by several channels, forming the offtake, have silted up. The principal channel, known as the Elasin, was ten miles north of Salimabad about forty years ago, but now it runs south of it. The river flows in an extremely tortuous course through the south-western part of Dacca district, keeping well to the south and west of the mass of old alluvium. Formerly the Dhaleswari used to join the Sitalakhya below Munshiganj, but now the junction is almost opposite Mirkadim, above Munshiganj. The total length of Dhaleswari is about 100 miles and in its lower reaches, it becomes a very wide river, even during the dry season. The mean discharge of the Dhaleswari in the rainy season, at Munshiganj, is about 200,000 cusecs.

The Buriganga

The Buriganga is a notable distributary of the Dhaleswari and following a zig-zag course for about twenty-six miles, skirting the edge of the old alluvium, before rejoining the large stream. It takes off south of Savar and flows past Dacca. It gave the old metropolis its water connections in the past and was easily navigable, so that the great Mughal fleet (the Nawara) could often anchor near the town.¹ It has been showing signs of silting up and there is a considerable growth of water hyacinth even at Dacca. The river is, however, of great advantage to the capital and there is a regular steamer route to Narayanganj, Chandpur, Barisal and Khulna.

The Sitalakhya

The Sitalakhya is a river of considerable importance between the Dhaleswari system and the Meghna. It flows along the eastern edge of the old alluvium and drains into the Dhaleswari below Narayanganj. Due to its cutting through the red earth, it has clear waters and high banks, which have been the sites of settlements since very early times. The river has been noted in the past as an important inland navigation channel, providing excellent communications for both civilian and military purposes.

The Gumti

Gumti originates from the Tripura Hills in India. At hilly stage, the river is very rough due to stiff slope. So, after a heavy rainfall, water come down from the hilly portion to the flood plain.

¹ Nafis Ahmed, Op. Cit, P.18.

very quickly. Moreover, the river is very meandering in the flood plains, so heavy rainfall in the upstream causes drainage congestion in the downstream side. To protect the urban areas such as Comilla, Jafarganj, etc. originally one embankment was constructed long ago on the left bank of the river and it was subsequently reinforced.¹ Due to the construction of one embankment and siltation, the riverbed goes up above the adjoining land. So it used to inundate the growing paddy land and villages on the other bank during monsoon, causing inconveniences and hardship to the poor villagers. In the past, breaches sometimes have occurred in the river embankment. But, during the past few years, embankment on the other bank has been constructed and considerable work has been done to straighten the river by cutting loop and strengthening the previously constructed embankment.

There is one railway bridge over the river near Comilla. The river falls into the Meghna at Daudkandi. Its flow varies from 100 to 20,000 cusecs at Comilla. Monthly annual average flow of the river at Comilla is 2,690 cusecs.

The Dakatia

Another tributary from the Tripura surface is the Dakatia. The main source of this river was the Kakri, but the Little Feni cut back and captured this upper portion. The Dakatia now has its source in the Chaudagram Khal, which connects it with the Little Feni. The Dakatia

¹ B. M. Abbas. A Report on the Flood Problem of the Gumti River. (Dacca: East Pakistan Water and Power Development Authority, July, 1961, P.6).

sends out a channel southwards, which forms the Noakhali Khal. The main channel meanders westward to Shekherhat, from where the old course goes south to join the Meghna at Raipur, and the new and more strong channel passes through the Chandpur Khal to join the Meghna just west of Chandpur Town. For three-fourths of the year, the Dakatia is fed by tidal currents from the Meghna. Water levels are affected by the tides with daily differences of one or two feet in the dry season. At the same time, tidal variations from one to four feet occur at the outfall in the Meghna River at Chandpur, and reversal of flow occurs in the Dakatia River. During the monsoon season, the levels at Hajiganj usually vary only about 0.2 feet due to tide and the flow is toward the Meghna River, except during an occasional high level in the Meghna River. The maximum water level recorded was 15.1 feet Survey of Bangladesh Datum (SOB).

The Little Feni

The Little Feni follows a very tortuous course southward, and falls into the Meghna Estuary, southeast of Companyganj and a few miles from the Big Feni Estuary. The drainage area is about 175 square miles. The stream slope is flat, and during low stages, some tidal variations occur causing up to about one foot variation between near and spring tides. The operation of sluice gates at Kazirhat constructed by BWDR¹ about 15 miles downstream, may have some effect on the river stage.

Average annual flow is about 767 cusecs. In the rainy season, it goes upto 15,000 cusecs. Flows vary considerably in the dry months. When breaches occur in the embankments along the southside of the Gumti

¹ BWDB stands for Bangladesh Water Development Board.

River, the spill from the Gumti may increase the flow in the Little Feni River.

The Feni

The Feni drainage basin is adjacent to the Halda River on the southside and to the Muhuri River on the northside. This is a hilly stream. During heavy rainfall it becomes very rough and tries to change its course. Its annual average discharge is about 2,076 cusecs. Minimum discharge during dry season is as low as 150 cusecs. Suvapur highway bridge is on this river and it has been washed away suddenly during the monsoon of 1970, before any effective measure could be taken to protect the bridge. There is also a railway bridge on this river.

The Muhuri

The drainage area of the Muhuri River at Parashuram is 261 sq. miles. It is also a hilly stream and it creates flood problems during heavy rainfall due to siltation of the riverbed and due to a number of meanders in the flood plain. The average annual discharge of the river is 856 cusecs. The river is effected by tide. It originates from Tripura Hills and drains directly into Bay of Bengal.

The Karnafuli

The Karnafuli rises in the higher Arakan Yomas and cutting across the main ranges of the Hill Tracts falls into the sea a few miles from Chittagong City. It is known as the Kynsa Khyong to the Marma. There are rapids at Demagiri in India and Barkal (these have been submerged by the Kaptai lake) and gorges at Chilerdak where it cuts through the Subalong Range and at Silchari where it cuts through

the Sitapahar Range. The Jamaimoromi Peak is besides this latter gorge. The main tributaries of the Karnafuli are Thega, Subalong, Rinkheong, Kaptai and Ichamati on the left side and Sajjak, Horina, Kasalong, Chengi and Halda on the right. Dhurung and Sarta are tributaries of the Halda, a river as prone to overflowing as the Gumti. The Karnafuli falls into the sea after executing a large S-bend along the Chittagong harbour. In ebb tide, the channel out into the sea can be traced through mud banks which are spreading further every year. Its estimated annual flow is 25 million acre-feet.

The Karnafuli watershed lies in the south-eastern portion of Bangladesh. Its drainage area of 4,250 square miles upstream of Kaptai dam site is heavily vegetated and for the most part, very mountaneous with some ranges exceeding altitude of 8,000 feet above mean sea level.

Before the construction of the Karnafuli Hydro-Electric Project, large floods occurred during the monsoon season each year. A review of the annual maximum discharge of the river was made before the construction of the dam. The review showed that during the monsoon seasons, there have been only two out of 18 years, in which the flood peak discharge were under 100,000 cusecs. In 12 out of 18 years, the flood peaks were under 150,000 cusecs and in 16 out of 18 years, the flood peaks were under 200,000 cusecs.

The Sangu

The Sangu rises in the Sangu Reserve Forest in the south-east of the Hill Tracts. It flows north-west for most of its course and falls into the sea just ten miles from the mouth of the Karnafuli.

The Marma call its upper course Sabok Khyong and its middle course Rigre Khyong. In its upper course, there are two small waterfalls and several rapids. Dolu, Hungor and Tankawati are its main tributaries. Its estimated annual flow is 3 million acre-feet.

The Bhairab

The Bhairab is an important river in the Moribund part of the delta. Its name, "the terrible", attests to the size it had reached when the main volume of the Ganges was carried by it. At present, the main stream is not navigable beyond Bagherpara Thana. It has two main branches, the Khulna-Ichamati and the Kobadak. The Khulna-Ichamati has part of its course in India and part in Khulna district. It is the boundary between the two countries. This river too is prone to change names. Down to Kaikhali, it is Ichamati, then it is Kalindi till Kaikhali, from which place it is the large estuarine river, the Raimangal, which splits up into two, the western named the Hariabhanga, and the eastern retaining the original name. Down to Kaikhali, the river will be referred to as Khulna Ichamati, while south of it, it is the Raimangal-Hariabhanga.

The Kobadak

The Kobadak, a corruption of Kapotaksha, flow south to the forest outpost of Kobadak at the edge of the Sunderbans, and there joins the Kholpetua to form the large estuarine river the Arpangasia. The Bhairab flows south-south-east, to Khulna Town, where it joins the Khulna-Atrai and becomes the Rupsha. Just south of the town, the Rupsha branches into two, the eastern one of which resumes the name

Bhairab and flowing southwards loses itself in the estuarine rivers, Keora and Bhola.

The Mathabhanga

The Mathabhanga is the western most river along the boundary of Bangladesh between Kushtia (Bangladesh) and Murshidabad (West Bengal). It was once a big stream, but at present it is a mere chain of pools in the dry season.

Between the Mathabhanga and the Gorai, a large right bank Ganges distributary taking off near Kushtia Town, there are a large number of rivers and khals. The Mathabhanga splits up into four main channels, the Churni, Chitra, Nabagonga and Kumar, within Kushtia sub-division. The Churni joins the Bhairab, and is an important source of its Khulna-Ichamati branch. The Chitra flows south-south-east to Uzirhat, where it divides into two branches, the Khulna-Atrai and the Chitra: the former joins the Bhairab north of Khulna Town, while the latter joins it to the south. The Nabagonga is another decayed channel, navigable part of the year and only up to Magura. The lower portion is, however, taking increasing amount of the Gorai's flow into the Pussur river. The Kumar, also called Pangasi, branches from the Mathabhanga ten miles from Alamdanga Town and flows in a south-easterly direction to a point five miles north of Magura Town, where it divides into two channels, one of which falls into the Gorai, while the other joins the Nabagonga through the Muchikhali at that town. The lower Nabagonga channel takes much of the Gorai's flow into the Pussur river.

The Gorai

The Gorai is formed of three large offshoots of the Ganges just

north of Kushtia Town. South of Kushtia its first offshoot, the Kali-ganga, branches off to join the Kumar near Sailkopa. This river has been completely dammed by one of the primary canals of the Ganges - Kobadak Project and the lower half of the course is now almost a dry bed. The main river bifurcates and rejoins several times as it flows south-east to Muhammadpur Thana, from there flowing south-south-west. It changes its name to Madhumati. The Kumar, Nabaganga, and Chitra join it through several channels south of Mollahat Thana. There the name changes to Baleswar, which in turn changes to Haringhata from the Bogi forest outpost of the Sunderbans. The Gorai-Madhumati has a flood discharge of nearly 250,000 cusecs, but in winter its flow has gone as low as 5 cusecs.

All the rivers between the Khulna-Ichamati, Ganges, Gorai-Madhumati and the sea are connected by cross-channels, which are especially numerous in the Sunderbans. They are of great importance to inland navigation in the delta, for though the rivers flow in a north-south direction, the traffic is mainly east to west.

The Pussur

The Pussur is the continuation of the Rupsha and is formed of the Union of the Bhairab and the Atrai. At present, much of its water is from the Gorai diverted through the Nabagonga. From near Baitaghata, the Rupsha changes its name to Kazibacha, which is given up near Chalna for the name Pussur. Near the Mangla anchorage, the Pussur receives the Mangla river, and near the forest outpost at Chandpai, it receives the Mirgamari cross-channel from the Bhola, both on the left bank. On

the right bank the Manki, Dhaki and Bhodra connect it with the Shibsa System. In the lower delta, the Pussur is second only to the Meghna.

Formerly it was third, after the Madhumati; but with considerable diversion of the Gorai flow through the Nabagonga, it is now bigger than that river. From its junction with the Mangla, it is now here less than a mile wide. Twenty miles from the open sea, it joins the Shibsa to form the three-to-five miles wide Morzal river, which empties into the Bay by the Marjata and the Pussur estuaries.

~~The land in between the Pussur and Bhola, is drained by the Sela, which is wholly within the Sunderbans.~~ Many cross-channels connect it with the systems on either side. A large cross-channel connects it with the Morzal, at the head of its estuary, which is the Bangara.

East of the Sela, the next big river is the Bhola, which begins as a small channel where the Bhairab becomes the Keora tributary of the Baleshor. The Bhola falls into the Haringhata estuary of the Baleswar. The Baleswar, which is the continuation of the Gorai-Madhumati has played a very important role in building up the Mature Delta. The rich Bagherhat and Pirojpur sub-divisions depend upon it for the annual deposit of silt. Formerly the flood waters kept the sea water from reaching beyond Bogl at the edge of the Sunderbans but with the diversion of the Gorai into the Pussur, the river is decaying. The flow was sufficient to make the forests of a fresh water nature to within ten miles of the sea. At the point of its junction with the Bhola, it widens out to four miles to form one of the sources of the huge Haringhata estuary, which also receives the flow of the Bishkhali and the Buriswar, and so reaches a

maximum width of twelve miles.

The Arial Khan

The upper part of the plain between the Gorai-Madhumati and the Padma, mainly lying in the Faridpur district, is full of rivers, steam and khals¹ of various sizes. Their shifts and changes have played a significant role in the life and economy of the area.

The Arial Khan, sometimes called the Bhubaneswar is the upper part of its course, is the eastern most distributary of the Padma. It marks the former main course of the Padma, before the development of the mighty eastern channel and its junction with the Meghna. At present, it is an active, large stream, winding its way in tremendous loops to the sea. It is connected with the Padma by several active or partially active affluents, the principal among them being the Mayna Kata Channels, Palong, Naria Khal, Kailara and Nayabhangni. There are, in addition, numerous inter-connecting links of fair size between the above-named rivers, some of which make steamer routes possible. Between the Arial Khan and the Madhumati there is a maze of rivers. The three largest are in the north, the Chandana, Bhubaneswar and the various channels of the Kumar. In the south is the Saildaha, or the Ghagar River, which flows into the Madhumati after draining the marshes called Nasibshahi, Atadanga and Kajalia Bils. The Arial Khan is a large, navigable stream and joins the sea as the Tetulia River. The total discharge of all the rivers in the Bangladesh part of the Delta is estimated to be 7 million cusecs, in the rainy seasons, and amounting to

¹ Khals means Small Streams.

about 900 million acre feet annually.

The Bils¹ And Haors

The plains of Bangladesh contain a large number of bils, the characteristics of which have been described in a general manner. The mode of their origin, however, has certain interesting geological and hydrographic aspects. The bils of Bangladesh, as a part of the natural physical environment, are not all of the same origin. They were formed principally in two ways:

- a. The largest number of them, which vary in size and are most commonly spread over the surface of the plain, are scars and "left out" of old river beds, now deserted by the streams which once occupied them. They especially abound in the area of the so-called dead and dying rivers.
- b. There are, however, a number of bils of vast size, which include some of the largest ones. These are basin areas. The basin areas are usually not discernible as low lying, though they become obviously so during the rainy season and present a vast sheet of water. Some are of enormous size and retain water permanently, though its extent varies during the seasons. Leading examples are the Gopalganj and Chalan Bils and the Sylhet haors or marshes.

"As regards the origin of the basins of the bils, Fawcus held that some amount of subsidence was implied, as the area covered by them

¹ Bil means marshy land generally remains under water during monsoon season.

is large. Apart from geological opinion with regard to subsidence mentioned already, support was lent to this view by the occurrence of coastal erosion and evidence of subsidence by a comparison of Rennell's surveys in 1770 and the survey work of 1906. The origin of these bils may be attributed to earth subsidence, as they could not be merely natural pockets due to silt-laden rivers building up their own banks and thus enclosing vast areas of lowland. Jack lent support to the explanation based on subsidence by mentioning the discovery of brick foundation, skulls and coins, etc., in these bil areas in Swarupkati and Bhandaria. He also pointed out that the bils have actually grown larger since Rennell's time. The Sylhet Basin is rapidly sinking, showing in some places a subsidence of about 35 feet in the last few hundred years. Remains of stumps and wood have been encountered in recent drillings up to depths of 50-60 feet. Bils, as has been explained previously, are usually saucer-like depressions, of a marshy character. In the rainy season they are full of water and resemble lakes. At other seasons the water level goes down and reeds and sedges make them look like marshes. Some bils dry up completely and are cultivated. A few on the other hand look like lakes throughout the year. They are all fed by surface runoff and by small channels that connect them with the rivers. The former source is the more important!¹

In the Northern Region there are a large number of Bils - a legacy of the much-changed river system. There are no big ones in Dinajpur district; Rangpur district has three: Tagrai west of Kurigram Town, Lunipukur west of Rangpur Town and Bara Bil in Pirganj Thana. In

Nafis Ahmed, Op. Cit., P-31.

Bogra district there are two large bils, just to the east of the Bogra Karatoya, the Nufail and the Keshpathar. Further east, in Shariakandi Thana are Sat and Gobarchapa Bils. In the south-west in the Raktadaha Bil, connected with the Parul in Rajshahi district. Along the Mahananda river are several Bils of which Baitia in Bholahat Thana is the largest. In the west-central Barind the main bils are Boro Mirzapur in Porsha Thana and Paticola in Godagari Thana. Along the eastern edge of the west-central part of the Barind are a number of Bils, probably marking an old course of the Atrai river. From north to south the big bils in this line are Chakchaki, Sabul, Ghugri, Kanchon, Manda, Utrail, Siddeshwor, Ghona, Hilna, Kumari, Shona and Bagsimli. Between these Bils and the Chalan Bil System are a number of others, such as Ajum, Malshi, Angra, Podda, Shewli, Gondi Parul and Shonaikanda. The Chalan Bil System is large, it consists of all those bils which join through various channels to form more or less one continuous sheet of water in the rainy season. They are, from west to east, Purba Madhnagar, Piprul, Dangapara, Laror, Tajpur, Niala, Chalan, Majhgaon, Briasho, Choumohon, Satail, Khardaha, Darikushi, Kajipara, Gajna, Bara, Sonapatila, Ghugadaha, Kuralia, Chiral, Dikshi and Gurka. These bils are the lower spots in the low-lying Bhar area, most of which is inundated in the rainy season. The Chalan Bil was formed when the Jamuna branch of the Brahmaputra expanded and dammed back the Ganges, causing the latter to deposit sediments at the mouths of the Karatoya and Atrai, which then flowed into the Ganges. It was probably a back-swamp before it was greatly expanded by the pent up flow of the Atrai and Karatoya, and became a lake of some 420 sq. miles. With the gradual silting up of its southern side by the annual deposits of Ganges,

it has moved twelve miles inland in the last century and a half. By 1909 the area of the bil is said to have been reduced to 142 sq. miles of which only 33 sq. miles were under water throughout the year. It was then estimated that 222.5 million cubic feet of "silt" was brought into it by feeder rivers, of which 53 million cubic feet were carried off by those draining it. The remaining 169.5 million cubic feet were deposited, which if distributed equally would raise the level of the bils half an inch a year. In 1913, however, it was found that the perennial water body was less than half of what it was four years back. In the 1950's various reclamation works have reduced the bil to about ten sq. miles.

In the Southern Region there are even more bils than in the Northern Region. The larger bils of this area are Kamladaha, Chakli, Taleria, Jhanja, Boalia, Malar and Jaleswor. The line of bils across the north of Khulna district and into the central Delta Basin contain the following large ones, from west to east, Dantbhanga, Boyra, Shahpur, Dakatia, Pabla, Bakar, Boro, Kolo, Patla, Baronal and Srirampur. They cover parts of Satkhira, Assasuni, Dabhata, Kaliganj, Tata, Dumuria, Daulatpur, Terokheda, Mollahat and Bagherhat Thanas.

The main bils in the Central Delta Basin are Katli, Nalua, Chatal, Moura, Nagarkanda, Kazlindanga, Baghila, Atadanga, Chanda, Pathram, Ujan, Digra, Ishwordi, Rathnoranga, Harhora, Ghazorai, Soladanga, Patridanga, Kasmira, Pabania, Gopalpur, Bashor, Kajalia, Ramsili Dighi, Boghia, Janijhania, Tungi, Dopura, Deulbari, Poddo, Dumaria, Satla, Ashkar, Suga, Baldia and Harta. Of these, Katli, Nalua, Kasmira, Pabania, Soladanga and both Pathrams dry in March and April, before they begin to fill up

again from May onwards. The other bils have some water all year round. Over most of the Central Region bils are comparatively few. There are many small basins in the Recent and the Pleistocene deposits, but they are slight depressions. Outside the Haor Basin the large bils are Belai and Howda. Belai is in the southern part of the Madhupur Tract, and Howda is in the northern part. In the Haor Basin there are no less than 400 haors and bils. The majority of these are, however, small appendages of the larger water bodies. In the deep central, the main water bodies are Baram-Banka-Habibpur-Maka-Makalkandi and Ghulduba Haors and the Panga and Bandha Bils. In the deep basin at the foot of the Meghalaya Plateau are the large Tangua-Sanir and Matian Haors. Close to the east are the Dakhar, Jilkar-Jhinkar and Patharchauli Haors. In the eastern part of the Haor Basin rim are the Jamaikata-Mahai-Nalua-Parua Haors. Between the Tarap and Bhanugach ranges there is the large Hail Haor. In the Central Sylhet Lowland there are a number of haors such as the Hakaluki group of Haors and bils and the Chatal, Bar and Hailka Haors. There are seasonal bils, with water only in the rainy season, all along the foot of the Meghalaya Plateau.

South of the Haor Basin, on the Tripura Surface Plain and the Titas plain there are a number of comparatively small bils, of which the major ones are Buroli, Hatia, Fada, Horkhai, Gogra-Sandipa, Bayeshakaha, Shafla, Belanga, Shahzadpur, Hugi, Langulia and Satbaria.

In the Chittagong Region Bils are even fewer: they are small and usually contain water only in the rainy season. There are, however, big marshes, overgrown with large grasses and reeds, along many of the rivers

of the Hill Tracts. The largest of these marshes is along the lower course of the Sajjak river. Gumai Bil is an important bil of this region.

In between the rivers and canals there are a large number of water bodies, mostly connected to them by numerous channels. Of lakes, strictly speaking, there are only three, the Rinkhyongkine, Bogakine and the Ahshula Bil. The Rinkhyongkine is on the water shed of Rinkhyong river in south-east Hill Tracts district. It is a mile long and a quarter of a mile broad and well stocked with fish. The Bogakine is west of Keokradang Peak, at a height of 1,222 feet; it is parallelogram in shape and quite deep. There used to be no fish in its waters till someone released a few magur (cat fish), and it is reported that they have multiplied exceedingly. The Ahshula Bil, though so called, is more properly a lake. It is at the northern end of the Eastern Barind. The banks slope steeply to the water and the lake is deep. Its alignment along the north-west-south-east direction of the Karatoya fault suggests strongly that it is due to block faulting at the same time as the land to the south was raised.

In the Southern Region there are also a number of Baors. These are cut off arms of decayed river channels, principally of the ox-bow type. All the baors are in the Moribund Delta. They are more stagnant than the Bils and generally have water throughout the year. The principal baors are Sagarkhali, Jaleswor, Bokor, Thampar, Khedapara, Rampur, Pathanpara, Katgarar, Jogini Bhagini, Ichamati, Baluherer, Joydia, Marjat, Bukbhona, Harina and Arol. They range in size from a quarter of a

mile to five square miles.

Ground Water

Judging from the many hundreds of wells that have been drilled, together with other types of evidence, it is obvious that practically the entire area of Bangladesh is underlain by a body of groundwater at a depth ranging from zero to about 40 feet, depending on the location and the season of the year. The total volume of the groundwater in storage is thus enormous, since the rock strata in which the water occurs has been shown by deep wells to have a thickness of 3,000 feet or greater. Naturally, only a part of this stored water is available for irrigation use, since the cost of pumping limits the depth at which wells can be operated. For most areas in the country, the depth of irrigation wells has been limited to 300 feet, and pumps are usually set at a depth of less than 100 feet.

Throughout Bangladesh the use of groundwater is becoming an increasingly important phase of the agricultural development. It will permit the irrigation of lands which otherwise would be derived irrigation water because of their location beyond the reach of surface water diversions or at elevations too high to be served from established or proposed canals. Groundwater also constitutes an additional source of water beyond that represented by the flow in streams. This status is particularly important in areas where the winter flow of stream is insufficient for all irrigation needs. The flexibility of supply gives it added importance, since with a properly constructed well field the supply can be increased to serve the cropping needs during the dry season when

surface flows generally are at a minimum and irrigation requirements are at a maximum.

Because of its relatively high cost, groundwater generally will not be competitive with surface flows where the supply from the latter source is ample. For this reason the use of groundwater in irrigation will be confined mainly to those areas where low-lift pumps or canal diversions are unfeasible. Throughout the country, wells are used extensively for domestic, industrial and municipal supplies where the cost of water is of secondary importance. However, except in the vicinity of a few of the larger cities, the total volume pumped for municipal and industrial use are not large, and at no place it is considered sufficient to cause any serious interference with irrigation supplies.

The universal distribution of groundwater throughout the country does not mean that irrigation wells can be obtained at all localities. It has been demonstrated in several localities that, despite the presence of groundwater at shallow depths, the permeability of the aquifers is so low that wells with sufficient yields for economic irrigation cannot be obtained. By test drilling and by geological evidence relating to the type of material likely to be found at depth at a given locality, these areas can be delineated. In this way site for tubewells should be finally selected.

Floods

The floods in Bangladesh are an annual phenomenon. As the rivers rise toward the flood peaks, large quantities of water flow over the banks and back up through side channels for overland storage. This

natural retention storage reduces the discharge to down stream reaches of the main channels by substantial amounts. Depths of flooding, quantity of storage, and velocity of flow in these large off-channel areas vary widely with topography and other natural and artificial conditions. In the very low areas, particularly along the Meghna valley, flood-water depths may exceed 20 feet, and depths of 10 to 12 feet are sidespread in the country. Although the flooded area approximates 10,000,000 acres representing storage of tens of millions of acre-feet, most of such off channel storage capacity is exhausted in the early weeks of the long flood period on the Ganges, Padma and Brahmaputra. With further increases of river in flow, more water goes to storage in the flooded areas thus reducing flows downstream.

The land slopes generally from the north to the Bay of Bengal, and the water surface during overland flooding roughly parallels the land slopes. Consequently the flooded areas operate as an auxiliary channel of large cross section with relatively low velocity. Excessive rainfall in Bangladesh adds a very large volume of water to the overloaded waterways during flood season.

CHAPTER V

ROLE OF WATER BODIES IN THE SOCIO-ECONOMIC DEVELOPMENT OF BANGLADESH

Socio-economic Development

Bangladesh being mainly an agricultural country, the rivers are thus the principal source of economic well-being of the people and where they are still active, and are performing their proper functions, as is still the case in the most part of Bangladesh, the people are healthy and prosperous. Where they are deteriorating and their beneficial activities have been interrupted, as in central and part of western and northern Bangladesh, the area has been progressively deteriorating both as regards health and productivity of the soil. The health of the rivers is thus a matter of vital importance and is almost synonymous with the health and happiness of the people themselves.

The decadance of the Bhagirathi shifting the main channel of the Ganges to the east has brought about in its terrain, the ruin of some other rivers which used to contribute materially towards the prosperity of the south western part of Bangladesh. These rivers are (1) the Bhairab, (2) the Jalangi, (3) the Mathabhanga and their distributaries, e.g. the Chitra, the Nabaganga, the Kobadak, the Betna, the Ichamati and others. These branches and distributaries of the Ganges which used to feed the entire south western part of Bangladesh, have all either died or are dying resulting not only in the prograssive impoverishment of the soil but also creating tremendous difficulty in

the drainage system. The extensive water logging of certain parts of south western region of Bangladesh specially Jessore district, resulted in large areas becoming intensely malarious and depopulated mainly due to the deteriorated condition of these rivers¹.

Broadly the south western part of Bangladesh is divided into two parts. The portions in the north and the west are dry and above flood level Rivers here are mostly dead and the lands are covered thickly with jungles. The area is very malarious and the fertility of the soil is gradually diminishing followed by depopulation. There are many large waste land blocks in this area.

"The adverse effects of deteriorating physical conditions are typically reflected in the story of epidemics and diseases in the Jessore district during the last 150 years. The progressive decrease of population in Jessore district is shown below in percentage:

1881-89 (-2.6), 1891-1901 (-4.0), 1901-11 (-3.0), and 1911-21 (-1.2).

The optimism of the Bengal Census Report of 1921, reporting that conditions in Jessore seemed to be improving, has been belied by the population figures of the succeeding decades. The average density, which was 663 in 1881, has declined to 643. The density in 1931 was 625 and the slight increase in 1951 after 20 years to 656 does not reflect the advent of any favourable conditions for it is primarily explained by the detachment from the district in 1947 of the two low-density thanas of Gaighata and Bangaon. The muslim immigrants from

¹ Nafis Ahmed, Op. Cit., P.295.

India since partition, numbering about 40,000 have also increased the population"¹.

In contrast to this portion, the area to the south and the south-east are low and subjected to inundation every year. Rivers in the region are fertilised and also raised by progressive deposit of silt. ~~Bills~~ and other depressions in this area are accordingly under going a process of land formation. The area are less malarious, people more active and villages more thickly populated than western zone.

The contrast between the two portions of the area is quite marked and is ascribed to the conditions of the rivers which pass through this. This view is supported both by Sir William Willcack in his "Ancient Irrigation System in the Province of Bengal", and Dr. Bently in his "Malaria and Agriculture". The dead rivers of the area which are now thickly covered with water-hyacinth and which are now useless either for irrigation or for transport, can be improved by reexcavation and clearing of Jungles. Paddy is the main crop of the area but the extensive cultivation of date-palms for manufacturing molasses and sugar relieves the monotony of the vast expanses of rice field. Upto the end of the 19th century indigo used to be widely cultivated in the area and one still meets with the old buildings scattered throughout the area where the planters used to live.

¹ Nafis Ahmed, Op. Cit., P.295.

Before the diversion of Tista in 1787, the Punarbhaba, the Atrai and the Koratoa, the most important rivers of north Bengal, used to get the silt-laden spill of the Tista flood. These rivers while intersect the northern Bengal were in consequence, allowed to continue their beneficent activities and the area was healthy and prosperous. Since the diversion of the river in 1787, they have been completely deprived of the Tista discharges. The pressure of water in these rivers has dwindled considerably and as a result their outfall had been choked by silt due to the backwash of the floods in Ganges and in the Brahmaputra. Consequently all these rivers have become decadent and there is a growing deterioration in the drainage system, in public health and in the fertility of the areas through which they pass.¹

The diversion of the Tista is believed to be responsible at least partially for the deterioration of the old Brahmaputra also which used to flow eastward past Mymensingh, into the Meghna and the present condition of the river is such that it permits of navigations at the top of the flood only, while during the dry season it gets cut off from the main channel and becomes practically dry. In consequence, the health of the people, productivity of the soil and drainage of Mymensingh and eastern portion of Dacca district have been greatly affected.

Rajshahi district is the south-western part of north Bengal. It has a positively bad reputation for health, the entire area being malaria stricken and is also noted for its landed aristocracy. Of these,

¹Op. Cit. Majumder, p. 30.

the House of Natore deserves special mention as it is associated with the name of the illustrious Rani Bhabani who has earned an imperishable name in the country on account of her personality and her charity which exceeded several crores of Taka. Her Zamindari comprised of 898 Mahals or Pargana divisions extending over nearly 13,000 sq. miles.¹ Amongst others the Zamindars of Taherpur, Puthea and Dighapatia are also famous.

With the exception of the Ganges, the Mahananda, the Atrai, the other rivers are of little hydrographic importance, and most of them are more or less moribund. The small Jamuna, a principal tributary of the Atrai passes by the town of Naogaon and can be navigated by boats but the river Boral, an offshoot of the Ganges, can hardly be navigated by boats, throughout the year due to the formation of a sandbank at its mouth. Similar is the condition of other small rivers like Nandakuja, Gumani and Gadai. The Narad, an off-shoot of the river Gadai passing through the town of Natore is a dead river. It is believed that once the Narad was a powerful river having a direct bearing on the prosperity of the whole sub-division. Its present condition has affect both health and agriculture and no attempt has yet been made to re-excavate it.

There are many bils in the district out of which the followings deserve special mention: Chalan Bil in Natore sub-division, Manda Bil in Manda Police Station, Raktadaha bil on the east side of Raninagar

¹ Op. Cit. Majumder, P. 30.

Police Station, Nalgara bil and Hasaigari bil in Naogaon Police Station. Most of these bills are full of water-hyacinth and do not contain water throughout the year. As a result, they greatly affect the health and agriculture of the whole district.

There are many tanks and dighis in the district, of which the dighis of Natore deserve particular mention. Once these were used as a source of drinking water. These dighis have been either silted up or are so choked up with water-hyacinth that they have become a menace to health.

The district is served by the main line of Bangladesh Railway which passes through its eastern part (Map-9). On the extreme south-west, there is a branch line from Godagari on the Ganges to Amnura. There is a good road from Rajshahi to Natore while on the south the Ganges serves as the main line of communication. The railway which passes through the eastern half as mentioned earlier is believed to have few culverts for the inlet and outlet for flood water. As a result, considerable damage is done to crops, sometimes from lack of water and sometimes from excess of it. There is practically no irrigation system in the whole district except some low lift pumps and deep tubewells for winter irrigation. The existing tanks can hardly serve the purpose as their condition is very unsatisfactory.

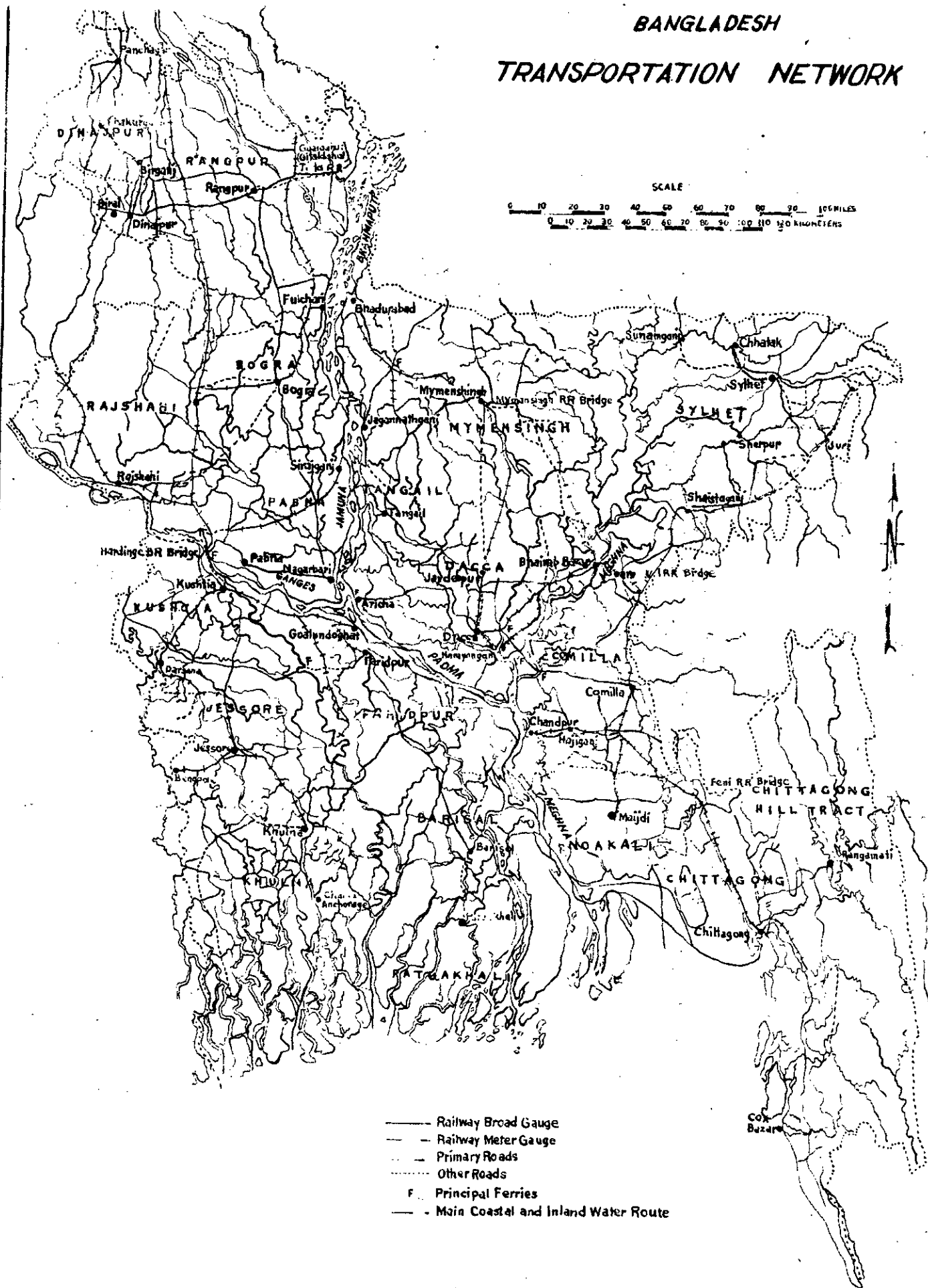
The economic condition in the Sadar and Naogaon sub-division is not unsatisfactory; but the condition is quite otherwise in the notoriously unhealthy sub-division of Natore.

BANGLADESH

TRANSPORTATION NETWORK

SCALE

0 10 20 30 40 50 60 70 80 90 100 MILES
0 10 20 30 40 50 60 70 80 90 100 110 120 KILOMETERS



MAP 9 TRANSPORTATION NETWORK

Pabna district is south-eastern part of the north Bengal. The district is served by two of the most important rivers of Bangladesh, namely, the Padma and the Brahmaputra (Jamuna) which wash its lands on the south and the east respectively, joining at its south-eastern tip. With the exception of the Lariatoya-Phuljhar which keeps some little current throughout the year, almost all the small rivers may be said to be dying; if not already dead. Most of them, particularly the Boral which is the outflow of the famous Chalan Bil, remain choked with masses of water hyacinth and are a source of great danger to crop and health.

The famous Chalan Bil covers part of the north-western belt of Pabna district and portion of Chatmohor, Tarash and Ullapara Police Station. The whole of the western belt forms a shallow triangle which during the rains becomes a vast sheet of water and for miles and miles has a depth of 8-12 feet. The other bil is Gandhasti and it is situated near the south eastern tip of the district.

The Sara-Serajganj Railway line which cuts the district from south-west to north east is believed to have made things worse for the western belt as there are very few inlets and outlets in the railway embankments. As a result flood-water of Chalan and other bils not finding sufficient outlets rises above the level of crops including deep water paddy and causes great havoc every now and then.

In the eastern belt major portion of the eastern part of Serajganj and Pabna Sadar sub-divisions are frequently inundated by high flood of the Brahmaputra (Jamuna) which often causes considerable

damage to the standing crops. The whole area is rather low. Late rains off and on cause drought. But once it rains, rainfall is usually adequate.

The district of Bogra lies in the south-eastern part of Rajshahi Division. It is rather a small district with an area of 1,470 sq. miles only and has only one sub-division. The small river Karatoya which runs from the northwest to the south-east, divides the district into two unequal halves with marked difference in the soil-the western part excepting a portion of Joypurhat and Panchbibi Police Station is composed of laterite soil, and is called "Khlar Anchal"¹. The eastern part is alluvium and is called "Pali Anchal"². Even though the "Khlar Anchal" contains a few bils it is relatively higher than the "Pali Anchal".

The "Khlar Anchal" is one-cropped area. Aman paddy grows here abundantly. The area under Rabi crop is negligible because the soil, being hard, needs irrigation constantly during the dry season. "Pali Anchal" on the other hand, is suitable for all crops and as such Aus and Aman paddy, Jute and Pulses are regularly grown.

In addition to these crops the district of Bogra was known-till 1890 as one of the centres of silk industry in Bengal. Castor oil plants on which the silk worms are fed were grown abundantly on the broadened ails of the fields. Gradually the industry died out. In 1920 an attempt was made by Government to revive the industry and to

¹ Khlar Anchal means eroded area.

² Pali Anchal means alluvial area.

introduce mulberry in place of castor and a farm was established for the purpose. But it did not get encouraging response, though some mulberry trees are still grown near about Bogra town where the farm is situated.

The environment of the district is better than that of the neighbouring districts and the lands being fertile, the general condition of the people is fair good. Cases of Kala-azar, Tuberculosis, Cholera, etc, were also reported from time to time more from the "Khiar Anchal" side than from the "Pali Anchal".

The main line of the Bangladesh Railway runs along the western boundary and a branch line from Santahar junction in the south-west to the north-east of the district of Rangpur. Though rather dusty, the district has good many roads and so communication may be described as satisfactory on the whole.

The river Jamuna, at one time passing through the district as a small branch of the river Brahmaputra, has now turned into a mighty river as the main flow of the rivers Brahmaputra, Tista and other small rivulets have added to its volumes. This river is navigable throughout the year and becomes violent during the rains causing considerable damage to localities along its bank.

Though small, the river Karotoa is one of the most important rivers of Bogra district. It enters the district at Mahabula on the north of Shibganj Police Station. Taking a zig-zag course towards the south it moves through the Police Stations Shibganj, Bogra and Sherpur

and joins the river Halhali near about Khanpur in Sherpur Police Station. The river is of historic importance and at one time it was the main source of communication and transport from the adjacent districts. The original river is now dead and has even lost its trace in some places, and even the remainder is now hardly navigable and is gradually deteriorating since the earthquake of 1897.

Innumerable tanks are found in the "Khlar Anchal" of the district and are believed to have served the purposes of irrigation. But most of them have now silted up and become beds of the water hyacinth. Owing to the clayey nature of the soil, "Khlar Anchal" needs irrigation facilities and re-excavation of these tanks would solve the problem and will also help the improvement of pisciculture.

As already stated, the rivers, excepting the Jamuna, are almost silted up and dead. The rise of water in the Jamuna inundates the "Pali Anchal" and the rivers, silted as they are, cannot discharge the water speedily thereby affecting the standing crops of those areas. The silting up of tanks in the "Khlar Anchal" has caused a serious set-back to irrigation which is indispensably necessary for those areas.

Water-hyacinth is a regular menace to the district. It is found abundantly in Gabtali police station and causes great harm to the crop. No effective measures have yet been taken for the control and destruction of this menace. The small rivers including Karotoa remain choked with it.

The productivity of land in both the areas is more or less constant. In the "Pali Anchal" though more than two crops are grown the fertility of soil has not deteriorated owing to its renovation by silt deposit every year. In "Khair Anchal" mostly one crop is grown.

Rangpur district is divided into two unequal halves by the river Tista which runs diagonally from the north-west to the south-east. Though all its areas are more or less plain, with a gentle slope to the south-east, the district of Rangpur is more pleasing to the eyes than many other districts of Bangladesh. Not being very far from the Himalayas, one is delighted to see in clear winter mornings some peaks of the great mountain ranges. Besides, its fertile soil nourishes a variety of crop which breaks the monotony characteristic of ordered paddy cultivation whilst its well-marked natural divisions afford a pleasant diversity of scenery. In the north-west, the landscape is open with long stretches of rolling sandy grass seamed with dried up river beds and interspersed with scattered homesteads and clumps of feathery bamboos. It is well above flood level. As the Tista is approached on the east, the level of the land falls and becomes a veritable maze of old river beds. Beyond the river and its stretches of sandy char, the character of the country changes once again. The soil becomes heavier, the land still lower and the old water courses are marked by a series of bils fringed with reeds and jungles. Towards the Brahmaputra, the lands again become more open and sandy, though not so elevated as in the north-west and much more closely cultivated. The central area round about Rangpur has a liberal scattering of untidy

jungly patches and unkempt fields surrounded by ails covered with thatching grass. Southwards, the central area lying between the sluggish course of the Nalea and the Ghaghat is heavily water logged and bears testimony to the local tradition that it marks the course of a once mighty river. On the extreme west the aspect changes once more. This is an area of old alluvium marked by stiff red soil and a profusion of big trees which here replace the preponderance of the bamboo. Boardering on Dinajpur there are still uncleared stretches of stunted "Sal" jungle where leopards abound. Further south, approaching Ghograghat, scrub jungle prevails. Throughout, the open areas are cultivated with paddy.

Rangpur proper is a reasonably good town with a college beautifully designed on the models of Moghal architecture. The imposing district Board Building is yet another of the same type.

The district is sharply divided into a tract of stiff reddish clay in the west which is a continuation of the "Barind" tract of Dinajpur and Rajshahi, and locally known as "Khairi". The new alluvium of the remainder of the district is known as "Pali".

The district has a few places of historical interest also. There is a running earthen embankment built in the form of a quadrilateral, about three quarters of a mile long from north to south and of an average breadth of half a mile in mouza char Dharmapal, in Jaldhaka police station. Tradition ascribes its construction to king Dharmapal, a monarch of the dynasty which preceded the Vaidya Kings of Bengal. It is said that for some years it formed his capital.

Another object of considerable archaeological importance is the long earthen rampart, locally known as "Bhimer Ghar" or "Bhimer Jangal". It is 30 to 40 feet high, about 80 feet broad at the base and is protected by a moat in the southern side. It stretches as far as Sadya-pushkarini, broken there for about a mile and then continues upto mouza Bhangain and after a break of another two miles continues from mauza Kutubpur to the river Ghagat. Various traditions are associated with this "Jangle".

The environment of the district is, on the whole, mild and equitable. The general health of the people is not bad. Once notorious for malaria, this disease is now more pronounced in the southwest part of the district only. Smallpox occurs in epidemic form along the navigable rivers.

The district is inhabited by Santals, Oraons and Mundas besides Hindus and Muslims. The Muslims predominate in the rural areas.

There are several railway lines, both main and branch, running through the district. Roads, though sandy and dusty, are quite numerous.

The Brahmaputra river dominates the eastern portion of the district and has entered the district at Kalaman Kular Char in Nageswari Police Station. It has been eroding strongly in Fulchhari and Sangata Police Stations making considerable accretions on the other bank of it in the Mymensingh district. On the other hand, it has its good effects as it promotes trade and industry by providing

facilities of communication, both by steamer and boats, and also increasing the fertility of the soil by silt deposits on the neighbouring lands.

The Tista river enters the district at Utter-Kharibari in Dimla Police Station and after passing through the boundary of Nilphamari, Rangpur, Kurigram and Gaibandha sub-divisions merges into the Brahmaputra and adds to its volume.

The Dharla river running parallel to the Tista in the north-east of the district is specially notorious for its destructive nature and is mainly responsible for the present ruinous state of the town of Kurigram. It enters the district near Moghalhat Railway station and passes through the north-eastern side of Kurigram town and finally merges into the river Brahmaputra near Bagua in Ulipur Police Station.

There are many dead and dying rivers in the district which at one time served the purpose of drainage but few of them now play any important role in the agricultural economy of the district. Instead they have adversely affected the general health of the people.

There are innumerable bils in the district but their sizes are not very large. Most of them are shallow and consequently considerable portions of these bils dry up in winter season and are brought under temporary cultivation. Some of them remain full of water hyacinth.

Tanks are very few in the district. Several important tanks have been noticed in Gobaindaganj, Sadullapur, Mithapukur and Pirganj Police Stations and these have been almost silted and dried up, as

they have not been re-excavated. If they are re-excavated, they may serve the purpose of irrigation and some of them may also be used for pisciculture.

The health and economic condition of the people on the whole is not bad. Those in the riparian areas of Kurigram and Gaibandha sub-divisions are comparatively better off.

The district of Dinajpur is known as the granaries of Bangladesh. The northern part of the district known as "Pali" area differs considerably from the southern part in certain features. It abounds in trees, jungles and clumps of Bamboos, the population being thin and unhealthy. The southern portion known as "Khair" is comparatively more open and is fairly densely populated.

The "Pali" area is the new alluvial soil and is light ash-coloured sandy loam with varying proportions of sand. It holds moisture and is consequently more fertile and suitable for double cropping.

"Khair" on the other hand is the result of an interesting geological formation called the "Barind" which belongs to the old alluvium. It is suitable for one crop, namely, winter paddy.

The district has a considerable population of Rajbanshis and Santals, the Santals being an interesting aboriginal tribe of sturdy jungle-dwellers able to stick where few others can.

A very high proportion of land in this district is cultivated by Bargadars, the ownership being concentrated in the hands of the more intelligent Jotedars, known as the "Dewaniyas".

The district suffers from shortage of labour, particularly in the north. Good many comes from other districts.

The general direction of the rivers of this district is from north to south. During the rains, the main rivers such as Nagar, Purnabhaba and Atrai are navigable by big country boats, but in the dry season they dry up, so far as they lie in this district and become fordable in many places. Most of these rivers have very considerably deteriorated and that is one reason why the health of Dinajpur district is far from satisfactory.

There are a number of bils in the district, prominent among those being (1) bils in Porsha, Police Station, (2) bil in Balurghat sub-division. They have not affected agricultural economy adversely, excepting that the lands covered by them have not been released for cultivation. There are plenty of big and small tanks mostly in the Balurghat and Sadar sub-division, some of them believed to be irrigation tanks. Of these, mention may be made of Mahipal, Ramsagar, Pramsagar. Most of them are getting silted up and can hardly serve any useful purpose. If properly renovated, they may be utilized both for irrigation as well as for pisciculture.

The normal rainfall averages 100 inches a year, being heavier in the north-eastern belt and comparatively less along the south-western. The ails of the fields are, therefore, kept rather high to conserve water and moisture.

Irrigation on a large scale is rare. During the dry season

in certain parts of the district, a system of irrigation by "Jat"¹ raising water from tanks and khals with the help of hollowed out trunk with a weight tied at one end so as to help pulling up the other end after being pressed into the water - is followed. The district being a predominantly rice growing area with a heavy surplus after meeting the requirements of its population, general economic condition on the whole may be called satisfactory. But this agricultural prosperity is confined only to a section of the people viz, the bigger Jotdars or Dewanias who form only a small proportion of the population. The bulk of the agricultural population who are adhiars or day labourers are generally very poor.

Major portion of Dacca district excepting the high and in the north generally known as "Tengar"² is extremely low-lying and goes under water during the rainy season from the middle of June to October. The entire sub-divisions of Munshiganj, Manikgank, southern portion of sadar and eastern portion of Narayanganj sub-division are low lying and are washed by three main rivers - the Padma, the Meghna and the Daleswari. The low-lying tract is subject to frequent changes in areas, owing to the changes in the course of the rivers. In the beds of these rivers big chars are formed almost annually.

The soil of the district may be broadly classified into two categories: (i) the red clayey soil - mostly found in the northern

¹ Jat is a device to lift water for irrigation.

² Tengar means dry lands.

division known as "Bhowal Parganas". This is not very fertile and is more suitable for the growth of Gajari trees and Jack-fruits, (ii) The soil of the southern, eastern and western divisions is almost homogeneous and consists of alluvial deposits. This is very fertile and is highly suitable for the growth of jute and paddy. The newly formed chars, being very sandy, cannot be brought under paddy and jute until made suitable by growing "Karcha" (a kind of grass used as fodder), sweet potatoes and water melons. Communication of the district is not unsatisfactory. All the district Head Quarters of Bangladesh are connected with Dacca by roads. Railway line from Narayangang to Kaoraid and Tongi to Daulatkandi both within the district form two valuable links. In addition, efficient steamer services are maintained on all the big rivers more or less throughout the year.

The Padma or Brahmaputra running from north to south-west of the district joins the Meghna at the south-east corner of the district, thus washing its entire western boundary. On the bank of these rivers lie Lohajang and Shivalaya, the two important gateways of commerce and trade of Munshiganj and Manikganj sub-divisions. The Meghna washes the entire eastern boundary of the district. Almost equally big in its lower reaches it is apt, off and on, to get pretty rough. But unlike the Padma its erosion is gradual. Besides coming down from Assam hills and valleys as it does, the river brings enormous deposits of decayed, vegetable matter which make its water most valuable. Important trade centres, e.g. Munshiganj, Mirkadim, Baidyerbazar and Narshin are on its banks.

Apart from providing good communication throughout the year, both these rivers make fine fisheries, specially for the famous Hilsa fish of Bangladesh. Hundreds of Boats with colourful sails keep on plying up and down rivers and add a picturesqueness which is unique.

The system of rivers in the middle of the district is of comparatively lesser importance and consists of the Dhaleswari, the Buriganga, the Lakhaya and the Banar. The Dhaleswari passes through Manikganj, Sadar and Munshiganj sub-divisions, while the Buriganga is a mere branch of the Dhaleswari which flows through the Sadar sub-division. Because of the silting up of both these rivers, most of the trade centres along their banks have greatly deteriorated. The Lakhaya with its feeder, the Banar, running north to south in the eastern part of the district forms the boundary between Narayanganj and Sadar sub-divisions. It is the only important source of communication for this part of the Dacca district. Narayanganj, the great Jute centre of Bangladesh is situated on this river. Rupganj, Kaliganj and Kapasia in the north are yet others on the same river.

Ichamati and Gazikhali in Manikganj sub-division, Old Brahmaputra and Haridra in Narayanganj sub-division and Balu, Turag and Bansi in the Sadar sub-division may be described as the dead rivers of the district. These having been dried up in most parts have greatly affected the drainage system and internal trade and communication of the district. They have now become, so to say, source of danger and disease.

An important feature of the district is that it is very densely populated and is definitely deficit in food. Nearly 80 per cent of the population are agriculturists and they are generally poor as the pressure of population on land in spite of its fertility is very high.

The major portion of the Mymensingh district is a flat plain of clayey soil deposited by the alluvial action of the Old Brahmaputra which in the past had its main current passing through the heart of the district. Although there are a few hillocks of the Garo Hills along the northern borders of the district-in the Jamalpur, Sadar and Netrokona sub-division - most of the villages are flat, the lands sloping down from the banks of Old Brahmaputra or its tributaries. Nearly the whole of Tangail district, Kishorganj and major portion of Jamalpur and Netrokona sub-divisions are liable to inundation annually and a large part of the country side remains under water for 2 to 3 months in the year.

The Madhupur jungle in the southwest is a tract of red laterite soil which covers portions of Phulbaria, Muktagacha and Valuka Police Station of Sadar sub-division, and Madhupur, Ghatal and parts of the eastern thanas of Tangail district. This type of soil continues up to the city of Dacca through Bhowal. This is a sort of tableland and the central portion consists of hillock of irregular shape sometimes rising to a height of 100 to 150 ft., intercepted by depressions known as "Baidas"¹. The tops of the hillocks are covered by Gajari trees,

¹ Baidas means depressed land.

the slopes by shrubs and bamboos and the "Baidis" are rich paddy fields.

The "Bhati"¹ area in the east-south-east is a very low lying country consisting of Haors (Bils) and covers the thanas of Itna, Kaliajur, Nikli, Astogram and portions of Kalma-Kanda and Bajitpur in the Kishorganj sub-division. The water flowing down the rivers from the Assam hills rises so early and recedes so late that nothing but Boro cultivation is possible in this tract.

The Old Brahmaputra runs through the heart of the district from the north-west to the south-east. It enters the district near Bahadurabad and flows through Jamalpur, Sadar and Kishoreganj sub-divisions and finally falls into Meghna near Bhairab. At one time it was the main course of the Brahmaputra with numerous distributary channels. The Bahadurabad-Dacca section of the Bangladesh Railway line runs parallel to its course by the south. The line has blocked and narrowed the natural field channels and the railway bridge near Mymensingh town is believed to have caused further obstruction to the free flow of water. The river has decayed and becomes fordable in many places during the dry season.

The Meghna with many of its branches flows by the east of the district. It has its origin in the Assam hills and gets supplies of water from the Garo-Hills too through the Bogai, Kangsa and the Sureswari rivers. These three hill streams carry very little water during summer. But they are very important during the rains when hundreds of maunds of paddy from Haluaghat, Durgapur and Jhanjail are exported by

¹ Bhati means rice producing area.

boat to other districts.

Boro paddy is sown generally along edges of the bils or marshes and irrigation is done by cutting small drains from the bils to the paddy fields by "Dons"¹.

Most of the lands in the districts are fertile and double crops are raised in considerable areas. The cultivators are industrious and adventurous and emigration to distant places for lands and occupation is not rare. General health of this district may, on the whole, be described as satisfactory.

Bakerganj is an alluvial deposit thrown by the rivers Padma, Brahmaputra and Meghna. Large deposits of pure sand are also found towards the sea-coast, where there is a belt of forest of irregular thickness.

The district comprises of two well defined parts. On the east there lies the island of Shabazpur, which is sufficiently raised from the sea level and contains only a few depressions in the interior. The main land on the west is, on the contrary, a low flat having "no single rise of even a few feet". It is intersected not only by large rivers but also by a good number of large and small khals. Except the homesteads, the entire portion of this main land block remains submerged under flood water for more than a quarter of the year.

The net land area of the district as recorded in the settlement report of 1905 was 3,490 sq. miles while according to the crop

¹ Don is a device for lifting water.

survey it now stands at 3,852 sq. miles. The process of land formation through continuous deposit of silt carried by rivers Meghna and Padma seems mainly responsible for this increase in the area.

There is no railway in Bakarganj and most parts of the district are served by steamers. Barisal is, therefore, an important steamer centre for lines to Dacca, Chandpur, Khulna, Patuakhali, Madaripur, etc. as also for some of the important places within the district e.g. Bhola, Khepupara, etc. Road mileage is lesser in comparison with other district. Communication in the interior is easier by boats and a net-work of steamers.

Situated on the Bay of Bengal, the district has been the playground of big rivers of the combined course of the Ganges (Padma), the Brahmaputra and the Meghna with their teams of tributaries. The khals of the district are so many as can hardly be counted. In the main land block in the west of the district marks of old river beds are also found. But the rivers and streams are so well spread that the death of a few rivers does not seem to be very material from the view point of agriculture and health.

Cyclone occurs rather frequently and causes great devastation to crops, fruit, trees, and human habitation. Frequent ingress of saline water damages and destroys crops in the southern part of the district. Dams constructed to prevent such ingress have not always been successful and have, on the other hand, been believed to increase malaria.

The occupation of the people is predominantly agriculture. The district is generally surplus in terms of food production and substantial quantities of paddy, chillies, as also betel nuts and cocoanuts are exported. The district is distinctly poor in industry.

Faridpur district comprises three well defined zones: (1) In the north there is a belt of land raised by the continual deposit of river silt until it has become high and dry. (2) In the south-east there is a fresh alluvium very well raised but intersected by a net work of streams which the Padma has left behind in its passage eastwards. (3) In the south-west the country is a vast marsh.

The greater part of the district appears as a series of flat cultivated plains. Villages are generally long straggling lines of homesteads surrounded by well-grown trees. Large plains are scarce in the south-east where the action of the Ganges keeps small water course still active.

The south-western part of the district appears like a desolate expanse of water during nine months of the year. The homesteads are generally grouped round a tank upon the mud of which they are raised. Even here in the heart of the bils houses are surrounded by green trees and contrary to appearance and expectation, the population is very dense.

Communication in the north is provided by Bangladesh Railway and a few trunk roads, in the south mostly by steamers and boats which can ply easily through the large navigable rivers and network of

streams. Internal communication is, however, poor specially in the south.

Ganges and its tributaries in the north and the combined course of the Brahmaputra and Ganges (Padma) in the north-east have all taken a hand in the building of the district. These rivers bring silts and in the east of the district the fertility of the land has been maintained. A certain amount of water coming down the Gorai and Madhumati also plays some part on the south-west boundary of the district. But the other rivers, namely, Chandana, Kumar, and Barasia are now for all practical purposes dead although during the rains they allow some navigation by country boats.

There is a series of bils which is often continuous and forms the extensive marsh. These bils remain under water for the major part of the year but jute and paddy grow in some of the bils before deep-water rushes in. These bils are now being used as fisheries.

Flood often causes damage to crops in the area lying within the river Kumar and Arial Khan in the south-east. There is no ingress of saline water in any part of the district.

The general economic and health condition of the district as a whole is far from satisfactory. Malaria, pox etc. and mal-nutrition are all equally common.

Chittagong is generally admitted to be the most picturesque, presenting variation in scenery from thickly wooded hills, as steep as any in the Himalayas, to flat alluvial plains. There are five

ranges of hills in the district, of which the following deserve special mention:

(a) The Ramgarh-Sitakunda Range - This range starts in the north from the Feni river and runs parallel to the sea ending in the hills on which the town of Chittagong stands.

(b) The Jaldi-Harbang Range - Starting south of the Sangu river and ending in the south in the Chakaria plain where the Matamohuri river forms its delta.

(c) The Cox's Bazar - Teknaf Range rising in the island of Maheshkhali and ending in the Naaf promontory, forms the southern extremity of the district. Other lesser ranges are the Rangunia-Patiya Range and the Kuntakhali-Gargania Range.

The soils are varied consisting of hard clay on the coastal side, locally known as "Mahina" and sandly loams and clay in the interior valleys which are very fertile and rich in organic matter. The coastal sides, though very fertile, are subject to deterioration due to the ingress of saline water at high tides. Due to the proximity of the sea, the climate of the district is on the whole pleasant, neither trying during summer nor severe during winter.

Internal communication of the district is rather unsatisfactory and is mostly carried out by country boat or by road. The railway line connecting the district with outside is the Bangladesh Railway which enters the district at Dhoom and continues up to Chittagong.

From Chittagong it has two branches, one proceeding to Dohazari in the south and the other to Nazirhat in the north.

Chittagong district extends over hundred miles along the sea coast part of which gets over flooded at high tides in the Bay, particularly during the rains. The ingress of saline water does considerable damage to the crops of about a hundred square miles in the Mirsarai Police Station in the vicinity of the Feni river. Barakunda and Kumira in Sitakunda Police Station and Kattuly in Double-Mooring Police Station are other areas so affected.

The economic condition of the people was on the whole satisfactory. Some contractors and businessmen are of course quite rich but their number is very small. Chittagong people have some tradition for sea-faring and the district provides the largest number of Mariners and Lashkars¹ in Bangladesh.

Comilla district is not so flat as others, its eastern side being rather high gradually slanting towards the west to the bank of the Meghna which forms its north-western boundary. The northern portion of the Brahmanbaria sub-division and also a part of the eastern side comprising Datta-Khola, Mushaura and Fultali, a part of Muradnagar (Dalpa), a portion of Matlabganj (Ruhiter Jala) and Kaduar Jala in Kachua constitute more or less bil areas. In these areas water gets in earlier and stays longer. This effects to growth of plants and the average yield of crops is less than that in other parts of

¹ Lashkars are sub-ordinate staff of ships.

the district. The crops of these areas are damaged by water-hyacinth also.

The northern portion of Brahmanbaria is along the bank of the Meghna river to the south-west border of the district. The soil of this area is very fertile on account of regular silt-deposit. Highland extends from the base of the Mainamati and Lalmai Hills in the east to a considerable distance towards the centre of the district. The soil in this area is alluvial in nature.

The Mainamati and Lalmai Hillocks are quite high. Such high areas are also found in some parts of Kasba and Burichang. The soil of these areas is dry and sandy. These hilly areas are not well suited for food production. Only thatching grass grow here in abundance.

The Meghna, the Titas, the Dakatia, the Gumti and the Dhonagoda are the most important rivers of Comilla district. The Meghna running all along the north-western boundary of the district joins the Padma at the south-western tip, whereafter the two wash a portion of the western end of the district jointly. The fertility of the western portion of the district is largely due to the play of these rivers.

Of the rest, the Gumti needs special mention. It rises from the Trippera Hills and flowing westward falls into the Meghna. It is rather narrow and cannot efficiently discharge the rain water coming from the hills and consequently inundates the villages situated near about this bank, damaging or destroying the crop very frequently.

Some areas in the southern part of Chandpur and Faridganj Police Station are liable to ingress of saline water from the Meghna which does some damage to the crops.

The hills in the north-east of Noakhali district are composed of a hard red clay which also contains fine sand of the same colour and nodules containing a large percentage of iron. The soil immediately below the hills is a fine yellow clay which becomes very hard in the dry season. Passing through Feni thanas towards the west and south, the soil gradually changes becoming less fine clay with more sand in it, gray instead of a yellow colour, until it approximates to the soil usually found in the other districts of the delta.

Communication in the district is satisfactory. There is a network of roads running throughout the district, and, besides, the Bangladesh Railway runs through the district both in the middle as well as in the east on way to Chittagong.

Unlike other deltaic districts, the main land of Noakhali is not intersected by any important rivers. The little Feni river in the east is not too big and has been bridged by a 200 feet iron bridge built by the district board. The big river Meghna on the west and south-west alone, therefore, supplies the life blood. Off and on it washes away large tracts in the south-west making people landless and homeless. As a result of this people of the riverside areas have to overcrowd Sudharam, Senbag, Companyganj, Begamganj, Lakshimpur, Hatia, Sandwip and Ramgati.

The Dakatia river that flows through Raipur and Lakshimpur has been silted up at its southern extremity and has adversely affected general health as also the trade of Raipur Bazar which previously used to be an important centre. The Malari, Suilonia and Kahua passing through Chhagalnaya and Parashuram thanas have also been silted up to some extent.

The economy of the Sylhet district is primarily agricultural. The Surma and Kushiya rivers traverse through this district. Northern, Eastern and Southern sides of the district is hilly. The Khowai, Manu, Jadukata and Piyan are some important rivers of the district. Besides there are innumerable low depressions in the district. During winter months Boro paddy is cultivated in these low depressions. But in most of the years this paddy is subjected to flood damage due to early monsoon.

There are numerous tea gardens in the area. There are some orange gardens though the quality is not very good.

Fishing industries provide a much need and valuable dietary supplement. There is a cement factory at Chattak. Sand and gravels are mined in the vicinity of Sylhet. Forest products are cut each year and shipped down the river. Country boats ply in most of the rivers throughout the year.

Communication in the district is satisfactory due to the availability of road building materials. There is a good number of roads in the district. Besides, one road connects Sylhet with

Shillong of Assam, India. Bangladesh Railway also connects Sylhet with Dacca and Chittagong.

The economic condition of the people is on the whole satisfactory. Some of the people of Sylhet have migrated to England and other parts of the world. They remit huge amount of foreign currency.

The soil of Chittagong Hill Tract is hard clay with a mixture of fine sand containing a large percentage of iron. On the whole, the soil is poor and the cultivator has to struggle hard to extract a living from it.

The economy of Chittagong Hill Tract is essentially agricultural. Rangamati is the district Head Quarter. It is connected by road with Chittagong city. The Karnafuli, Sangu and Matamuhuri are the important rivers of the district. The Kaptai Hydro-electric plant with an installed capacity of 80,000 KW is located on the Karnafuli River about 32 miles from Chittagong. Preparation for installing a third 50,000 KW unit is in progress. The 132 KV Transmission line from Kaptai to Madhnaghat has been installed. From that point one branch goes to Chittagong and the main line turns north and goes to Dacca.

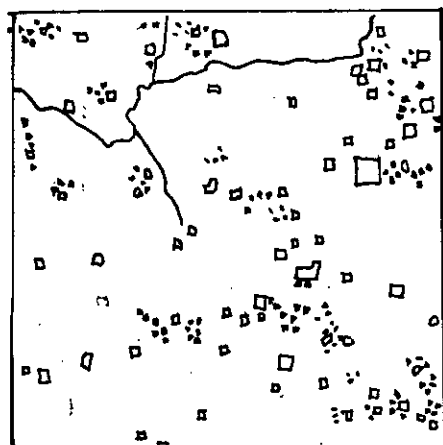
Kaptai is connected with Chittagong by a good hard surfaced road. There are two all weather roads going south one upto Cox's Bazar and the other upto Taknaf.

There is considerable traffic on the Karnafuli river by

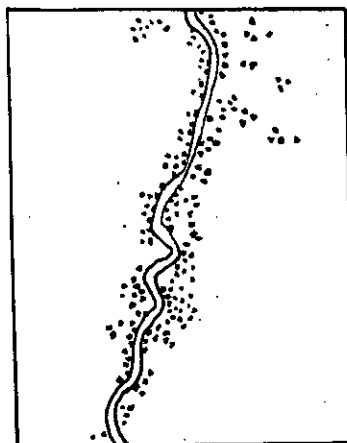
country boats. The Sangu and Matamuhuri become furious during monsoon causing flood and river erosion on both banks of the rivers.

Pattern of Human Settlement

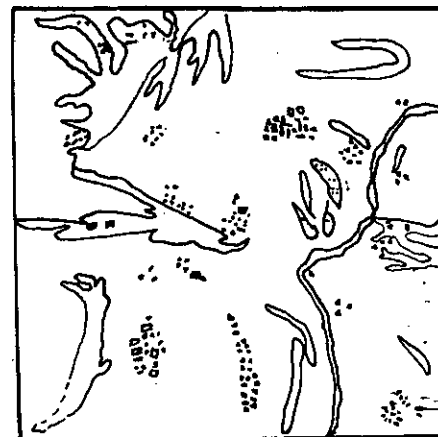
The flooding of almost all fields in the rainy season forces the settlement in Bangladesh to be in the higher ground or to rise the land artificially for the homesteads. In the low basins, river flood plains and most of the Delta the levees (existing and abandoned) form most of the "high" ground available. Linear settlements on levees and swales are very common (MAP-10). It is the dominant type in the Immature Delta, the lower parts of the mature and active Deltas, the Mahananda, Tista, Jamuna, Ganges and Meghna flood-plains, the Bhar Basin and Haor Basin. Linear settlements are also found along the base of the hills of south Sylhet and the Chittagong Region because of the spring line, where water is available closed to the surface; where small streams form from springs along the Jaldi and Sitakunda Ranges, there are linear settlements of upto five miles length. In areas with considerable middle and high level fields many of the homesteads are scattered. The linear tendency is still there, but there are single or clusters of homesteads away from them. About half the homesteads form ill defined linear patterns, a third form clusters and the rest stand apart singly. This settlement pattern (scattered) is common in the Mature and Active Deltas, the old Brahmaputra flood plains, the piedmont plains, east and south Sylhet, the Trippura surface and parts of the Chittagong Region lowlands. In the Trippura surface it



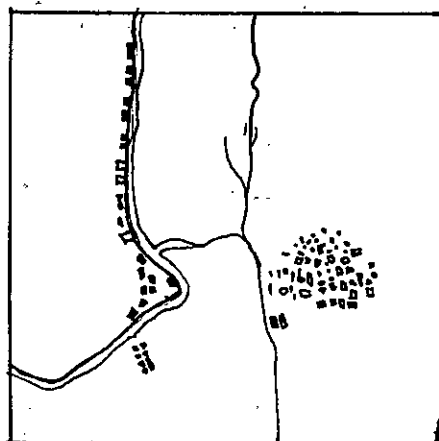
SCATTERED & SEMI-NUCLEATED



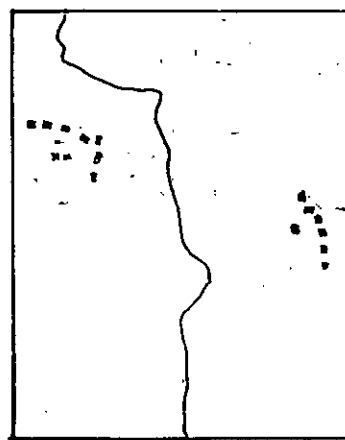
LINEAR



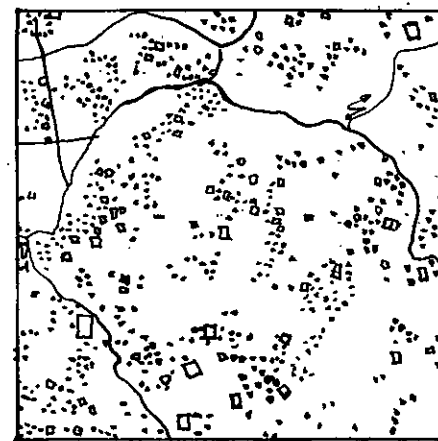
SEMI-NUCLEATED



NUCLEATED & LINEAR



NUCLEATED



SCATTERED

SOURCE :

Harun Er Rashid; East Pakistan—A Systematic Regional Geography and its Development Planning Aspects (Karachi: Sh. Ghulam Ali & Sons, 1967), P. 380.

MAP 10. SETTLEMENT PATTERNS

reaches its highest development, where the country side is thickly dotted with small clusters of homesteads. Pressure of population has forced scattered homesteads even in low areas such as the Padma-Dhaleswari Doab, the Bhar Basin and Haor Basin. In these places, the homesteads are built upon ten to fifteen feet high artificial mounds and when the water level rises they are in effect small islands. In the Moribund Delta the tendency towards nucleation is strong. The settlement pattern can still be called scattered, but here the clusters of homesteads are common and often big. The isolated homesteads is uncommon streams naturally force much of the settlement to be linear. In the west central Barind and the Madhupur Tract the tendency to scattering is strong, because of the juxtaposition of uncultivated hillocks and strips of cultivated fields. In the eastern part of the Barind the semi-nucleated patterns of big clusters of homesteads is common.

The fully nucleated settlement pattern is found in Haor Basin and the Hill Tracts district. The Jhumia Moghs, Chaks, and Tipras live mostly near the stream, where the Mrus, some of the Tipras, Kumis, Lushais and other small tribes line on the highest ridges. The settlement pattern of both groups is nucleated. The former group has much larger villages than the latter. There is often no definite pattern.¹

¹ Harouner Rashid, "East Pakistan - A Systematic Regional Geography and its Development Planning Aspects" Lahore (Shah Gholam Ali & Sons 1967, P. 383)

Population distribution

The distribution of population in Bangladesh is primarily guided by physiography and soil. The lowest density just above 100 persons per square mile, occurs in the rugged areas of the Chittagong Hill Tracts and the mangrove swamps of the Sunderbans (MAP-23). The marshy areas (haors) of the Sylhet district and the lands newly reclaimed from the mangrove swamps in the Khulna, Patuakhali and Bakerganj districts are monocultural and support a comparatively small population. The Barind and the Madhupur Tract, the two major Pleistocene terraces of Bangladesh, are covered with comparatively infertile soils and carry low population densities. The parts of Kushtia, Jessore and Dinajpur districts which are not annually inundated and hence are not regularly enriched with fertile alluvium also fall into the low density category. The lands along the major rivers, the Padma, Meghna and Brahmaputra which are annually flooded carry the heaviest density of the population. The density near the confluence of the Padma and the Meghna rises to over 2000 persons per square mile¹.

¹ F. Karim Khan, 'An Introduction to Economic Geography, Dacca: Green Book House Limited, Dacca, 1971, P. 693.

TABLE I

DISTRICT-WISE ESTIMATED POPULATION OF 1972

Sl. No.	District	Population	Density per square mile
1.	Chittagong	43,81,328	1,520
2.	Chittagong Hill Tracts	5,67,780	112
3.	Comilla	64,46,426	2,485
4.	Noakhali	35,00,360	1,886
5.	Sylhet	50,72,638	1,059
6.	Dacca	75,77,434	2,629
7.	Faridpur	46,69,238	1,733
8.	Mymensingh	81,25,868	1,606
9.	Tangail	21,83,500	1,678
10.	Barisal	45,06,457	1,656
11.	Jessore	32,16,894	1,263
12.	Khulna	35,96,682	772
13.	Kushtia	17,13,019	1,250
14.	Patuakhali	17,53,228	1,183
15.	Bogra	23,12,044	1,540
16.	Dinajpur	25,11,497	963
17.	Pabna	28,77,371	1,523
18.	Rajshahi	41,28,746	1,130
19.	Rangpur	55,75,778	1,506
Total :		747,16,288	

¹ 1961 Population is multiplied by 1.363 to obtain the population of 1972 as 747,16,288 with a density per square mile of 1352.

Rural development Programme

Problems of water development in Bangladesh are typical of those found in countries with monsoon climates: there is either too much water or too little. In the monsoon season (June-September) the great rivers rise above their banks and large quantities of water flow over the country side; during the relatively long dry season (November-May) many of these rivers do not carry enough water to permit even local inland navigation.

The extremes in discharge indicate that the flow of the Brahmaputra, Jamuna, Padma and the Meghna may differ between seasons by a multiple of ten. This variation has led hydrologists to distinguish between and to treat separately, problems of irrigation and navigation during the winter or "low-flow" months, and of flood control during the summer or "high-flow" months.

There is a large untapped agricultural potential in Bangladesh. Present cropping intensities on some 20 million cultivated acres are substantially below those which climate and water potential would permit and yields are only one fourth of those found in many other countries.

Water is needed between the months of November and May for agricultural and industrial consumption and for maintaining river flows to allow sufficient inland navigation, to avoid damage to fisheries and to prevent penetration of sea water inland. To some extent these are conflicting demands and optimal division of scarce winter water

among them is the crux of the planning task associated with the "low-flow" problem.

In many areas of Bangladesh, supplementary surface water for winter irrigation may not be available. In such cases, increases in in cropping intensity will be dependent largely on additional water supplies through ground water development.

So far, the approach to ground water development has been highly pragmatic. Little or nothing is known about potential recharge, soil permeability and other hydrological parameters needed for a full assessment of the aquifer potential. Substantial study and exploration will be required before reliable estimates of ground water availability can be made.

In spite of substantial difficulties, considerable progress was made in the water development of Bangladesh, both in planning and in actual project implementation. Of major significance for overall planning was the preparation of a "Master Plan" for Water and Power development. Although only a preliminary document, the Master Plan outlines a large number of irrigation and flood control project. Additional material and recommendations relevant for project planning have also been prepared by the Bangladesh Water Development Board (BWDB), World Bank and other consultants.

So far, a few major water development projects have been completed. Chief among these were the Karnafuli Multipurpose Project, Comprehensive Drainage Scheme for Faridpur District, Re-excavation of

Ghungur, Salda and Buri Nadi, Prevention of Flood in Feni Sub-Division in Noakhali District, Improvement of Gazaria Ichamati River in Bogra District, Ganges-Kobadak Project, Kushtia Unit-Phase-I, Tista Sub-Project, Ground Water Development and Pump Irrigation Project in the (Northern districts of Bangladesh), Coastal Embankment Project, Phase-I Improvement of Old Dakatia and Little Feni Rivers, Dredging the River Gumti in Comilla District, Dacca-Narayanganj-Demra Irrigation Project, Brahmaputra Right Flood Embankment Project, Small Irrigation Schemes (BWDB), Small Irrigation Scheme (Deptt. of Agriculture) and Comilla Tube-wells.

Karnafuli Multipurpose Project

One of the biggest projects of Bangladesh in respect of water resource development is the Karnafuli Multipurpose Project. Its primary purpose was the generation of electricity for the power hungry industries of Bangladesh. The availability of 80,000 Kilowatts of electricity generated by the turbulent waters of the Karnafuli river in fact meant a tremendous saving in foreign exchange for Bangladesh, where fossil fuels have to be almost entirely imported.

Built at a cost of nearly Taka 490 million - out of which Taka 350 million were contributed by the United States, over half of it in dollars, the project was inaugurated in early 1962, with two of its three planned generators pushing 80,000 Kilowatts of electricity into the country's, power grid. A third generator of 50,000 Kilowatts will soon be installed.

In addition to power generation, the Karnafuli Multipurpose Project also provides flood protection and irrigation facilities to the villages lying downstream along a 40 miles stretch of the Karnafuli river from the dam site at Kaptai to the Bay of Bengal. In the severe flood of 1962, the year the project was commissioned, it was credited with preventing major flood damage to the Chittagong area.

Comprehensive Drainage Scheme For Faridpur District

This scheme has been completed at a cost of Taka 41.10 million and would benefit an areas of 3,75,000 acres in Faridpur district.

Re-excavation Of Ghungur, Salda And Buri Nadi

The object of the scheme was to remove the drainage congestion and recurring flood of an area of about 72 square miles traversed by the three rivers namely Ghungur, Salda and Buri Nadi in the district of Comilla. The scheme was completed by re-excavating the rivers for a length of 42 miles. Agricultural production has gone up in the project area after completion of the project.

Prevention Of Flood In Feni Sub-Division In Noakhali District

The scheme aimed at easing of drainage congestion over an area of 22,000 acres which would mitigate the miseries of the people due to frequent floods. The following works were involved in the scheme.

- (a) Excavation of a side channel from Muhuri river to Kahua river and re-excavation of Kahua river.

(b) Excavation of a side channel from river Muhuri to join the Chataliachara.

(c) Strengthening the loops of the Selonia river.

(d) Diversion of the Selonia river along Pahalia Khal.

(e) Remodeling of Road and Railway bridges.

After completion of the project, the yield of crops has gone up in the area.

Improvement Of Gazaria Ichamati River In Bogra District

It was a drainage scheme to minimise the drainage congestion from an area of 15,000 acres.

Ganges-Kobadak Project, Kushtia Unit, Phase-I

This is primarily an irrigation project although flood protection is provided by the canal embankments. Drainage is provided by improvement of natural channels.

The water for irrigation is lifted from the Ganges. Two pumping plants subsidiary and main have capacities of 1500 cusecs and 3900 cusecs respectively. After full development of the project, it will irrigate an area of 1,20,000 acres. People of the project area has shown great interest in irrigated agriculture. They are also changing their cropping pattern from local varieties to the high yielding IRRI varieties. This will increase the demand for more water. So Bangladesh Water Development Board is contemplating to install deep Tube-wells in the project area to meet the extra demand of water of the farmers.

Tista Sub-Project

This project was completed during 1967-68 with a view to boost up food production by bringing under cultivation an area of about 33,000 acres of land in the district of Rangpur by constructing a diversion dam over Buri-Tista river with a canal system and related structures.

Ground Water Development And Pump Irrigation Project In The Northern District Of Bangladesh

With the completion of the project, an area of about 1,86,000 acres has been provided with irrigation facilities by installing:

- (a) 362 tube-wells with power and transmission line facilities.
- (b) 689 diesel-engine driven low-lift pump in 95 stations, and
- (c) 60 electrically driven low-lift pumps.

The northern districts of Dinajpur, Rangpur, Bogra and Rajshahi will benefit from this project.

Coastal Embankment Project - Phase-I

This project is one of the most important ventures in Bangladesh in the field of water resources development. It aims at saving 2.50 million acres of land from tidal inundation. The tidal inundation destroys ground crops and makes the land unfit for cultivation unless the salts are leached. Heavy flooding during the monsoon rains also damages standing crops. The Coastal Embankment Project - Phase-I is saving the areas in parts of Khulna, Barisal, Patuakhali,

Noakhali and Chittagong districts from such damage and is adding to agricultural production. Salinity studies have been conducted and are being continued to determine what additional areas require protection from salinity intrusion. The project envisaged to build 2,600 miles of embankment.

Improvement Of Old Dakatia And Little Feni Rivers

The scheme involved solving the problem of drainage congestion of an area of 1,24,000 acres. This will bring benefit to the paddy growing lands in the Noakhali and Comilla districts.

Dredging The River Gumti In Comilla District

This drainage scheme which benefits Comilla district has been completed at a cost of Taka 11.90 million.

Dacca-Narayanganj-Demra Irrigation Project

This project has provided irrigation facilities to 14,732 acres and flood protection for an area of 14,500 acres at a cost of Taka 23.15 million.

Brahmaputra Right Flood Embankment

The project is located between Kaunia and Serajganj along the right bank of Tista and Brahmaputra rivers. Flood protection features include a continuous embankment, 135 miles in length, along the right bank of the Tista and Brahmaputra-Jamuna rivers from Kaunia to the Harasagar river. Structures consisted of three large drainage regulators and 22 irrigation sluices through the embankment.

Transportation and communication in the area have been improved by utilization of embankment as a road. Drainage sluices and inlet structures for the control of flood water are placed at suitable location in the embankments. Natural channels for drainage and irrigation are provided by the Karotoya, Sarai and Manas rivers. The project was executed at an expenditure of Taka 78.95 million.

Small Schemes

A large number of small schemes were executed by BWDB and Directorate of Agriculture to reduce the intensity of flood and drainage congestion of local nature. They also include some small irrigation schemes.

Comilla Tube-wells

This project is located in an area, a major part of which is normally flooded every year. The project was executed by the Bangladesh Academy for Rural Development (BARD), Comilla. The BARD has demonstrated its capability in organizing rural co-operatives and in installing tube-wells in the Comilla Kotwali Thana during 1963-64 and 1964-65 and in 7 other thanas of the Comilla district. 40 tube-wells had been installed in 8 thanas of the Comilla district at an average cost of about Taka 20,000 each.

Other Water Development Programme

Besides the above schemes, BADC has completed installing large number of Low Lift Pumps, Shallow Tube-wells and Deep Tube-wells

throughout Bangladesh. Moreover Irrigation Directorate has executed a few small water control works in Bangladesh.

Flood Problem

Floods constitute one of the most critical problem facing Bangladesh. Each year major rivers flood close to a third of the country. With the increase in population and a greater demand for high agricultural productivity, there is an increasing need for controlling floods.

Role Of Water As A Devastating Agent

Most of the flood problems in Bangladesh result from large flows in the major streams such as the Brahmaputra, Ganges and Meghna rivers. However, flooding by smaller streams, local rainfall, the high ocean tides and cyclones also are of major importance.

Major streams

The livelihood of the people of Bangladesh is dominated by the three great river system the Brahmaputra-Jamuna, Ganges-Padma and Meghna rivers which flow into the Bay of Bengal. Over the centuries, these three rivers have built the largest and one of the most fertile deltas in the World. Ranging generally from sea level to 100 feet in elevation, this delta covers most of Bangladesh.

These rivers have a total drainage area of 600,000 square miles, with only 7.5% lying within Bangladesh. During peak flow these rivers discharge upto 5 million cusecs (2.5 times the all-time record

of Mississippi river) and carry an enormous sediment load of about 2.4 million tons annually, greater than any other river system in the World. The combined rivers flowing into the Bay of Bengal are exceeded in size possibly only by the Amazon river in South America and the Congo river in Africa.

The result of the Ganges and Brahmaputra rivers is derived from snowmelt of the Himalayas and monsoon rains from the lower elevations. The snowmelt flood peak on the Brahmaputra occurs in June and can be the highest peak flow of the year. However, the peak annual flood generally is due to runoff from the monsoon rains combined with snowmelt. High flows can be expected any time between about June 1 on through October although they are more likely to occur during July, August, and the early part of September. Even during this period in any year the river level might fluctuate up to about 10 feet. The flow of the Ganges generally reaches high stages near the end of July and remains high through August and September. In some years, the stage declines rapidly during September.

By mid July, the flow of the Padma at Goalundo downstream from the junction of the Ganges and Brahmaputra rivers reaches bankful stage which are maintained until the end of September. This is a period when both the Ganges and Brahmaputra rivers are at high stage. The yearly peak flow stage, which generally occurs between late July and early September, fluctuates within a range of about 4 feet-in other words the highest peak stage is about 4 feet higher than the

lower peak stage. However, during the high flood period (for many particular date) the high flow stage could be about 7 feet higher in one year than the corresponding flow in another. These fluctuations in stages are an important consideration in connection with the area, depth and time of flooding and on resulting effect upon crop production and other economic generation. Fluctuations in the flow of the Meghna river at Bhairab Bazar appear to be about the same as the Padma at Goalundo although the flow is only about one-tenth as large.

Table 2 compares the peak levels recorded at Hardinge Bridge, Bahadurabad and Goalundo for the periods 1954 to 1956 and 1962 to 1970, and gives the flooded areas for the corresponding years.

According to Table 2, in terms of flooded areas, the most severe floods have been in 1954, 1955 and 1962 which is in accordance with the water level recorded at Goalundo and Bhadurabad.

The Goalundo peak flood occurs generally between the end of July and the beginning of September, except it once occurred on the 21st of September. The same regularity is observed for the Ganges river - peak flood between August 19 and September 21. The Brahmaputra river however is much more irregular. There has been one flood in June, six in July, five in August, one in October. As pointed out previously, these facts may have a great effect on crop damages.

TABLE - 2

FLOOD CHARACTERISTICS

Year	Ganges-Hardinge Bridge		Brahmaputra-Bahadurabad		Padma-Goalundo		Flood area in square miles.
	Peak above or below danger level 44.5	Date	Peak above or below danger level 63.0	Date	Peak above or below danger level 27.0	Date	
	PWD (feet)		PWD (feet)		PWD (feet)		
1954	4.40	30-31/8	2.50	31/7	5.30	4/8	14.200
1955	4.20	19/8	2.90	1/8	4.00	19/8	15.000
1956	3.30	21/9	2.20	24/6	1.00	21/9	13.700
1962	3.00	28/8	2.60	23/8	3.00	28-29/8-1/9	14.400
1963	2.70	9-11/9	0.40	16/7	2.10	4-5/9	13.600
1964	2.70	11/9	1.40	4-5/8	2.80	8/8	12.000
1965	0.50	16/9	1.00	15-16/8	1.40	17-18/8	11.000
1966	2.30	31/8-1/9	1.20	26/8	2.40	2-3/9	12.900
1967	2.90	16-17/9	0.40	13/7	0.60	24-25/7	9.900
1968	1.50	29/8	1.30	7/10	2.10	31/7-1/8	14.400 (Two floods)
1969	3.60	28/8	1.60	23/7	1.90	30/8	Not available.
1970	1.20	23/9	2.20	28/7	2.40	31/7-1/8	Not available

* 19.500 in 1968 annual report page-5.

Source: WAPDA, "Annual Reports on Flood in East Pakistan" Hydrology Directorate,
Dacca, 1954 to 1970.

Smaller Streams

Many smaller streams throughout Bangladesh cause severe flood problems. Examples are: the Tista, Atrai, and Karatoya tributary to the Brahmaputra river; the Kushiya, Surma, Manu, Khowai, Lakhya and Gumti rivers, tributary to the Meghna river; the Mahananda river tributary to the Ganges river and the Little Feni, Muhuri, Karnafuli, Sangu and Matamuhuri rivers directly flowing to the Bay of Bengal. Runoff from these streams is directly related to the monsoon rains. Accordingly the flows and stages fluctuate greatly over short periods of time during the monsoon season. These flash floods can occur any time from June through September.

Rainfall

Mean annual rainfall in Bangladesh varies from 60 inches in the west to 200 inches in the northeast, with most of the country recording 70 to 100 inches. About 80% of the rainfall occurs during the 5-months monsoon season, May through September, and about 5% during the 5-months period, November through March. During the monsoon period extreme rainfall often occurs but there are large variation from year to year as indicated in the following tabulation of monthly rainfall during the period 1934-69.

TABLE 3

MONTHLY RAINFALL

	Dacca in inches	Comilla in inches	Chittagong in inches
June			
Minimum	0	8.72	8.24
Mean	13.54	19.44	21.07
Maximum	30.28	41.30	37.76
July			
Minimum	4.57	5.13	7.28
Mean	12.90	17.54	23.54
Maximum	26.50	41.22	52.66
August			
Minimum	4.09	5.34	0.11
Mean	13.33	14.59	22.93
Maximum	27.75	27.25	42.78
September			
Minimum	3.28	2.99	3.33
Mean	8.82	10.40	12.22
Maximum	28.12	29.12	29.88
October			
Minimum	0.03	1.06	1.77
Mean	4.57	7.89	8.81
Maximum	16.70	25.29	22.79

Cyclonic Storms

Cyclonic storms are an important features of Bangladesh's climate and have caused great suffering and damage to the people and the structures in the cyclone path. The storms usually form in the south-east portion of the Bay of Bengal, move in a northerly or north-westerly direction and often turn north-easterly or easterly toward the east coast of Bangladesh. There are some data of unknown reliability on the occurrence of cyclone in Bangladesh that date from 1970, and definitely incomplete information that dates as far back as 1584.¹ Severe cyclonic storms are defined as circulating winds with surface velocities about 54 miles per hour. Approximately 34 damaging cyclones have been reported in the Bangladesh coastal area in the 100-year period from 1868 through 1967. Thus cyclone frequency during this time have averaged about once in every three years. However, there have been seven severe cyclones recorded in the period 1960 through 1967.²

Storm winds move at speeds upto 150 miles per hour and cause wide spread damage. However the most devastating element of the cyclonic storm is the water surge.

¹ Institute of Engineers, "Report of Institute of Engineers Subcommittee on Cyclone Disaster in East Pakistan", Dacca, March 25, 1962, p. 29.

² International Bank for Reconstruction and Development, "Land and Water Resources Sector Study - Bangladesh, Vol. VIII. The Flood Problem" Technical Report No. 24, International Development Association, May 15, 1972, p. 5.

Historical data on surge heights vary considerably. Inundation caused by the 31 October 1876 "Bakerganj Cyclone", has been variously reported at 10 to 45 feet above normal tide level. Storm surges for recent cyclones have been noted to be some 10 to 20 feet in height. Theoretical analysis of surge heights were made by World Bank using data on actual cyclones and considering the shape and configuration of the Bay of Bengal and Bangladesh coastline. It was determined that cyclone storm surges of 15 to 25 feet can be expected. Waves approaching the shore tend to expend their energy by running up a slope beach and thereby causing inundation to heights even greater than the true height of the offshore storm surge. Cyclonic storm surges could thus inundate lands, or overtop embankments, upto elevation of 30 to 55 feet, should the surge occur at the time of high tide.

Reports of property damage and loss of life caused by recent cyclones have been greater than those of earlier cyclones. This is probably the result of increases in population density as well as the availability of more complete report on damage. The time of occurrence of a cyclone as related to the stage of planting or growth of rice influences markedly the amount of crop damage. Cyclone damage in the coastal areas of Bangladesh during the period 1960 through 1966 has been estimated to be over Taka 700 million to property and more than 50,000 lives have been reported lost. The November 1970 cyclone took several hundred thousand lives and caused an estimated Taka 8,400

million of damage.¹

Flood Damage

The "Flood Control Plan" prepared in September 1968 by the Planning Department, presented the following estimated average annual flood damages.

	Million Taka
Damage to crops	1,200
Damage to cities and towns	2,000
Damage to roads and canals	1,300
Indirect losses	1,000
Total Taka	4,500

These are direct damages and do not take into consideration the losses which occur because of crops not planted due to the regular occurrence of deep flooding or the threat of occurrence of such flooding. The above figures are not supported by any document and seems to be exaggerated.

The direct agricultural damage recorded is with respect to the Aus crop and the jute crop (due to early in June-July), and the Aman crop (July to September floods). The full growth (a height of 2.5 feet) of Aus is reached in May and June. If the depth of flood water is higher, damages appear after two or three days of submergence

¹International Bank for Reconstruction and Development, "Land and Water Resources Sector Study - Bangladesh, Vol. VIII, The Flood Problem" Op. Cit., P.5.

and increase rapidly thereafter. Submergence in still water for five days causes a crop loss of 40 to 50%. However, since the crop is almost ripe in July, flooding causes little damage.

Indirect agricultural damage generally is not recorded. For instance, there may be lower yields induced by the delay in transplanting the Aman crop, or due to the impossibility of growing transplanted Aman, when the flood recedes after mid-September (Transplanted Aman may than be replaced by Rabi crops).

Apart from agricultural damage, other damages recorded are mainly to dwelling houses. The principal towns which have flood problem are: Dacca, Chandpur, Faridpur, Madaripur, Gopalganj, Tangail, Dinajpur, Bhairab Bazar, Serajganj, Habiganj and Sunamganj. But, the urban population is rather low (5.00 million inhabitants out of a total population estimated at 75 million) and damages to dwelling houses occur mostly to farms in small villages. Damages also are recorded for roads and bridges and other facilities. However, the agricultural damage far outweighs the damage to dwellings, roads etc.

Table ⁴ gives the total recorded losses with the corrections made. Because of the inaccuracy of the data collecting process, this task can give only rough estimates. Direct annual recorded losses would be between 600 and 700 million rupees. Crop losses would represent roughly 85% of this total. As shown in Table 4 the maximum recorded rice crop losses (1,105,571 tons in 1968 cleaned rice) represent one-tenth of the total rice crop production for the same

year, and the recorded losses from 1962 to 1970 on an average 4.5% of the annual production.

TABLE 4
YEARLY FLOOD DAMAGE

(In million Taka)

Year	Losses to crops and properties (without shadow pricing)	Added cost for crop losses (with shadow prices)	Total
1962	1020	78	1098
1963	83	48	131
1964	243	47	293
1965	45	21	66
1966	544	67	611
1967	90	39	129
1968	1645	44	1689
1969	330	95	425
1970	1380	-	1380
Total	5383	439	5822
Annual Average	600	55	655

Resource: IBID/IDA "Land and Water Resources Sector Study - Bangladesh, Vol. VIII. The Flood Problem" Technical Report No.24, May 15, 1972, Table 4.

TABLE - 5
COMPARISON OF RICE CROP LOSSES

Year	Estimated rice crop losses (Cleaned rice - Tons)
1954	443,000
1955	474,000
1956	800,000
1962	754,000
1963	83,500
1964	181,000
1965	34,647
1966	459,400
1967	83,255
1968	1,105,571
1969	217,360
1970	1,190,000

Source: IBID/IDA, "Land and Water Resources Sector Study - Bangladesh, Vol. VIII, The Flood Problem" Technical Report No. 24, Table 5.

For damages to houses, the total results given at the country level are not homogeneous from one year to another. The annual average value of losses for damaged houses is proof of this fact.

Year	Number of Damaged Houses	Total Value of Damages	Annual Average Value of Houses per Damaged House ¹ (Taka)
1962	197,333	39,466,550	200
1964	222,729	26,545,724	110
1966	69,659	13,931,925	200
1968(June-July).			
	412,924	313,681,750	760
October	115,915	14,441,950	125
1969	131,221	16,473,513	125

Relation Between Damages And Flood Characteristics

Comparing the annual damages stated (see Table 4 and 5) to the flood characteristics gives useful ideas about the type of flood frequency analysis that may be done. The flood characteristics which have the main influence on flood damages are:

The Depth Of Flooding

This may be represented by the peak levels at certain key station, mainly Bhadurabad. One can see from Table 5 that, of the most severe floods according to the extent of damages (1954, 1955, 1956, 1962, 1966, 1968 and 1970), five correspond to the highest recorded peak levels at Bhadurabad (1954, 1955, 1956, 1962 and 1970). The 1966 flood was certainly far less severe than the 1954, 1955 and 1956 floods because it was mainly localized in the Mymensingh and Sylhet districts. The damage data stated, however, is not comparable since more data has been recorded within the last few years.

¹International Bank for Reconstruction and Development, "Land & Water Resources Section Study - Bangladesh, Vol. VIII. The Flood Problem". Op Cit; P. 11

It appears from experience that for any flooding season, damages are always severe when the Brahmaputra peak level at Bahadurabad exceeds 65.00 PWD (two feet above danger level).

The Season Of Flooding

The season explains why the 1968 damages due mainly to two Brahmaputra flood have been so severe although the peak levels recorded at Bahadurabad were lower by 1 to 1.70 feet than the peaks of the other big floods. A difference in water level of one to two feet explains the differences of damages from one season to another. This is in accordance with the resistance of the rice price described earlier. The explanation for the 1956 damages is exactly the same; it was a very early Brahmaputra flood.

Duration Of Flooding

The duration itself may explain certain crop damages even if the depth of flooding is not high. It may have an indirect effect - the postponement of crops giving lower yields or even the impossibility of growing certain crops. The duration of flooding, however, is not independent of the peak level. Along the main rivers for which we analysed these water levels, the peak levels caused a submergence of riverine lands, generally longer than five days and exceeding a depth of two to three feet. These characteristics are very dangerous for rice cultivation. The depth duration frequency analysis will also be necessary to explain the damages occurring around the fringe flooded areas of large and small basins.

Loss Of Lives

Loss of life is stated by the Relief and Rehabilitation Department. They have been as follows for the period 1962 to 1969:

<u>Year</u>	<u>Loss of Lives</u> ¹
1962	177
1964	10
1966	39
1968	221
1969	77

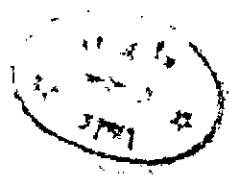
The magnitude of these losses is very small in relation to those stated for cyclones.

Flood Control

Until now the people of Bangladesh have adopted to flood condition with very little modification of their environment. Cities, villages and homesteads have been located in higher areas or on built-up mounds. Rice varieties are planted which take advantage of the normal flood condition at different periods of the monsoon season. By exercising more control over flood condition it is possible to reduce flood damages. Besides direct damage to crops, floods hamper rice production in a more fundamental way. In deeply flooded lands (over 15 feet in the Meghna Valley) farmers cannot grow rice. On lands

¹ International Bank for Reconstruction and Development, "Land & Water Resources Sector Study - Bangladesh, Vol.VIII. The Flood Problem", Op. Cit; P. 11.

that are flooded from 3 to 12 feet they can grow only low-yielding broadcast Aman rice. Where flooding is from 1 to 3 feet, farmers grow higher-yielding Aus and transplanted Aman rice but they must accept risks from occasional higher flood or from drought and they do not generally use fertilizers or improved seed effectively. In many instances, because of the risk involved, farmers plant both Broadcast Aus and Broadcast Aman to insure some production in case one of the crops is lost due to flood or drought - a form of insurance which carries a substantial cost. Thus, flood protection has benefits as well as costs. It is essential for these benefits and costs are to be clearly identified in specific circumstances before decision to invest in flood protection is taken. In particular, in providing flood protection for agriculture, consideration must be given to all phases of water management, including irrigation and drainage. For instance, if embankments are constructed to keep flood water out, provision for drainage also must be made to prevent internal flooding due to high rainfall. Furthermore, it must be recognized that elimination of flooding also eliminates irrigation water so that a replacement supply must be provided. The impact of flood protection on fisheries must also be analyzed. If complete control of the water is afforded, the incremental costs of providing winter irrigation also are generally small. Flood protection projects, in order to be effective, must involve many disciplines including planners, engineers, economist, agriculturists, fishing biologists and many others working closely with the local officials and farmers. In addition to the ordinary planning



and engineering, economic and social aspects the consideration relating to the possibility of loss of life due to flooding is of primary importance.

Remedies Of Flood

Physical plans for the remedies of flood in Bangladesh falls into five general categories;

(a) embankment for containing flood flows; (b) floodways for the passage of excess flows past critical reaches of a stream; (c) channel improvement and stabilization for improving the alignment and stabilizing the channel, thereby increasing the flood-carrying capacity of the main river and for protection of the embankments, (d) storage reservoirs upstream and on tributaries, and (e) pumping plants and sluices to evacuate local drainage. Any one or a combination of these methods could be employed in providing flood protection. To prevent flooding by the major rivers (Brahmaputra, Ganges and Meghna) only embankments and channel improvements appear to have practical application. Storage reservoirs, to be helpful, would have to be tremendously large and if suitable sites are available they would be outside Bangladesh.

There is little likelihood of developing surface storage which would be of significance in curtailing flood flow although this possibility should not be completely eliminated, especially on the Brahmaputra river. The possibility of utilizing vast underdeveloped ground water resources in India to reduce flood flows also has been suggested and should be explored further. Previous studies have indicated that

floodways are not a practical solution, particularly for flooding by the major streams; however, it probably would not be desirable to confine the flood flows of the Brahmaputra/Padma rivers to a single channel throughout their length. Of course, pumping plants and sluices would be necessary along with embankments to care for local drainage.

As discussed previously, local rainfall and small streams rising mainly within Bangladesh result in severe flooding in many areas. For protection against floods by ocean tides, embankments and associated works will be needed.

To Use Water As A Resource

Water is perhaps our most widely used resource. The development of water and related land resources is a highly complex matter. Doing the job rightly, requires a thorough understanding of many aspects of potential projects, including the following: Characteristics and inter-relationships of relevant resources; modern engineering, industrial and agricultural technology; economic trends and impacts; social and cultural forms; and even political relationships. Such completeness of understanding is necessary because development projects must fit effectively into a very complicated physical environment and into an even more complicated social and political environment.

In water resource development, the application of this criterion requires multiple-purpose development i.e. comprehensive

The financial criterion is often a source of controversy and

and confussions with respect to water resource development. Questions may arise as to the completeness and accuracy of the cost data; misunderstanding after arises relative to the cost to the government and how much project users and beneficiaries are to pay; and there is frequently confusion between financial and economic feasibility of projects.

Four categories of beneficiaries can and should be identified: (a) private individuals or association (b) local communities, (c) regions and (d) the nation as a whole.

The private individuals or association of individuals, who gain directly from water development projects are the primary users of the facilities or services of the projects. There is widespread agreement that this class of beneficiaries, in so far as they can be identified and the benefits measured, should pay at least part, if not all, of the cost of facilities or services used.

In some situations the local community is the best means of identifying primary beneficiaries and of assuming their reimbursement responsibilities. This is particularly true for such function as domestic water supply, local flood control and navigation works, population abatement, and recreational use of water. Secondary benefits might also be the basis for some local repayment responsibility.

Because of the intangible nature of the primary benefits from such projects, as extensive flood control works, comprehensive

water shed protection, recreation facilities, and fish and wildlife refuges, a region may be the unit best suited to assume reimbursement obligation. The region might also assume some repayment responsibility for indirect economic effects assuring to the people such projects as irrigation, land drainage, navigation, watershed protection and recreation which has more than local significance.

The national interest in water resource development is undeniably great. It includes many benefits which accrue to the nation as a whole and affect both the security and welfare of the whole population. Illustrative of these benefits are the strengthening of national security, the conservation of soil, water, forest and mineral resources, and the provision of food fibers, and electric power at reasonable prices. The amount of national contribution should vary with the degree of national interest involved.

It has already been indicated that there are various types of public objectives and benefits from water development projects which cannot be measured in usual commercial terms of the market value. Yet these public value may be most important in planned development of water resources. Thus, when one of the objectives is the conservation of resources, evaluation cannot be of the monetary benefit cost variety. Market prices in part reflect scarcity values, but a project that successfully halted resource deterioration and strengthened the resource base might lead to a reduction in the Taka value of the products and services of resources by making possible an increase in their supply.

Reference was made earlier to the intangible benefits of multiple-purpose projects including among others national defense, protection of public health and safety, provision of recreational facilities and preservation of scenic places. Sometimes these benefits are costless by products of development for other purposes which increase the productive power of the nation - irrigation and domestic water supply, navigation, power and sometimes they rise to additional costs. When additional costs are incurred the benefits and cost should be evaluated on a separate basis. These public or intangible benefits deserve separate consideration because they are "end values" themselves rather than means towards the achievement of end values and make direct contribution to the general well-being of the society through making possible a more whole some and satisfactory way of life.

A criterion of a particular significance to this area, as well as being important to the nation as a whole, is the optimum development of each principal region in Bangladesh. Bangladesh is composed of a number of well defined region, each with a different combination of geographic, economic and social features. The natural resources of each region are in varying stages of and have varying capacities for development.

Although Bangladesh is well endowed with natural resources, we cannot afford to be profligate with them. Hence, we should strive for the optimum use of our water resources through multipurpose,

basin-wide projects and optimum regional development.

The economic well being of the people depends considerably upon the nature of the resource base. Hence, the development and conservation of our natural resources - of which water is a key resource - is imperative in the great task of building an expanding national economy of increasing strength. The significant economic objective of water development programme is to strengthen the resource base of this nation.

CHAPTER VI

THE ROLE OF WATER RESOURCES IN THE GROWTH AND DEVELOPMENT OF URBAN AREAS

Growth And Development Of Urban Areas

River transport facilities have played an important role both in the growth and development of urban areas in Bangladesh. Till the coming of the railways in the later half of the last century, rivers were the almost exclusive means of transport, particularly for bulk and long distance movement of goods. Almost all urban areas were located on rivers, confluence of rivers, providing the more favoured sites. While waterways importance has declined in some parts like the northern districts of the country and also in south-western parts of Kushtia and Jessore districts, because of the decaying and moribound nature of the rivers in these areas, river transport still continues to be important in most other part of the country in the growth and development of urban areas.

In fact in some areas in the deltaic areas of the south, in Barisal district and adjoining area, it still continues to be the most exclusive means of communication. Town like Barisal and Khulna and also the other towns in these areas are important converging points for the excellent river waterways that exist in these parts.

Khulna is an important river port of south western part of Bangladesh. With the port facilities that nearby Chalna port provides, Khulna has become the leading port for the export of jute. Narayanganj

which is situated almost in the centre of the country, is however, the leading river port. Chandpur which is situated at the confluence of two major rivers is also an important river port.

The geographical distribution of declining urban centres has varied from decade to decade, but in some areas like south-western parts of Bangladesh, in the moribound delta with its obstructed drainage (Kushtia and Jessore districts), and also in the extensive low-lying ill drained areas of the northern districts, the number of declining urban centres have generally been much larger than in the better drained and consequently healthier eastern parts of the country. Both the population and the economy of these ill-drained malarious areas suffered from stagnation and these in turn adversely affected the growth and development of urban centres located in such areas, Kumarkhali, Kotchandpur and Maherhpur had declined from 1901 to 1931, showed some gains in 1941 and large decreases one again in 1951.¹ Natore in Rajshahi district is an example of such declining town due to the rapid deterioration of rivers and drainage condition of the area. So water transportation system is playing a significant role in the growth and development of urban areas of Bangladesh.

A study of agricultural activities, which are development on water resource, particularly cropping pattern and distribution of urban centres does reveal some co-relationship. Though rice is the pre-dominant crop every where in the country, the bulk of it is consumed by

¹ Harouner Rashid, Op. Cit., P. 369.

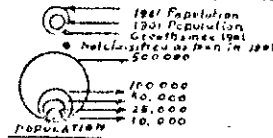
the producers and little of it enters the trade, except in certain areas. Jute, the main cash crop, however, plays an important role particularly in the economy of those areas where it is produced. If the main jute belt (areas with more than 10 per cent of its cultivated area under jute) is considered, it is found that more than 40 per cent of the total number of urban centres with population more than 5,000 are located within this belt. It also includes about half of the fifteen largest urban centres of the country (MAP-11).

Though jute cultivation and its trade may not be directly responsible for the presence of this large number of urban centres, the economic prosperity that this crop has generated particularly for the people of the jute belt has been far reaching and there is no doubt that it has helped in the growth and development of a large number of towns both within and adjacent to the jute belt.

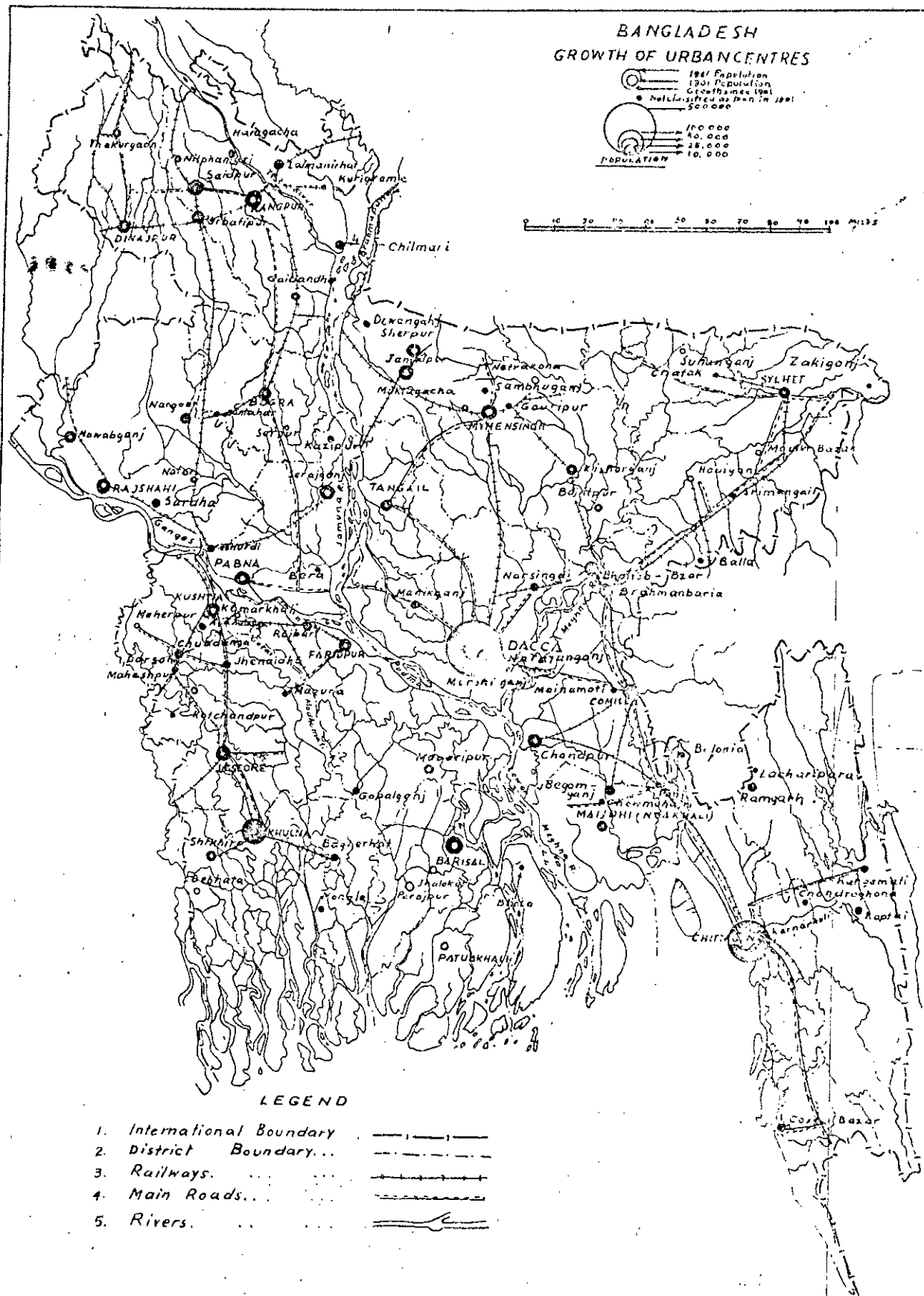
Within the jute belt the urban centres are located at those centres having good communication particularly cheap river transport facilities. As the bulk of the jute is exported, those centres combining river and rail transport facilities usually have benefited more from the trade of jute. Narayanganj, Bhairab Bazar, Chandpur, Brahmanbaria, Gaibandah, Domar, Phulchari, Kishorganj, Netrokona, Jamalpur, Bajitpur, Munshiganj, Narshingdi, Madaripur and Sirajganj are good examples of this type.

In Bangladesh, past development works were agricultural oriented. Governments endeavour was to become self-sufficient in food. So

BANGLADESH GROWTH OF URBAN CENTRES



0 10 20 30 40 50 60 70 80 90 100 Miles



LEGEND

1. International Boundary
2. District Boundary
3. Railways
4. Main Roads
5. Rivers

MAP II. URBAN CENTRES OF BANGLADESH

comperatively more investment was made on agricultural sector than in any other sector. As a result of which a few water resource oriented schemes has already been completed and a large number are in the hands of Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC), Irrigation Department of Bangladesh Government, Bangladesh Academy for Rural Development, Comilla, and Agriculture Directorate. These agency's water resource development works are creating more job opportunities, bringing more agricultural produce, increasing housing and administrative land use in the surrounding urban areas. Thus their water resource development works are directly or indirectly contributing to the growth and development of urban centres of Bangladesh.

Water-power is cheap to generate. So its importance is significant in Bangladesh where there is hardly any exploitable coal for the generation of thermal power. The Karnafuli Multipurpose Project is the only hydroelectric project of Bangladesh, so far developed. Though the idea dates back to-prepartition times, the scheme was completed in 1963.

Investigations into the generation of hydro-electric power started on Karnafuli by the Port Commissioner, Chittagong, as far back as 1906. In 1922 the Bengal Government took up the matter, considered the problem of finding a suitable site for hydro-electric power station and calculated the power available. Four sites where rapids exist: Barkal, Uttar Chatra, Bara Harina and Demagiri at river

distances of 84 and 114 and 130 respectively, were examined and the first one, Barkal, with a rapid of 39 feet in a length of 1.50 miles was recommended. In 1924 the Government set up an expert committee to examine the recommendations. They decided to abandon the scheme, on the ground that the quantity of power estimated, 6,480 KW was too small for transmission, and though the cost of work, estimated at Taka 2.50 million, appeared low, it would not compete in price with a similar quantity of power generated from oil and coal at Chittagong. In 1946, Mr. Moore, then Superintending Engineer, Eastern Circle, Bengal, working in connection with the post-war development schemes, re-examined the reports and recommendations of 1922, and found serious errors in estimating the storage capacity of the proposed reservoir. He noticed that the storage capacities of the major tributaries of the Karnafuli above Barkal site, i.e. Bara Harina, Thega Khal, Tulianpuri and Tuichong, were altogether neglected. The water spread of the reservoir was taken as a long narrow channel about half a mile wide with a capacity of 2,000 million cubic feet or 45,800 acre feet at full supply R.L. of 131.80. Mr. Moore found the storage capacity at R.L. 150 of approximately 4,817,000 acre feet by interpolation of 100 feet and 200 feet contours. This changed the whole aspect of the scheme.

Preliminary surveys after 1947 suggested sites at Sublong and later on in 1951, at Silchari. But eventually the site at Kaptai was chosen. It is fortunate that the first developing port of Chittagong

and its urban and industrial regions have benefited directly from this new development. Facilitated by interlinked thermal power stations, Dacca and Narayanganj also use generated power. Other benefits include navigation facilities on the Karnafuli down to Chittagong and to the sea and a check on the rapid silting at the port.

The power station has an installed capacity of 80,000 KW, with two generators. A third generator is under installation and it will generate another 50,000 KW of electricity. The intension was to tie the hydro-electric project into a power gride incorporating thermal generators at Chittagong and Narayanganj, to which system the 'peak load' generator on the Karnafuli would be a valuable and economic addition, being much cheaper to operate for occasional demands for power, than a thermal unit.

In order to provide for excess flow in the rainy season, a spillway was excavated to carry a maximum flow of 525,000 cusecs through 16 gates (14 feet x 20 feet).

Due to the completion of Karnafuli Hydro-Electric Project, cheap power for the industrial development of urban centres of Bangladesh was ensured. In 1959-60 the GDP of Bangladesh for large scale manufacturing industries was Taka 406 million and it was 2.80 per cent of the total GDP. In 1964-65 it increased gradually to Taka 633 million and it was 3.53 percent of the total GDP. But a sharp increase in GDP was observed in 1969-70 when it rose to

Taka 1335 million and it was 5.96 per cent of the total GDP of the year in the manufacturing industries.¹ So availability of Kaptai's power has contributed tremendously in the industrialization of our urban centres. Therefore water resource of Karnafuli river contributed substantially in the growth and development of existing urban centres and also growth of new industrial cities and towns where cheap raw materials were available.

The extensive inland water bodies of Bangladesh provide the basis for a large fresh water fisheries industry and this is important to the economy in term of employment, income, food supply and export trade. There are about 534,000 fresh water ponds and lakes covering an area of 190,000 acres, 742,000 acres of bils and haors (natural depressions) and 20,193,000 acres of rice fields (when inundated in rainy season) in Bangladesh. Moreover there are 40,000 acres of brackish water ponds and 410,000 acres of deltaic water.² All these water areas to some extent serve as important fish growing areas.

¹ Bangladesh Water and Power Development Authority. "Feasibility Report for the protection of Chandpur Town, Vol. II, Economic Investigation and Urban Planning", (Dacca: Prokaushali Sangsad Limited, 1972, P. 5).

² Dr. Md. Abdul Karim, "Fish Culture in Bangladesh", (The Bangladesh Observer, October 17, 1972, P.4).

Following table shows the production of fish in Bangladesh in different years:

TABLE - 6

PRODUCTION OF FISH IN BANGLADESH

<u>Year</u>	<u>Quantity in Metric Tons</u>
1961-62	707,957
1962-63	736,759
1963-64	749,514
1964-65	758,895
1965-66	765,231
1966-67	788,290
1967-68	810,006

Source: Directorate of Fisheries, Government of the Peoples Republic of Bangladesh.

Bangladesh has 320 miles of coastline along which innumerable distributaries of the Ganges-Padma drain into the Bay of Bengal. The huge amount of sediment brought by the rivers every year has formed the Argo Flat, a shallow area nearly 20 feet deep and about 600 square miles in area. The rivers also bring huge amount of fish food but the region suffers from an absence of harbours because of the swampy character of the coast and shallow character of the river channels. Fishing is, therefore, done on a small scale from November to February, when the sea is least turbulent. Dubla Island, Rangati and Baisdia in the Sundarban area, and Cox's Bazar, Kutubdia, Sonadia

and Moheshkhali along the Chittagong coast are marine fishing centres.¹ Recently USSR has supplied Bangladesh Government with 10 fishing trawlers. These are being used to catch fish in the Bay of Bengal.

The means of transportation being meagre and the decomposition of the fish being rapid, the fish are dried in yards and salted before they are exported. Goalunda, Madaripur, Khepupara, Chandpur, Chittagong, Cox's Bazar, Narayanganj, Akhaura, Bhairab Bazar, Khulna, and Sylhet are the main fishing urban centres (MAP - 11). The growth and development of these urban centres are also depend on fishing industries.

The Kaptai reservoir with an area of 162,000 acres in an important place for the propagation of fish. Kaptai has also become an important fishing centre of Bangladesh. It has got ready market with good communication facility at Chittagong, Rangamati and Chandraghona.

From Table 6 it can be observed that our production of fish is increasing year after year. But due to rapid increase in population, the exportable surplus is diminishing year after year. The picture appears more dismal if we have a look to the export of fishes from Bangladesh to the different countries of the World. Bangladesh was one of the biggest exporters in the sub-continent. In the year 1963, she alone exported fish valued at Taka 77.20 millions. But Bangladesh does no longer hold that important position. Fish export from

¹ F. Karim Khan, "An Introduction to Economic Geography", (Dacca Green Book House, 1971, P. 722)

Bangladesh has miserably declined after the Indo-Pakistan war of 1965. The export figure of fish in different years have shown in Table - 7.

TABLE - 7
EXPORT OF FISH FROM BANGLADESH

Year	Quantity in Metric Ton	Value in Taka
1957-58	11,969	1,39,43,000
1958-59	14,095	2,02,55,000
1959-60	15,671	2,64,39,000
1960-61	17,418	3,83,43,000
1961-62	19,629	5,08,08,000
1962-63	30,373	7,77,20,000
1963-64	24,392	6,71,56,000
1964-65	14,583	4,58,68,000
1965-66	634	21,72,000
1966-67	2,195	1,10,71,000
1967-68	1,481	99,61,000

Source: Kh. Bazlul Haque, "Fish Resources Declining" The Pakistan Observer, December, 1969, P. 4.

Bangladesh has now good friendly relation with India. So she will be able to regain her fish market in India. With the export of more and more fish in India our fishing ruban centres will began to grow rapidly.

It is said before that most of the urban centres in Bangladesh

are located on the banks of the rivers. So, most of them has taken the advantage to develop its water front. The 35 feet wide and near a mile long stretch, popularly known as Buckland on the bank of the river Buringanga at Sadarghat in Dacca city was once a pleasant retreat for city dwellers. Thousands of citizen used to visit the Buckland Bund at down and desk for fresh air and refreshment. But the panoramic view of the Bund with hundreds of "house boats" tied side by side is no more seen there due to the negligence of our city Authorities in maintaining it.

The whole Bund area is now a big commercial place. Concrete banches on the Bund for the visitors and the beautiful red, pink, green, white, blue and yellow house boats are no longer there. People now only visit the place for purchasing commodities or availing motor launches or to hire ordinary boats. Large number of shops have sprung up all through the Bund area from Shyambazar to Badamtali Ghat. Thus the scenic beauty of the place is completely lost. The plan for the construction of Buckland Bund was taken about a century ago. The planners were a group of renowned philanthropists of Dacca City who felt the necessity for a healthy retreat for the citizens. In 1960 those Philanthropists appealed to the owners of riverside land, from Shyambazar to Badamtali Ghat, to donate the area for making the Bund. The land owners responded instantly to their appeal and generous contributions were made by the philanthropists for the purpose.

When the Dacca Municipality was set-up in 1864 the construction

of Buckland Bund was undertaken by them. Since then the Bund area came under the management of the Dacca Municipality. On March 5, 1884 the tender for construction of Buckland Bund was accepted by the Dacca Municipality.¹

Before the creation of Pakistan in 1947, entry of all sorts of transports into Buckland Bund was prohibited. Only walking through the area was then allowed. In the river, along the Bund country boats with merchandise or passenger boats and the famous boat houses used to lay in anchor.

Gradually the Dacca Municipality introduced toll on the merchant boats which anchored along the Buckland Bund. For smooth collection of tolls the Municipality leased out the bund on yearly basis. One Hatam Bepari, a local businessman, managed to get the "ejaradari" of the Bund every year. Previously the Municipality did not get more than 300 Taka yearly out of the lease. But in 1962 the amount exceeded one lakh Taka from ejaradari.

In 1963, the management of the century old historical Buckland Bund was transferred to the Island Water Transport Authority (IWTA) by the Dacca Municipality at the instruction of the then East Pakistan Government. The IWTA built a terminal there for the inland river transports.

¹ Khalilur Rahman, "Buckland Bund no Longer a Retreat". The Bangladesh Observer, September 18, 1972, P. 7.

Similarly, river fronts were developed in Khulna, Rajshahi, Barisal, Chandpur, Bhairab Bazar, Chittagong, Kushtia, Mymensingh, Narayanganj, Narshingdi, Sylhet, Comilla and Chandraghona etc., places. These river-fronts are helping in the healthy growth and development of urban centres of Bangladesh.

Water resources, like artificial lakes, tanks and springs etc., in the urban areas in Bangladesh are helping in the healthy growth and development of these centres. Dhanmondi lake in Dacca, Railway's Foiz lake of Pahartali in Chittagong, Kaptai lake in Kaptai and Rangamati, are a few example which are helping in the growth and development of those urban areas. A large number of tanks in Comilla, Chandpur, Feni, Rangpur, Dinajpur, Natore and other urban centres are helping in their growth. Besides the recreational uses of these lakes and tanks, in some cases, they are being used for municipal water supply. Artificial water springs in urban areas are also helping in increasing the aesthetic beauty of the city. Thus the spring near Shahbagh Avenue and DIT Avenue of Dacca have increased the beauty of the city and have broken the monotony characteristic of roads of Dacca.

Recreational uses of water resource and its contribution to the growth and development of urban areas in Bangladesh is limited. Karnafuli reservoir is the largest artificial water body in Bangladesh. On the shore of this water body only two urban centres are flourishing and these are Rangamati and Kaptai. Excellent possibilities

exist for making the reservoir a tourist attraction by providing more modern amenities in these urban centres and more water sports facilities at moderate rate. However, increased recreational use of the reservoir by local people does not appear likely until personal incomes increase and appropriate public recreation facilities are provided to meet the needs of the local people.

Cox's Bazar is another urban centre in Bangladesh which is developing as it is situated on the shore of Bay of Bengal and it has a long sea beach near by. The beach is very beautiful and it attracts both foreign and local tourist. Cox's Bazar remains very busy throughout the year, but during the winter the weather remains very good and it attracts more people.¹

Industrial Development

The primarily agricultural character of the Bangladesh area since time immemorial needs no emphasis. It was known as a paradise for its fertility and its abundance and variety of crops. Therefore, the early beginnings of industry were based mainly on the resources of the land. According to the dictates of ancient and medieval economy handicrafts and small industries flourished to supply local needs. But early in its history a variety of industrial products acquired a wide reputation for their excellence, and began to figure

¹ Government of the People's Republic of Bangladesh, Bangladesh: The Youngest Republic. (Dacca: Ministry of Information and Broadcasting, 1972, P. 12).

in inter-provincial trade as well as in world commerce. Generations of skilled artisans maintained the dictates of demand and supply.

With the advent of Muslim power, the development of better communications and the consequent increase in contact with Northern India, Bangladesh's manufactured products acquired more fame. The court and the nobility, the urban rich and the foreign traders made ever greater demands on these articles. The story has already been related to the waning of the supremacy of Bangladesh's manufactured products, and their unequal competition with the methods of production of a fast developing industrial age in the west and the unfortunate results of political and economic policies.

Thus as the nineteenth century wore on, Bangladesh lost practically all its former industrial skill and finally sank to the position of a raw material base, supplying the growing needs of Calcutta and the jute fibre demands of the outside world, cheap machine-made goods took the place of the old manufactures at home and also displaced them abroad.

Modern industry made hardly any progress in Bangladesh, though rich in agricultural resources, lacked contemporary initiative. By 1902 there had began an outburst of manufacturing activity, chiefly buttressed by European capital, and the metropolitan districts were becoming a vast industrial tract. Outside Calcutta and its neighbourhood there was little industrial enterprise. Huge European capital invested in the various branches of the jute industry

on the banks of the Hooghly. Thus Calcutta, the hubs of European enterprise, indirectly prevented development elsewhere, particularly in Bangladesh.

At partition in August 1947, the area inherited a legacy of industrial backwardness dating from the dawn of the modern industrial era in British Bengal. It has been amply demonstrated how, throughout the past decades, this area served as a hinterland for building up the industries, wealth and prosperity of Calcutta. With all its variety of agricultural resources and vast multitudes, Bangladesh made little progress with modern industry. Some of the reasons for this have been explained above. Therefore, in 1947, Bangladesh inherited only 10 cotton factories out of 400 in India, none of Bengal's 106 jute mills, not a single iron and steel plant, paper mill, chemical works, coal-mine or established hydro-electric project. It was left with about 49 seasonal jute baling presses (only 27 pucca presses), 58 small rice-mills of all description, 3 sugar factories and 1 cement factory. No industrial use was so far made of such products as tobacco, wheat, hides and skins.¹

A major part of the industries of Bangladesh are in and around Dacca. Of factory industries nearly half are in this Region because of the concentration in Narayanganj, Demara and Tongi and about a quarter of cottage industries. In the Dacca area most of the industrial factories are in Narayanganj and Demra to the southwest,

¹ Nafis Ahmed, Op. Cit., P. 222.

Postagola and Islampur in the south, Tejgaon and Tangi in the north. The jute mills are located in the Narayanganj-Demra area along the Sitalakhya river. There are 10 jute mills, employing over 30,000 persons. Along the Sitalakhya are a number of boat-building yards. There are also four textile mills in this area, and Narayanganj is an important centre for hosiery products. Along the Buriganga, in Dacca city (Postagola and Islampur areas), are a number of leather and rubber factories, tanneries, match factories, cotton textile mills and a big flour mill. In the industrial areas of Tejgaon and Tongi, to the north of the city, are a variety of industries, ranging from confectionary products and cigarettes to telephone equipment and PVC Pipe. The total industrial labour in the Dacca region was about 69,000 in 1961.¹

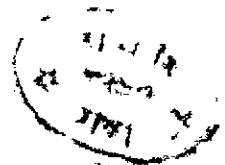
There are three jute mills in Ghorashal and two jute mills in Narsingdi, both in Dacca district. Ghorashal, on the Sitalakhya river, has developed into one of the major industrial towns of the country. An Urea ferterlizer factory with a capacity of 340,000 tons per year, and a larger power plant have been put up there. A few miles upstream a small sugar mill at Charsindur. There are two other sugar mills in the area at Kishorganj and at Dewanganj in Mymensingh district. South of Narsingdi dozens of villages specialize in handloom cloth weaving.

¹International Bank for Reconstruction and Development, "Land and Water Resources Sector Study - Bangladesh, Volume-II - The Regional Development Potentials and Constrants" Technical Report No. 1. International Development Association, May 15, 1972, P. 42.

A yarn mill at Kaliganj supplies a good part of their demand. Another area with a well-developed cotton handloom industry is around Tangail. There are two cotton mills in Tangail district. Further north, in Mymensingh district, the only big industrial units are the two sugar mills. This is the major jute growing district of Bangladesh and there are four pucca jute baling presses at Sarishabari and one each at Gouripur and Nikli. However, there are no jute mills in this principal jute growing area. There are 16 pucca jute baling presses in Narayanganj, 3 in Dacca and 1 in Narsingdi, Narayanganj is, of course, the major inland part and the principal jute trading market of the country.

Handloom cotton weaving is important in the Baburhat area of Dacca district, Bajitpur of Tangail district and Bajitpur of Kishorganj in Mymensingh district. Embroidering of fine cottons is a speciality of Dacca city. Boat building is important in this area. In 1950 there were over 1,300 enterprises engaged in building country-boats. The largest units are in and around Narayanganj, Narshingdi and Bhairab Bazar. Brass and Bell-metal utensils are made on a cottage industry basis at Dhamrai and Savar in Dacca district, Islampur in Mymensingh district and Kagmari in Tangail district.

Though there is a certain amount of concentration around Chittagong, industrial activity is more dispersed in this area than in and around Dacca. The tea industry is concentrated in southern Sylhet, with a few factories in north Sylhet and northern Chittagong



district. Of the 110 tea factories in Bangladesh, 98 are in Sylhet and 12 in Chittagong district. Apart from tea, the major industrial units in Sylhet district are an 80,000 ton capacity cement factory at Chhatak and a 90,000 ton capacity Urea fertilizer factory at Fenchuganj based on the important natural gas deposits there. In Sylhet town there is a small match factory. In Comilla district the main industrial units are a jute mill at Hajiganj, 2 textile mills at Comilla, two pucca jute baling presses at Ashuganj and three presses at Chandpur. In Noakhali district, the only major industrial unit is the jute mill at Choumohani, where there are also a few oil mills. In the Hill Tracts district there is one tea factory and two plywood factories near Kaptai and close to the Chittagong border at Chandraghona are a large paper mill of 30,000 ton capacity and a rayon mill. Further south there is an industrial estate at Harbang, which is almost an enclave in Chittagong district. At this industrial estate there are a match factory, two textile mills and a cigarette factory. In Chittagong district, the only factories outside of the Chittagong city and its suburbs are the tea processing factories in the tea estates, and a textile mill close to the industrial area of Chandraghona.¹

The industrial areas of Chittagong city are in six different sites. These are at Sholasahar in the northeast, at Kalurghat on the Karnafuli river in the southeast, in the Patenga peninsula between

¹ IBID/IDA, Vol. II. Op. Cit., P. 83.

the sea and the Karnafuli river, at Kattuly, Kumira and Sitakunda on the west and northwest, following the road and railway to Dacca. The major industrial area is in Patenga, where there is a steel mill, two TSP fertilizer factories and an oil refinery. The six jute mills at Chittagong are in the Kalurghat and Sholasahar areas. The Kalurghat area also has saw mills, tanneries and a glass factory. The Kattuly-Kumira areas have cotton textile mills, a cigarette factory, pharmaceutical factories and units for making paints, some 20 miles north from downtown Chittagong, is a motor vehicle assembly plant mostly dealing in trucks.¹

Factory industries in the southwestern part of Bangladesh are concentrated in and around Khulna city. The industrial suburbs of Khulna are in Khalishpur, Daulatpur and Gopalpur, stretching north along the road to Jessore. Most of the factories are between this road and the Bhairab river. In this area there are seven jute mills, a 30,000 ton capacity newsprint mill, two cotton textile mills, two match factories, nine pucca jute baling presses, twelve Kutcha jute baling presses, oil mills and several saw mills. Southwest of the city is the country's largest shipyard. There is very little industrial activity outside the Khulna area. In Jessore there are no large units. In the Kushtia district there are two sugar mills at Darsana and Jagati and two cotton textile mills and several oil mills

¹ Chittagong Development Authority and B.A.W. Trevallion. Chittagong Region and Metropolitan Chittagong - Proposal for Development. (London: Ministry of Overseas Development, 1967, P. 121)

at Kushtia. In Faridpur district, there are two pucca jute baling presses at Goalando and one at Charmugria. At Barisal there is a floating dry-dock and a shipyard for inland water vessels. There is also an oil mill (vegetable oil processing plant) in Barisal and in Nalchiti. In Patuakhali district there is a small match factory at Kehpupara. Small oil and rice mills are found in many towns. This completes the sparse picture of factory industries in this area.

In cottage industries too, it does not do much better. The south and east of this area is an active delta and therefore boat-building is important. There were 2,314 boat-building establishments in this Region in 1961, concentrated in Barisal district. Gur (Jaggery) making is important in Jessore, Kushtia, northwest Khulna and northwest Faridpur. Gur is made from sugarcane and Khajur-palm juice. Cotton handloom weaving is important in parts of Rajbari and Madaripur sub-divisions of Faridpur district. Brass and bell-metal ware is made on a cottage basis in Palong thana near Madaripur.

There are very few industrial units in the northwestern part of Bangladesh. Indeed, this has been one of the major complaints of this area against the planners of the country. Bogra is considered as the industrial centre, but even here the size and diversity of industrial units is very limited. There is one textile mill, one chemical factory turning out soap mainly, one match factory, and one cigarette factory. There are also a number of small units making Biris (small cigars rolled in a special leaf). All the other industrial units are

scattered about. This is a feature of the area quite distinctive from the other areas of Bangladesh whereas in other areas industries are concentrated in two or three centres in this area they are scattered. This is due to the absence of year round navigation facilities in and around any of its existing urban centres. Most of the river systems of this area remain almost dry during the dry months of the year. Besides, river banks of the river Brahmaputra and Ganges are vulnerable to erosion and siltation. So, cost of maintenance of an inland river port along the banks of these two rivers would be prohibitive. Moreover this area is not connected with the country's capital and port city Chittagong either by rail or road. So due to communication difficulties this area cannot take the advantage of marketing its industrial products to the other parts of the country. These may be the reasons of industrial backwardness of this area.

There are seven sugar mills, at Panchagarh, Thakurgaon, and Sitabganj in Dinajpur district, at Mahimaganj in Rangpur district, at Jaipurhat in Bogra district, and at Harian and Gopalpur in Rajshahi district. In addition, there are two proposed sugar refineries (Nilphamari and Panchagarh), a proposed jute mill at Rajshahi and a proposed paper and newsprint plant at Paksey. Also there are three textile mills, each one at Ishurdi, Bogra and Sirajganj. Jaggery (uncrystalized brown sugar), is produced at the village level and there are several hundred small units scattered about the sugarcane growing areas, especially in Rajshahi and Pabna districts.¹

¹ IBID/IDA, Vol. II, Op. Cit., P. 22.

This area grows one quarter of all the jute of Bangladesh but has only one jute mill at Sirajganj with 250 looms. Most of the jute is baled for export as raw jute and some of it is manufactured in the Khulna area. There is a profusion of Kutchha baling presses, where raw jute is baled by manual labour and moved to other areas for further processing. There are 347 kutchha presses in Rangpur district, 92 in Dinajpur district and 29 in Pabna district. Jute bales pressed by mechanical means, and therefore better packed, are known as pucca bales. These are usually for export as raw jute. There are 12 pucca baling presses in the northwestern part of the country; 3 in Saidpur, 2 in Gaibandha, one each at Bansi, Alamnagar, and Bonarpara (Rangpur), one each at Atrai, Naogaon and Santahar (Rajshahi district) and one in Phulhat (Dinajpur district).¹

There are over 100 rice mills concentrated in Dinajpur and Rangpur districts. Seed oil mills are very often a part of these rice mills. These mills are concentrated in Phulhat, Birampur, Setabganj, Fulbari, Ruhea, Hili and Chirirbandar of Dinajpur district and Saidpur, Alamnagar and Domar of Rangpur district.

There is a major railway workshop in Saidpur and minor railway workshop in Parbatipur, Lalmonirhat and Ishurdi.

A fair amount of cottage industry is located in this area. Handloom textiles are concentrated in the Shahzadpur and Santhia

¹ IBID/IDA, Vol. II. Op. Cit., P. 22.

thanas of Pabna district. Handloom products from these areas are traded all over Bangladesh. A small amount of silk reeling and weaving is carried out in Lalpur, Nawabganj and a small silk industrial plant is located in Rajshahi.¹

Carpentry, especially for making cartwheels and the frames for horsebuggies known as ekka, is important in Rajshahi, Pabna and Rangpur districts. Pottery making is important in eastern Bogra, from where much of Rangpur and Dinajpur districts are supplied.

Boat building is important only in parts of Pabna and Rajshahi districts. According to the 1966, survey of cottage Industries carried out by BSIC, there were 177 boat building units in Pabna districts, 66 in Rajshahi districts, 33 in Bogra district and only 9 and 5 respectively in Rangpur and Dinajpur district.

Biri making (small cigars) is an important cottage industry in Bogra, Sirajganj and Pabna. Most of the units are families, but there are a few with over 20 workers and could thus be classed as factories. An important future development could be based on the coal and lime stone of the Jamalganj area, north of Noagoan. A cement factory, based on the lime stone, found just to the west of Joypurhat, has been planned. The lime stone is in thick beds, but 1,600 feet below the surface. Vast quantities of coal lie below the limestone, down to a

¹ East Pakistan Small Industries Corporation, "Survey of Cottage Industries in East Pakistan", Dacca, 1966, P. 34.

depth of 3,519 feet.¹ The coal could be shaft mined or burnt underground and piped out as coal gas. Krupp A.G. Essen, Germany, did find coal extraction to be economic. If this were to be confirmed (despite possible liberalization of trade with India), then a number of coal based industries, such as dyes and chemicals, could be established nearby.

Regional Planning

The Regional Development Plan should be elaborated for one Planning Region selected on the basis of previous studies.

The Regional Plan shall consist of a long term programme for development of a balanced economic, social and physical framework in the region. The development programme shall be based on thorough and detailed information on the physical, demographic, social and economic aspect of present situation and shall make proposal for the physical development of the region with inducations of all the effects of the development programme on the physical environment.

A special emphasis should be given to the location and planning of cities, as this is an important and principal part of the Regional Plan.

The Regional Plan shall have special reference to the location and development of urban and industrial areas within that region.

¹ Harouner Rashid, Op. Cit., P. 307.

It shall be prepared in close consultation and co-ordination with all development agencies and nation building departments. It shall contain concrete policy recommendations, cost estimates, etc. that make it capable of implementation by the Government.

The Regional Plan shall indicate the general programme for economic and social development of the Region, and the location of all elements of those programme, taking into account the natural resources and the suitability of different areas of the Region for various kinds of development.

It shall indicate the stages by which this development will be achieved and comprise a long range development programme.

The Plan shall consist of the following programmes for economic and social development of the Region.

- a) Existing natural and man-made resources of the Region & Programme of their development;
- b) Programming and location of industrial activities;
- c) Programming and distribution of agricultural activities;
- d) Land use characteristics, physical conditions of soil and programme of extension of land area;
- e) Programme for water economy and flood control;
- f) Population growth, density, migration, employment position, man-power resources, occupational structure of the population and its distribution in relation to the location of work places and future

trends in their development;

g) Programme for location of new cities and towns and development of old towns and human settlement in the Region;

h) Programming and distribution of services and facilities for population;

i) Protection of nature, historic and cultural monuments;

j) Locations and trends of trade centre;

k) Organization of transport system (railways, roads, water transports and air);

l) Organization of water supply, sewerage disposal and drainage systems;

m) Power generation and distribution;

n) Existence and programme for development of building industry in the Region;

o) Programme for tourism development of the Region;

Physical planning of the Region consists of the following:

a) Comprehensive analysis of existing characteristics of the Region;

b) A comprehensive programme for overall development of the Region with emphasis on identification and development of key places and location of new and development of old towns in the Region;

- c) Preparation of plans (i) For the Region (ii) For key places;
- d) Explanatory description of the planning proposals;
- e) Proposal for implementation;
- f) Cost estimates for plan implementation;
- g) Proposal for organization of implementation and future planning works;
- h) Final Report on Regional Plan, Outline Development Plan, Physical Development Strategy for Bangladesh. Formulation of perspectives for key-places and towns potential for development in Bangladesh.

Future Possibilities of Regional Planning

In Bangladesh regional planning is in its infancy. In 1968-69 an attempt has been made by the United Nations and U.N. Special Fund in their pilot project. "Location and Planning of Cities in East Pakistan".¹ to achieve the following objectives:

1. To conduct research and prepare an outline Physical Development Plan for the whole of the country, within the framework of National Economic Plans.
2. Within the outline Physical Plan to identify potential areas or centres or sites for industrial development.

¹ Government of East Pakistan. Location and Planning in East Pakistan: Annual Report 1968-69 (Dacca: Urban Development Directorate, 1970).

3. To plan these areas, or sites or centres as new towns.
4. To prepare detailed plans for one or two of these new towns and develop these as new towns to act as counter magnets to Dacca, Chittagong and Khulna.
5. To provide a broad yardstick to the Government for guiding the physical development of the country within the framework of economic development policies.
6. To provide policy level guidance for the general growth and development of Dacca, Chittagong and Khulna.

The Project was fully operative upto 1970. United Nations has obtained the services of a senior physical planner. Mr. V. M. Abramov, from the Soviet Union and he was guiding the project as Chief Adviser Cum-Project Manager. An annual report was published in 1968-69 showing the detail programme of the project. Due to the political turmoil of Bangladesh during 1970-71 and 1971-72, the work of the project had to be stopped.

Future possibilities of Regional Planning of Bangladesh is essential to determine, as the pressure of population is increasing day by day. The following objective should be attempted:

- 1) The balancing of population and employment so that no daily mass movements of population to and from work and home are necessary;

- 2) The improvement and rationalisation of transport routes to take the best advantage of existing facilities and to make the most effective use of the resources available for constructional improvements;
- 3) The strengthening of the pattern of services centres in such a way as to secure for the great majority of the population concerned a reasonable accessibility to all grades of service;
- 4) The location of large non-agricultural uses of land in the open country in such a way as positively to make the best use of natural resources;
- 5) The helicopter and the hovercraft may yet completely transform modes of travel in Bangladesh and demand the preparation of regional transport plans totally different from those appropriate to the present situation;
- 6) Ecological balance should be maintained in developing various resources of Bangladesh;
- 7) Air and Water pollution must be controlled on a regional basis;
- 8) Environmental quality must be preserved at all cost. High quality for the built environment should be promoted through land use planning, urban design and the systematic application of multidisciplinary planning and development techniques. The assurance of a high quality environment should be a national goal.

Concept Of Floating City

The objective of the floating city is to divert a part of the countries population to the sea with all the amenities of modern urban areas.

A plain surface is created with the help of buoyancy tanks. By setting in order the materials framed earlier, the housing units will be built on the surface. Reinforced plastic of super quality is generally used in building such city. The housing units do not require plinths. As they are constructed with reinforced plastic they become very light.

The city contains full-fledged radar equipment and a net work of computer system. The city is self-propelled too. So, the event of hurricane, cyclone and tidal bore, danger can instantaneously be averted with meteorological forecast, only by steering the city out of danger zone. It may pass the storm with its self-propelling contrivance.

This type of city can generally float within 10 to 30 miles off the coast. The surface communication maintained by ship and heliport will be there in the city. Thus thousand of housing units can be built with modern amenities on the surface. The cost involved in each unit will be less than that of a corresponding city on land.

In Hawaii there is a floating city for 500 people. Another "floating city" for 10,000 people is under construction at Okinawa in Japan under international mariners inspiration.

Possibilities Of Floating City In Bangladesh

The population explosion and an insurmountable space problem have set a great challenge for the urban and regional planners of Bangladesh. With our limited land resources we cannot go on invading valuable agricultural land, other than farm use. Already the country is facing tremendous shortage of food. The land that can be economised for other uses can be used for agricultural purposes for the greater benefit of the country.

However, there is still scope in our urban and rural areas to develop vertically. Construction of a "floating city" is possible where the country is highly industrially developed. For us it is still a dream.

When vertical development in our urban and rural areas will be the impossible and the technological base of Bangladesh will be highly developed, then we should go for floating city in Bay of Bengal to reduce the pressure of population from the main land.

CHAPTER VII
REVIEW OF WORLD PROGRAMME IN THE
COMPREHENSIVE WATER DEVELOPMENT.

World Situation At A Glance

Making optimum use of the water resources of continents is a task which has long back engaged human effort and which in recent decades has taken the form of "comprehensive river basin development". The term "Comprehensive river basin development" means the orderly marshalling of water resources of river basins for multiple purposes to promote human welfare. As new techniques for the use of water have evolved and as human needs have increased, the management of water for augmenting food and water supply, for transport and for energy production has become more complex and more urgent. Opportunities for promoting further fruitful economic and social growth in comprehensive river basins development of the world - both large and small - are great.

The need for comprehensive river basin development arises from the relationship between the availability of water and its possible uses in the various sectors of a drainage area. It is now widely recognized that individual water projects - whether single or multi-purpose cannot as a rule be undertaken with optimum benefit for the people affected before there is at least the broad outlines of a plan for the entire drainage area. Comprehensive river basin development with the aim stated involves the co-ordinated and harmonious development of the various works in relation to all the reasonable possibilities of the basin. These may include irrigation and drainage, electric power

production, navigations, flood control, watershed treatment, industrial and domestic uses of water, recreation and wildlife conservation.¹

The importance of comprehensive river basin planning has been stressed by many speakers and writers. In support of comprehensive river basin planning Henry Caulfield, Executive Director, Water Resources Council, U.S.A. gives six basic reason as follows:²

- a) Comprehensive water and related land resources planning of a river, or a regional grouping of river basins, provides the best way of inducing regional growth of population and economic activity, where water resource development is the key to growth generally;
- b) Comprehensive planning is the best way of assuring that development of water and related land resources will keep pace with and adequately support regional growth of population and economic activity;
- c) The comprehensive approach enables development of a plan, or alternative plans, over bigger geographic areas. This is particularly important where local water supplies are found to be inadequate. In other words, consideration of larger areas will often permit greater development than could take place within a more restricted area if dependent wholly upon the resources in that area.

¹ United Nations. Integrated River Basin Development. Report of a Panel of Experts. (New York: Department of Economic and Social Affairs, 1970. P.1).

² Floyd E. Dominy, "Comprehensive River Basin Planning and Development," International Conference on Water for Peace, Vol. 6, Planning and Developing Water Programme, United States Government Printing Office, Washington D.C. P.301.

d) because proposed uses of water and related land resources in a river basin normally involve both conflicts of use and opportunities for complementary action, the comprehensive river basin approach provides the means for complementary action and tends to reduce conflicts by bringing under study a wide array of alternatives and by affording the opportunity for mitigating adverse consequences over a wider area;

e) individual project plans can be put within the framework of systematic analysis of an area and, if justified, gain in credibility as feasible in the public interest;

f) a river basin plan properly prepared and presented to the public enables better communication and public discussion of proposed future uses of water resources within a basin or region.

Comprehensive river basin planning affords the best means to consider both short and long term needs. By looking ahead there may be opportunities for overall savings by including facilities during initial construction for use in future years or by the reservation of sites for future uses. Long-range basin planning will also provide the means by which future changing patterns in use with time can be recognized in advance, thus avoiding the establishment of vested rights or uses, which often tend to freeze operational plan¹.

While evidence of development of water resources by human effort has been found in early civilizations, notably in Asia and in the Mediterranean region, such development generally centred upon one

¹ Floyd E. Dominy, Op. Cit., P.302.

immediate use, with other uses incidental. Thus, in some basins, benefits to agriculture stood out above any other use of the precious water. Irrigation techniques, including regulation of the flow of water in canals, were developed at a very early period to a remarkable degree.

Use of water for mechanical power by means of water wheels to lift water for irrigation also dates from at least 3,000 years ago. In Iran Parsian wheel was developed and it was first operated manually and later by animals¹.

Improvement of rivers for navigation began in China at an ancient period. At a later date, the Romans improved many waterways and interconnected certain rivers in their lower reaches.

For thousand of years dikes have been constructed in China as a method of preventing disastrous floods. Dikes were also used by the Romans for flood protection in the river valleys. In France, in the Lowlands and in the English fens, comprehensive systems of dikes, canals and sluices came into existence at an early date. Roman civilization left aqueducts in several parts of the world as reminders of the basic importance of water in maintaining urban life².

The building of dams for the storage of water was well known in early times, but such reservoirs generally were limited in size and scope.

¹ Liaquat Hossain. "Experiences in Developing an Irrigation Project Near a Metropolitan Region" Eighth Near East-South Asia Irrigation Practices Seminar, Kabul, September 19, 1970. P.2.

² United Nations, Department of Economic and Social Affairs, Op. Cit., P.2.

and designed chiefly to store water for use in period of drought.

With the beginning of the industrial revolution water needs for irrigation, water-power, navigation, flood control and water supply experienced a sharp increase. Need for industrial water began to appear and for standards, of water purity for human use. While the needs multiplied and new projects were undertaken, the prevailing pattern remained one of building single projects to serve single purposes. Multipurpose use of water in single large projects on a wide scale is a relatively recent development stemming from technological innovations.

In 1907, the important concept of multiple use and comprehensive planning for water resources development was actively promoted for the first time in President Theodore Roosevelt's letter to the newly appointed Inland Waterways Commission. The multiple-purpose project concept has been successful in meeting local needs in an efficient manner and characterizes much of the planning and development in the United States from the early 1900's to to-day. The Bureau of Reclamation's Hoover Dam on the Colorado River has often been cited as an outstanding example of the multiple purpose project¹.

The multi-purpose project concept failed, however, in meeting total regional or basin needs. As early as 1917, the Congress of U.S.A. directed that all examination and surveys of projects relating to flood control shall include a comprehensive study of the water shed. One of the most significant early actions in river basin planning was the

¹ Floyd E. Dominy, Op. Cit., P.298.

"River and Harbours Act of 1927", which led to the so-called "308 Reports" by the Corps of Engineers. These were the first reports of a comprehensive nature concurring most of the rivers of the United States¹. The major emphasis in these reports was on the development of navigation, hydro-electric power, and flood control. They did not focus on the long term water supply and consumptive uses.

The first comprehensive regional river basin planning work was undertaken in U.S.A. by the Tennessee Valley Authority (TVA) in 1933. "T.V.A. is a federal regional agency, created with the passing of the Tennessee Valley Authority Act by the United States Congress, enacted and signed by President Franklin D. Roosevelt. This Act provided for creation of a public corporation charged with the duty to manufacture and sell fixed nitrogen fertilizer and fertilizer ingredients, to produce and sale electricity, navigability and flood control, reforestation, agricultural and industrial development, mineral resources, as well as to aid national defence. It thus includes many more important aspects of human concerns².

The original studies of the Crop of Engineers, as stated earlier, gave birth to the blue prints that have been used for carrying on the development of such areas as the Missouri River basins, the Columbia River basin, California Water Plan and many others in U.S.A.

¹ Floyd E. Dominy, Op. Cit., P.298.

² Golam Rahman, "The T.V.A. - A Programme for the Development of a Region". (Oklahoma, U.S.A.: Submitted to Professor J. Lee Rodgers in partial fulfillment of Planning 350, May, 1964. P.1).

T.V.A. has shown a new way in the development of whole river basin as a unit area. In India this approach has been adopted by the creation of the Damodar Valley Corporation for harnessing the resources of the Damodar Valley. Comprehensive Development of the Kitakami River basin in Japan was also initiated on the principle of T.V.A.

"The Tennessee Valley Authority has caught the imagination of all the people across this broad belt of Asia. They think of it as a device for insuring crops in a land where crop failures mean death from starvation. T.V.A. has also means to them increased productivity of the land, new forests, the end of erosion, modern method of farming. It means the harnessing of floods, the storing of rain water, and the installation of modern irrigation systems¹".

Comprehensive River Basin Development In India

Planning for comprehensive river basin development in India is currently at a low ebb. Over the centuries new development and techniques in water resource engineering have gone hand in hand with new techniques of management and planning. Rapid technological advance in the years since independence in 1947 has not been equalled, however, by the bold and progressive steps that are needed in comprehensive river basin planning. A pinnacle was reached in the establishment of the Damodar Valley Corporation in 1948. Since then little need has been attempted.

Undoubtedly the furthest steps in the direction of comprehensive planning by a river basin authority have been taken in India by the

¹ David E. Lilienthal. TVA Democracy on the March. (New York: Harper & Row, Publishers, 1953, P.211).

Damodar Valley Corporation. The Damodar Valley Corporation Act provides extensive power. The Corporation is to "execute and operate scheme for irrigation, the generation of power and flood control". Besides these three main purposes the corporation "will promote navigation, afforestation, public health, and industrial, economic and the general well being of the people of the valley"¹. An authority with such a general charter has the powers of a strong, regional development agency and it is not surprising that there are forces antagonistic to Damodar Valley Corporation. These have been successful in forcing a retreat. The Corporation is now being pushed back and stripped of some of its functions. These even include such water centred activities as irrigation which has been transferred to the Government of West Bengal. The D.V.C. may well be the further point ever reached by any basin authority in India in the push towards integrated and comprehensive river basin development.

In spite of relatively advance method of planning, the Damodar Valley Corporation has not been without its serious weaknesses. The area under irrigation has persistently failed to come up to expectation and the Damodar Valley Corporation's navigation canal from Durgapur to Calcutta completed in 1959 has still to be used some twelve years later.

Of the three main ideas in integrated river basin development, comprehensive development is the least essential and the least accepted.

¹ United Nations. A Case Study of the Damodar Valley Corporation and its Projects. Flood Control Series No. 16. (Bangkok: Economic Commission for Asia and the Far East, 1960, P.93).

The idea of multiple-purpose storage on the other hand is well accepted. The current debate in India centers more around the second idea of basin wide planning. This has not yet been achieved and it is the idea towards which most effort and attention be directed in the immediate future.

Regarding the proper functioning of basin wide planning, Ian Burton says "In order to have a basin wide planning a strong authority is not necessary. But in the absence of a strong authority a general willingness to cooperate for the common good must pervade the attitude of the State. This general willingness has hitherto been lacking"¹.

Damodar Valley Project

The Damodar Valley Project in India, under the Damodar Valley Corporation, has promising possibilities for the economic and industrial betterment of the Damodar basin. It is a scheme for multiple purpose development of the Damodar River and its tributaries (Map 12). There are to be seven dams in all, four of which - Tilaiya, Konar, Maithon and Panchet Hill - are included in the first phase of the scheme. The first phase also envisages construction of the Bokaro thermal station and transmission lines, and an irrigation barrage at Durgapur along with its canal systems.²

¹ Ian Burton. "River Basin Development in India". Indian Journal of Power and River Valley Development, (Issue Reviewing Indian Irrigation Practice, Calcutta, December, 1965, P.60).

² United Nations. Proceedings of the Fifth Regional Conference on Water Resources Development in Asia and the Far East. Water Resources Series No. 23. (New York: Economic Commission for Asia and the Far East, 1963, P.27).

Tilaiya Dam

This project consists of a concrete gravity type dam, 1,147 feet long with a maximum height of 95.6 feet above the river bed. The spillway located in the river section is 495 feet long, including the piers. The flow of water over the spillway will be controlled by fourteen tainter gates, each 9.6 feet high and 27.8 feet long. The power house is to have an initial installed capacity of 2,000 kilowatts in each of two units, with provision for a third unit.

Enough water will be released from the Tilaiya reservoir to provide rabi (non-monsoon) irrigation for 7000 acres and kharif (monsoon) irrigation for 13,000 acres, totalling 20,000 acres a year.

Konar Dam

This project provides for a concrete gravity type dam about 910 feet long, with a maximum height of 156 feet above the Konar River bed, and a continuous earth embankment 3,900 feet long on the right bank and 5,650 feet long on the left bank, together with a saddle dike 2,336 feet long. The flow of water over the spillway is to be controlled by nine tainter type gates, each 32 feet by 31 feet. Two under sluices, 7.3 feet in diameter are to be located in the spillway. The dam will also provide about 400 cusec of cooling water for the Bokaro power station, and irrigation for 68,000 acres of rabi (non-monsoon) crops and 36,000 acres of kharif crops. The constructions of an underground power station with a proposed capacity of 40,000 kilowatts has been postponed for the present.

Maithon Dam

The Maithon dam across the Barakar River is a composite structure, 162 feet above the river bed, partly concrete and partly earthen. The length of the main dam is to be 3,150 feet, with dikes on both the eastern and the western sides. The spillway in the concrete dam will be provided with six under sluices, approximately 9.6 feet by 5.5 feet, and twelve tainter type crest gates, 40 feet by 49 feet. The project is mainly for flood control purposes but will provide irrigation for about 270,000 acres in the lower valley. There will be an underground power station with an installed capacity of three times 20,000 kilowatts in each of three units.

Panchet Hill

The Panchet Hill project provides for a main earth dam 7,138 feet long with a concrete spillway 745 feet long and dikes on both sides. The height above the Barakar River bed to the road level is to be 129 feet. The spillway in the concrete dam is to be provided with ten under sluices, 5.5 feet by 9 feet, which can discharge 3,600 cusecs and fifteen tainter type crest gates of 40 feet by 39 feet, with a discharge capacity of 48,000 cusecs. The work is primarily for flood control on the River Damodar, but it will provide perennial irrigation to about 680,000 acres in the lower valley. There is to be a power station with an installed capacity of 40,000 kilowatts.

Bokaro Thermal Station

This comprises three units of 50,000 kilowatts each, with provision for a fourth unit of the same size. This scheme, with a

concrete barrage to provide cooling water, has already been completed.

Barrage And Irrigation

The System consists of a concrete barrage, 2,271 feet long and 37 feet high, at Durgapur, with an irrigation and navigation canal on the left bank, approximately 85 miles long, an irrigation canal 39.8 miles long, on the right bank and 1,430 miles of branch canals, distributaries and drainage channels.

The barrage will divert water, released from dams in the upper valleys through the main canals, to provide perennial irrigation to an area of 1,026,000 acres. The left bank canal will provide an alternative transport route between Calcutta and coal-fields of West Bengal.

Benefit And Costs

The scheme is expected to cost Tk.860 million. Additional benefits to be derived, apart from irrigation and power, on completion of projects under the first phase are expected to be as follows:

Extra food grains, 350,000 tons per year; extra fish, 4.13 million per year; area to be protected by flood control measures 2,800 square miles; expected cargo in river navigation 2 million tons annually.¹

The Tennessee Valley Authority In USA

A very good example of comprehensive water development is afforded by the Tennessee Valley Authority (TVA) in the United States. The TVA water control system of 1956 was composed of thirty major dams

¹ United Nations, Flood Control Series No. 16, Op. Cit., P.90.

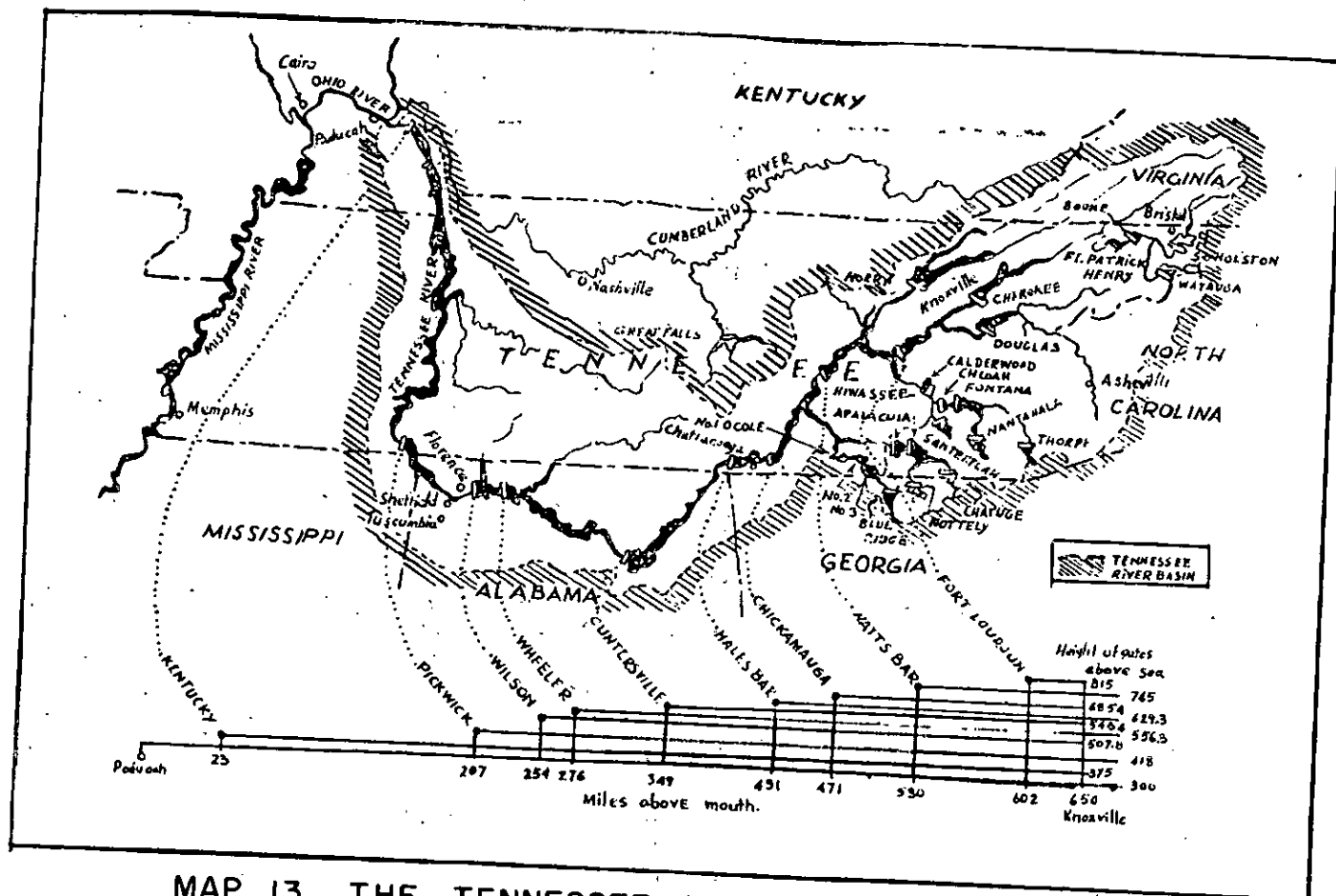
and their associated facilities lying within the Tennessee river basin (Map 13). Twenty-five of these are owned by TVA and the five which are owned by the Aluminium Company of America are operated as part of the system by agreement between that company and TVA. The combined gross storage capacity of the reservoirs behind these thirty dams is about 22.6 million acre-feet, of which about 14.9 million acre-feet are useful controlled storage. The remainder of the reservoir capacity is dead storage. A 650 mile continuous slack water navigation channel from Knoxville, Tennessee, to the river mouth is the part of the system. Hydrogeneration on the system is slightly more than 3 million K. W. installed capacity.¹

Water regulation in TVA was planned in two phases:

- (1) Seasonal or long range control
- (2) Day to day or short range regulation

The value of the system in providing flood protection was clearly demonstrated during the flood of January-February 1957. The flood resulting from 20 days of rainfall within 21 consecutive days would, if it had not been regulated, have been the highest at Chattanooga in the last 90 years, second only to the flood of 1867. The unregulated stage at the Chattanooga gauge would have crested at 54 feet. Such a flood would have been a calamity, causing damage estimated at \$66,000,000, involving the flooding of some 12,000 houses and driving many thousands of people from their homes.

¹ United Nations, Water Resources Series No. 23, Op. Cit., pp. 25-26.



MAP 13. THE TENNESSEE VALLEY AUTHORITY
WATER CONTROL SYSTEM

for the proper use, conservation, and development of the natural resources of the Tennessee River drainage basin and its adjoining territory for the general social and economic welfare of the Nation". He also said, "This Authority should also be clothed with the necessary power to carry these plans into effect"¹.

A leading English publication, "The Architectural Review", for example, devoted its entire June 1943 issue to a lengthy description and interpretation of TVA by Julian Hexley, the distinguished scientist and publicist. In a concluding paragraph he says, "Last, but not least, the TVA idea, of the planned development of natural regions such as river valleys, has already found its way into the World's general thinking. TVA ideas and methods are helping to guide the growth of new planning agencies such as the Middle East Supply Council; studies are being made of how a set up of general TVA type could be adopted to serve as an international instead of a national agency (thus among other things undercutting and transcending nationalist sovereignties, as the TVA undercuts and transcends States' rights and boundaries), and adjusted to promote the planned development of regions of greater backwardness, like parts of Africa."

TVA's development of democratic methods of consent and participation by the people also touches a desire that is widely shared. TVA is a demonstration, and one that can be readily understood, of this truth in any perspective of time, unified resource development anywhere helps

¹ House Document 565, 76th Congress, 3rd Session 1940, P.222.

everyone everywhere. A stronger, more productive Tennessee Valley region has benefited the whole American nation and all its region.

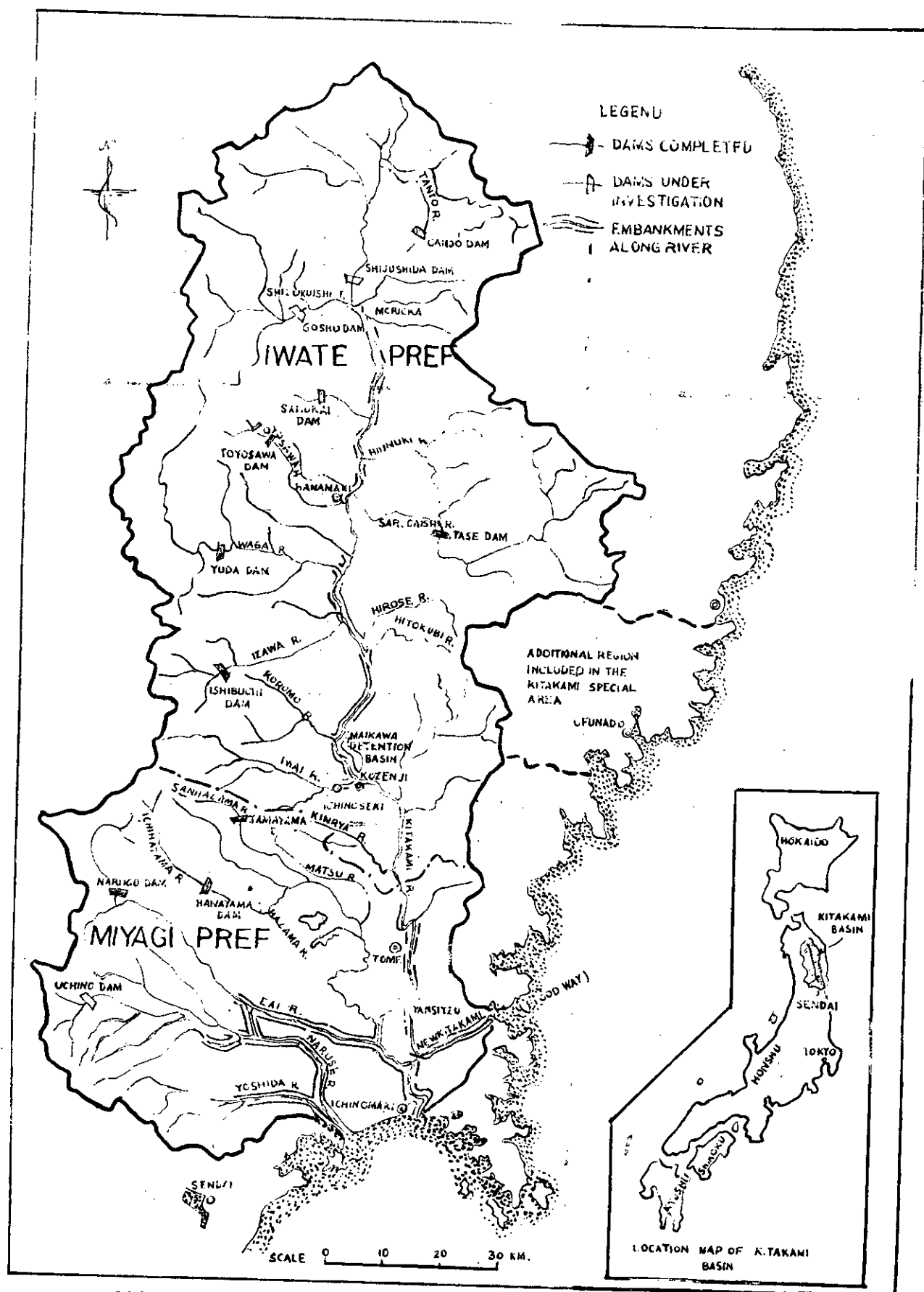
Comprehensive Development Of The Kitakami River Basin In Japan

The main objective in the development programme of the Kitakami river basin in Japan is the prevention of natural disaster, principally flood. All the major components of the solutions are related directly or indirectly to flood control. They include dams and reservoirs, embankments, bank protection, channel improvement, torrent control and soil conservation (see Map 14).

The final plan of flood control adopted in the comprehensive development of the Kitakami basin was the result of repeated investigations of floods resulting from severe typhoons that swept over the region. Flood discharges recorded at different stations, detailed studies of typhoon tracks, and careful investigations taking into consideration the effect of reservoirs helped in the establishment of the flood flow at various sections of the river. On the basis of these flood flows, the flood control works such as embankment, cutoffs and river training works were designed.

Figure 1 illustrates the master plan and the flood control scheme for the Kitakami river. The diagram shows the various reservoirs and their detention capacity as well as the natural and regulated peak flow along the tributaries and the main river. The location of the reservoirs may be seen in Map 14.

Included in the water plan of the Kitakami basin are altogether 12 reservoirs and four detention basins adjacent to an overflow levee.



MAP 14. LOCATION MAP OF THE KITAKAMI
AND THE KITAKAMI RIVER SYSTEM

Of the 12 reservoirs, 10 serve more than one purpose, and 2 are planned solely for irrigation. Of the 10 multiple purpose reservoirs, 9 serve the purposes of flood control, power generation and irrigation and the remaining one serves the dual purpose of irrigation and power.¹

The total effective storage provided for flood control in 8 multiple purpose reservoirs amounts to 8,800 million cubic feet, which has the total effect of reducing the peak discharge at the reservoir sites from 472,000 cubic feet per sec to 203,400 cubic feet per second, a reduction of 270,000 cubic feet/sec. Because of the time lag of flood peaks from different tributaries, the net effect of the reservoirs in reducing the peak discharge in the main stem of the river at Kozenji was estimated to be 70,600 cubic feet/sec. against a peak discharge of 314,000 cubic feet/sec. The Markawa detention basin adjacent to an overflow levee near Kozenji can further reduce the peak flow by 247,000 cubic feet/sec. thus bringing the flow within safe limits. The four detention basins (apart from the reservoir) have the combined effect of reducing peak flow by 68,900 cubic feet/sec.²

It is of interest to note that the total storage provided for flood control in the Kitakami, expressed in thousand cubic feet per square mile of drainage area, is only $\frac{1}{4}$ and $\frac{1}{5}$ of those of TVA and DVC respectively.

¹ United Nations, Water Resources Series No. 23, Op. Cit., P.28.

² Ibid., P.30.

The new area to be provided with irrigation by the reservoir projects is estimated 21,900 acres and an additional 99,000 acres of land will be provided with supplementary irrigation. The total installed capacity of 7 projects completed or under construction amounts to 150,900 KW and the energy generated is about 430 million KWH¹.

One of the important objectives of the plan is to provide basic facilities for industrial development in a few selected localities in the area. Such facilities include harbour, road, railway and city planning, (the last takes care of water supply). Specifically included in the comprehensive plan is water supply to Ofunada city.

The present plan presents a combination of flood control by reservoirs, embankments and river training. The lack of suitable dam sites, particularly along the main streams of the Kitakami, limits the possibility of providing additional reservoirs for flood control. Without sufficient storage, the control of flooding will have to depend on embankments to be constructed along the main river and the lower reaches of the tributaries. These embankments will have to be aligned quite close to the river owing to the shortage of land for cultivation. Because of this and of the fact that the river current in the Kitakami is swift, considerable expenditure has to be assigned to river training and bank protection works which, together with reservoirs, account for about 61 percent of the total expenditure of the comprehensive programme.

¹ United Nations, Water Resources Series No. 23, Op. Cit., P.30.

There does not seem to be a comprehensive plan covering the basin as a whole for rational utilization of the available water to meet future consumptive and non-consumptive requirements. Such a plan would normally include an analysis of area-wise distribution of the available water, its seasonal variation, the storage required and available for regulation of flow, the present and future demand for consumptive and non-consumptive uses and the ultimate and economic limits of water utilization for agricultural, industrial, domestic and other purposes. It is understood that, at present, there is hardly any serious competition among the various uses in the basin, even during low water period.

It may be pointed out that, unlike TVA or DVC, the comprehensive development of the Kitakami area is not administered by a single authority. There is a comprehensive plan, but its execution is carried out separately by ministries and prefectures acting within their normal administrative competence. Thus, the development of the Kitakami relies upon existing agencies to carry out each component of the programme, there being no central body to coordinate and supervise its day-to-day execution.

Missouri River Basin Development

The Missouri River Basin is essentially a rural economy. Agricultural enterprises provided job for 32 percent of all employed persons within the region.

The following guiding principles were followed in developing the resources of the Missouri river basin:

1. The programme should be comprehensive - for the basin as a whole and for all its land and water resources.
2. The people who will be affected by the programme should have ample and continuing opportunity to participate in the formulation and to influence the operation of the programme.
3. The combined efforts of the State & Federal Governments should be employed in carrying out the programme.
4. Goals should assure a proper balance among all the various phases of the resource programme.
5. Each project in the programme should offer total benefits in excess of all costs.
6. Costs should be borne in more direct relation to the sharing of the benefits.
7. The programme should encourage the diversified development of the basin's resources for both progressive growth and stability.
8. Each part of the programme should be flexible enough to respond to changing needs, yet specific enough to direct programme and project plan forward in a consistent course.
9. The programme should be planned and managed to achieve widespread benefits to the residents of the basin.
10. The programme should recognize the basin's limited supply of water and should be based upon a sound preference in the use of this vital asset.

In a major part of the basin the supply of water was extremely limited. Therefore, the programme gave precedence to the uses of water in the following order:

1. Domestic and municipal consumption and pollution control
2. Irrigation, including ground water recharge and industrial consumption
3. Hydroelectric power
4. Fish, Wildlife, and recreation
5. Navigation

General objective of Missouri river basin development was to enhance economic opportunity for the people of the basin, improve their welfare and enlarge their contribution to the Nation. The programme goals necessary to achieve this objective in line with the foregoing principles are as follows:

1. Watershed management and land conservation
2. Forestry
3. Flood control
4. Irrigation
5. Electric power
6. Municipal and industrial water supply
7. Navigation
8. Streambank stabilization
9. Pollution abatement
10. Mosquito control
11. Drainage
12. Fish and wildlife
13. Recreation
14. Industrial development
15. Salvaging scientific resources

Comprehensive Plan

In 1944 a plan for the comprehensive development of Missouri river basin was formulated. The plan called for construction of 90 reservoirs with a total capacity of 45,700,000 acre-feet (which is more than the annual average flow of the Missouri River at its mouth); over 100 irrigation projects to supply full irrigation for 4,760,000 acres of dryland and supplemental water for 538,000 acres; 17 power plants with an installed capacity of 758,000 KW and an annual production of nearly 4 billion KWH.¹ Local organizations in the form of irrigation district, rural electrification associations, and water conservation district were formed. A large part of this job is now completed and the plan has been expanded to include more irrigated acreage and more hydro power production.

Three departments of the Executive Branch of the United States Government were given the responsibilities for the implementation of the plan. These were the Department of War working through the United States Army Corps of Engineers, the Department of the Interior Working through the United States Bureau of Reclamation, and the United States Department of Agriculture. Each of the ten States in the basin were charged with heavy responsibility for co-operation in the plan.

After the completion of work, the Army Corps of Engineers was given responsibility for operation of major flood control structures. From the beginning, the major flood control activity was recognized as

¹ The Report of the Missouri Basin Survey Commission. Missouri: Land and Water. (Washington: United States Government Printing Office, 1953, P.34).

a completed Federal Government responsibility and not organized into local entities in the manner found desirable for minor flood control, erosion control, and irrigation.

While all of this great programme of constructing major facilities was getting underway, a vast, paralleling attack was initiated. This was aimed at minor water retention and detention structures, erosion control and water spreading on watershed land. The local people performed these treatment measures and operated and maintained the work thus built. There were organized hundreds and hundreds of soil conservation districts which implemented the techniques of water spreading, wind and water erosion control, trees planting and range revegetation - all under the technical guidance of the United States Department of Agriculture working through the Forest Service, the Soil Conservation Service and the Land Grant Colleges. This programme was intended to provide and is providing permanency to the major flood control and water storage programme previously outlined because it will hold the soil in place and slow the filling by sediments of the great water storage reservoirs. It will thus preserve the watershed, assuring stability in the upstream economy and protect the societies and huge values created downstream. These values comprise irrigation, municipal water for growing cities, hydro-electric power, recreation, and fish and wildlife.

The California Water Plan

The history of water resource development in California has largely been that of control and regulation of the supply at its source, to insure its availability when needed, and conveyance to the area where needed. Fortunately, the greater portion of the water resources of the

State so far developed and utilized has been regulated in ground water storage by nature, thus reducing the need for construction of surface storage reservoirs. The main problems of California are:

1. Unprecedented expansion in both the consumptive and non-consumptive needs for water.
2. Unbalanced distribution of its water resources and water requirements. The major sources of water are in northern California, whereas the major urban areas and productive agricultural lands are to the south, in which only 30 percent of the total natural run-off occurs. About 70 percent of the total stream flow occurs to the north of the latitude of Sacramento, but 77 percent of the present use of water and 80 percent of the forecast ultimate use lie south of that latitude;¹
3. Large variations of run-off within the season and from year to year and periodic droughts;
4. Periodic floods from rivers and stream throughout the State, particularly in the valleys and flood plains where most of the 14 million population live, resulting in major damage to property and loss of life;
5. Need for the provision of peaking energy by an extensive development of hydro-electric power.

California is thus faced with serious problems both of flood control and of meeting the requirements of areas suffering from water deficiency.

¹ Joe, S. Bain, Richard, E. Coves, and Julius Margolis. Northern California's Water Industry (Baltimore, Maryland, U.S.A.: John Hopkins Press, 1966, P.720).

The plan was formulated in what is known as the Central Valley Project, the principal units of which are:

1. The Shasta Dam located on the Sacramento River for the storage and regulation of water supplies in the areas of origin. The dam is a concrete structure 602 ft. high, impounding 4½ million acre-feet.
 2. A few miles downstream is located the Keswick Dam, a much smaller installation, which regulates and balances the water released from the Shasta Dam.
 3. Some 30 miles downstream from Sacramento, the delta cross channel provides for the regulated passage of Sacramento River water through the delta channels to the Tracy Pumping Plant. During this passage, a portion of the water is utilized to stem the inflow of salt water from the ocean into the delta, and an additional portion is taken into the Contra Costa Canal.
- At the Tracy Pumping Plant, six 84 inch centrifugal pumps, each with a capacity of about 340,000 gallons per minute, lift the water 196 ft. above sea level and discharge it into the Delta-Mendota Canal.¹
4. The Delta-Mendota Canal, with an initial capacity of 4,600 second feet, skirts the San Joaquin Valley through its western foothills for a distance of 120 miles to discharge its water into the San Joaquin River at Mendota in order to set free the water of this river.

¹ United States Department of the Interior. Tracy Pumping Plant and Intake Canal and Discharge Lines. Technical Record of Design and Construction (Denver, Colorado, U.S.A.: Bureau of Reclamation, May, 1959, P.51).

5. By this exchange of water, almost the entire flow of the San Joaquin River can be stored behind the Friant Dam for diversion north and south to land in the San Joaquin Valley.

6. Millerton Lake, formed by the Friant Dam with a capacity of 520,000 acre-feet will regulate floods and store San Joaquin River runoff for diversion into the Madera and Friant-Kern Canals.

7. Madera Canal will divert water northerly from Millerton Lake to furnish a supplemental irrigation supply to the Madera irrigation district and the Friant-Kern Canal will divert water southward from Millerton Lake for irrigable areas with deficient water supplies.

8. The Trinity River Dam to divert surplus water from the Trinity river to the Sacramento River for use in the Central Valley.

Plan's Physical Accomplishments

a. About 376 new reservoirs throughout the State with a total gross storage capacity of about 77 million acre-feet are to be added to the 20 million acre-feet of storage capacity in existing reservoirs. Out of this, 282 would be conservation reservoirs, 30 would be operated primarily for power generation, 60 would serve as regulatory diversion reservoirs and 4 would be operated solely for flood control.¹

b. New hydro-electric power generating facilities in connection with water development works, with a total installed capacity of about 7,800,000 KW and a seasonal energy production of about 34 billion KWH.²

¹ Department of Water Resources, "Implementation of the California Water Plan", Bulletin No. 160-66, Appendixes A through F, August, 1967, P.F-20.

² Ibid.

c. Pumping installation with an aggregate installed capacity of about 12,300,000 KW and a seasonal energy requirement of about 49 billion KWH.¹

Thus it will be seen that this master plan has been conceived as a comprehensive plan to meet the requirements for water when the land and other resources of California have reached a state of virtually complete development. It is a flexible pattern which is susceptible of development by logical and progressive stages to meet the growing demands of the State and into which future definite project may be integrated in an orderly fashion.

¹ Department of Water Resources, "Implementation of the California Water Plan," Bulletin No. 160-66, Appendixes A Through F, Op. Cit., P.F-20.

CHAPTER VIII

A PLAN PROPOSAL FOR COMPREHENSIVE WATER DEVELOPMENT FOR BANGLADESH

Previous Proposals By International Experts

There have been several investigations by international experts of the problem of floods and water resources development in Bangladesh. They are in substantial agreement about the causes of the problem and its solution. Krug Mission Report, General Hardin's Report, Professor Thijsse's Report, Master Plan of EPWAPDA for Water Development of Bangladesh prepared by the International Engineering Co. Inc. and NEDECO report on Inland Waterways and Ports of Bangladesh are the principal proposals.

Krug Mission Report

A high level United Nations Technical Mission, known as the Krug Mission, carried out in 1956 a detailed investigation into the general question of Water resources development in Bangladesh. Its report presented in 1957 dealt with the history, causes, frequency, magnitude, and effects of floods, and the practicability of various methods of protection against flood damages in Bangladesh. It stated that artificial retention storage is beyond reach, and that embankments, diversions or flood escapes, and channel improvements can help but may also have adverse effects and create recurring liabilities. Recommendations were generally limited to suggestions for further studies, but the report did state that the only available method of reducing the flooded area is confinement of floods to the river channels.

General Hardin's Report¹

The report of February, 1963, by General John R. Hardin, a former Chairman of the Mississippi River Commission, closely paralleled the findings of the Krug Mission in the analysis of flooding in Bangladesh and possible means of mitigating the damage from floods. General Hardin's report stated that flows of 2,500,000 cubic feet per second in the Ganges and 3,000,000 cubic feet per second in the Brahmaputra are considered reasonable expectations, and peaks could coincide as in 1962. In addition, it was stated that embankments and channel improvements to increase flood capacity usually benefit navigation. The report proposed channel improvements and confinement of rivers by embankments to give full protection against the flood to be expected once in 10 years on the average. Sluices and fuse plug sections in the embankments would be provided to take off the load from the embankments when this flow is sufficiently exceeded. Such an approach recognised the need for an immediate start on protective measures, despite the paucity of data. A high degree of protection should be considered, when more will be known regarding discharge, storage, cross sections, etc.

Professor Thijsse's Report²

A study of the hydraulic situation in Bangladesh was made by Professor J. Th. Thijsse of the Netherlands in May, 1964. This report presents an analysis of distribution of flood to be 2,200,000 cfs in

¹ John R. Hardin, "Flood Control of East Pakistan". Wittman, Maryland, February, 1963, PP.1-33.

² J. Th. Thijsse, "Report on Hydrology on East Pakistan", Co-operative Book Society Ltd., Dacca, May, 1964-1966, PP.1-58.

the Ganges, 2,600,000 cfs in the Brahmaputra and 500,000 cfs in the Meghna. Professor Thijsse rules out reservoir storage for reducing flood stages, and suggests that the existing distributies be maintained as long as possible. Channel improvement and embankments are discussed as means of reducing flood hazards. It is not considered feasible to regularise flood flows in rivers of such great size as those crossing Bangladesh.

Master Plan Of The Then EPWAPDA For Water Development Of Bangladesh Prepared By IECO¹

Master Plan of the then EPWAPDA for Water Development of Bangladesh was completed in December 1964 by the International Engineering Company Inc. of Sanfrancisco, California, U.S.A.. In the Master Plan it is assumed that there is no possibility of controlling the magnitude of the flood flows by head water storage, and diversions to reduce flood peaks appear to be impractical. In Bangladesh flood control should be interpreted as control of the effects of flood flow in the sense of providing protection against damage.

Embankments along the rivers to prevent over-bank flow are clearly the first step in flood control, and because of the way the flat delta is interlaced by rivers, entire areas must be encircled by embankments to prevent inundation. To prevent flooding by heavy rainfall, pumps will be installed expect along the coast, where sluices will remove the excess water. Each encircled area becomes a project of

¹ International Engineering Company Inc. "Master Plan, East Pakistan Water and Power Development Authority", Vol. II, San Francisco, U.S.A., December, 1964, PP.183 - 374.

the Master Plan, and planning is such that, as projects of this type are completed, the river will become almost fully confined between embankment and the flood flows will be confined to wide river channels. Confinement will raise the river levels during floods, and the flood peaks will not be so flat after much of the storage on project lands has been removed, but preliminary calculations shows that the rise will be within acceptable limits.

These flood protection projects will give large benefits, not only in the prevention of damage but in the production of more food. At present broadcast aman rice is grown on these flooded land. This crop, which occupies the land from March to December, has a low yield. With flood protection, it can be replaced by two rice crops, Aus followed by transplanted Aman rice, both of which have higher yields.

Along the coast, the area is divided by the rivers into inland islands which are inundated by the highest tides. The resulting salinity causes low crop production. These areas are being improved by encircling them with low embankments to prevent flooding and by providing automatic sluices to remove excess rainfall.

It is planned that eventually most of the agricultural lands will be irrigated by surface or by ground water, with development schedule as production is needed.

Hydro-electric power will be developed wherever it is feasible, but this will be insignificant in the power programme and will contribute little to the financing of irrigation projects.

The main objective of the Master Plan of the then EPWAPDA for Water Development of Bangladesh was to increase food and hydro-electric power production. Use of water for other purposes such as navigation, recreation, fisheries development, wild-life preservation etc. has not been given due consideration in the plan. Regional aspect of water resource development had not also been considered in the Master Plan. Individual project has been developed only considering the hydrological condition of the area. Attempt has not been made to integrate one project with the other project to fit in the over-all Master Plan of water resources development of the country. These deficiencies of the Master Plan most probably were due to non-inclusion in the term of reference all the above items of works.

NEDECO Report On Inland Waterways And Ports¹

Netherlands Engineering Consultant (NEDECO) studied the hydrology and morphology of rivers of Bangladesh very thoroughly with a view to improve the waterways and inland ports of this country. They submitted their reports to the erstwhile EPIWTA in 1967. They have recommended local improvement of the rivers through different means, for example, by groynes or training walls for sufficiently stable rivers and temporary means such as bandalling, dredging etc. for unstable rivers. They have discouraged permanent general improvement of big rivers, as it is neither suitable nor justified from economic point of view. However, they have recommended general

¹ EPIWTA, "Survey of Inland Waterways and Ports, Vol. I, General Report", Netherlands Engineering Consultants, The Hague, Holland, July, 1967, PP.1 - 56.

improvement for short reaches of rivers like Lakhya, Buriganga, Bhairab, Hurasagar etc. The recommendations made by the NEDECO are worth considering for the improvement of the waterways in Bangladesh. Drawback of the NEDECO report is that it only considered the improvement of waterways within Bangladesh and the international aspect of our waterways had not been dealt with probably because it was not included in their terms of reference.

Proposals By Experts Of Bangladesh

There have also been several investigations by the water resources experts of Bangladesh regarding the problem of flood and water resources development. Their studies are very interesting and can be used as guide in future planning of Water Resources for the Regional Development of Bangladesh. The following investigations of the experts as noted against their name are very remarkable:

- a) Utilization and Development of Deltaic Area of East Pakistan by B. M. Abbas . . .
- b) Protection of East Pakistan Against Flood and Cyclonic Surges by A. M. Md. Ghulam Kibria.
- c) An Approach to Water Development by B. M. Abbas . . .
- d) Flood Control Plan of East Pakistan by Planning Department, Government of East Pakistan.
- e) Resuscitation of the Waterways of Bangladesh and the Future by A. M. Md. Ghulam Kibria.
- f) Flood Control and Water Resources Development in Bangladesh by M. R. Tarafder.
- f) Planning for Flood Control in Bangladesh by B.M. Abbas.

Utilization And Development Of The Deltaic Area Of East Pakistan by
B. M. Abbas¹

This article was written by Mr. B. M. Abbas for presenting in the proceedings of the Regional Symposium on Flood Control, Reclamation, Utilization and Development of Deltaic Areas, held at Bangkok, Thailand, 2 to 9 July, 1963. He advocated for prompt utilization and development of Bangladesh's deltaic area. He said that the land of the country is fertile, the climate ideal for multi-cropping and the combination of copious rainfall, mighty rivers and ground waters creates one of the world's greatest natural system.

As the upper catchments of all major rivers lie outside Bangladesh and there is no suitable reservoir sites within its borders, except in the Chittagong Hill Tracts, so he preferred to divert flood flows, affect channel improvements, provide protective embankments, and pump monsoon drainage for flood protection. He advocated for large scale flow irrigation, pump irrigation and tubewell irrigation in Bangladesh.

In order to protect the land from saline tides, most of the low cultivated lands in the coastal areas of the country must have protective embankment. The drainage of enclosed polders must be effected by regulating sluices installed in these embankments.

Navigational improvement aspect should be incorporated in water resources developments of Bangladesh, as it is the cheapest

¹ B. M. Abbas, "Utilization and Development of the Deltaic Area in East Pakistan" Proceedings of the Regional Symposium of Flood Control, Reclamation, Utilization and Development of Deltaic Areas, Water Resources Series No. 25, Economic Commission for Asia and the Far East, United Nations, New York, 1963, PP.133 - 151.

mode of transportation. Wherever feasible, hydro-electric generation facilities will be included as part of water control schemes. He also recommended to study the feasibility of generation of tidal power in the completed portion of Coastal Embankment Project area.

Protection Of East Pakistan Against Flood And Cyclone Surges by
A. M. Md. Ghulam Kibria¹

This article of Mr. A.M.Md. Ghulam Kibria appeared in "the Pakistan Engineer" a monthly journal of the then Institute of Engineers, Pakistan, in the 15th Annual Convention Issue, 1969 and it was read by the author in the technical session of the convention. Mr. Kibria envisaged that the problem of flood and cyclone surges could be solved by:

- a) Constructing embankments along the principal rivers and estuaries for a length of 4000 miles in addition to what have already been constructed by WAPDA.
- b) Providing necessary drainage regulators to drain the protected areas.
- c) 3000 miles of the principal drainage channels must be dredged to proper cross-sectional area to drain sufficient water.
- d) All the 20 or so estuaries of Bangladesh must be closed by enclosure dams (with necessary tidal sluices) for drainage of the upland flood flow and lockgates for

¹ A. M. Md. Ghulam Kibria, "Protection of East Pakistan Against Floods and Cyclonic Surges", The Pakistan Engineer. Monthly Journal of the Institute of Engineers, Pakistan, 15th Annual Convention Issue, Dacca, 1969, PP. 529 - 571.

navigation) as is being done in the Netherlands in connection with the Delta Plan.

An Approach To Water Development By B. M. Abbas¹

This article of Mr. B. M. Abbas . . has been published in November, 1964 issue of "the Pakistan Engineer" a monthly journal of the Institute of Engineers, Pakistan. The author proposed to mitigate recurring flood damages through protection by means of river embankments and through lowering of flood levels by channel improvement by dredging. River training works and stabilization of the river banks were also envisaged by the writer.

He advocated extensive development of irrigation from sub-surface water by means of tube-wells. This will reduce the demand of large scale withdrawal of water from the rivers in the dry season. This will help in navigation and reduce the intrusion of salinity during the dry season. Implementation of pumps as well as barrage projects for large scale irrigation was also envisaged by him.

Flood Control Plan Of East Pakistan By Planning Department,
Government of East Pakistan²

This flood control plan of Bangladesh was prepared in August 1968 by a Committee formed by the Planning Department, Government of then East Pakistan.

¹ B. M. Abbas, . . , "An Approach to Water Development", The Pakistan Engineer, Monthly Journal of the Institute of Engineers Pakistan, Vol. — 4, No.11, November, 1964, PP.503 - 505.

² Government of East Pakistan, "Flood Control Plan of East Pakistan", Planning Department, Dacca, September, 1968, PP. I-1 to IX-1.

The Committee recommended the following measures for the control of Flood in Bangladesh:

1. Construction of Embankments.
2. Improvement of existing channels by dredging.
3. Opening of off-take of spill channels by dredging.
4. Protection of cities and towns by embankment, bank protection work and pump drainage etc.
5. River Training.
6. Estuarine works - Closure of estuaries with tidal sluices.

Resuscitation Of The Waterways Of Bangladesh And The Future by
A. M. Md. Ghulam Kibria¹

This article was read by Mr. A.M.Md. Ghulam Kibria in a symposium of the Institution of Engineers, Dacca, Bangladesh in July, 1972. He indicated that the resuscitation of the dead waterways of Bangladesh (and also West Bengal) simply by diverting the flow of the existing channels would be of no use. This would create more problem and might be more harmful than good. According to him the correct approach would be to prepare a Master Plan covering entire Bangladesh and West Bengal, utilising the existing and dead rivers for regional development of water resources i.e. to tackle with the overall problem of drainage congestion and flooding during the monsoon as well as to improve inland navigation and irrigation during the low water period. Accordingly he suggested the following

¹ A.M.Md. Ghulam Kabria, "Resuscitation of the Waterways of Bangladesh and the Future", Symposium of the Institution of Engineers (Bangladesh), Dacca, July 1972, PP.1 - 18.

hydro-technical works to be taken up in order of priority:

1. Barrages across (a) the Brahmaputra at Bahadurabad, (b) the Ganges at Hardinge Bridge, (c) the Tista at Gaddimari, (d) the Meghna at Bhairab Bazar.

All the above barrages along with the Farakka Barrage in West Bengal and the proposed storage dams in the upper catchments of Ganges and Brahmaputra will form the main backbone of the water control and distribution.

2. Marginal embankments may be constructed along the Brahmaputra, the Ganges, the Padma, the Madhumati, the Meghna, the Tista and other tributaries wherever such dyking will minimise flooding and improve drainage of the protected areas. He also advocated pump drainage specially in the low lying areas of Rajshahi. Sylhet Hoars may be tagged with the Coastal Embankment Project for draining.

3. Training of the principal open rivers by bank stabilization and dredging wherever needed as well as improving the drainage condition within the protected areas by dredging and canalising the dead and dying rivers which will form the main drain-cum-navigation routes during the monsoon and irrigation canal-cum-navigation routes during the low water period.

4. Estuaries which do not tap fresh water from the North and are essentially saline channels during most of the year may be closed gradually. Ultimately all the estuaries will have to be closed with provision of gigantic tidal gates to tackle with the up-land drainage. Diversion of required quantity of low water flow

from Brahmaputra catchment to the same of the Ganges and Tista may be made possible by excavating a canal from Bahadurabad to Rajshahi via North-Western Zone of Bangladesh.

Flood Control And Water Resource Development In Bangladesh By
M. R. Tarafder¹

Mr. M. R. Tarafder, presented this article in August 20, 1972 in the Institution of Engineers (Bangladesh), Dacca in a seminar on Flood Control and Water Resources Development in Bangladesh, sponsored by the Ministry of Flood Control and Water Resources, Government of People's Republic of Bangladesh. The author classified the flood control measures into two groups: (a) Structural measures and (b) Non-structural measures. Flood control by structural measures include storage reservoirs, embankments or levees, channel improvement and bypasses or floodways. Non-structural measures of flood control consist flood forecasting, warning and evacuation, flood proofing, land management, flood plain zoning and flood insurance.

While talking about structural measures Mr. Tarafder advocated for construction of storage reservoirs in the upper catchments as a means of mitigation of flood hazards downstream. Co-operation with upper riparian neighbours is essential for successful implementation of reservoir projects. A few barrages may also be constructed inside Bangladesh like the Brahmaputra, Ganges, Meghna, Tista, Gorai barrages and others for flood control, navigation and augmentation

¹ M. R. Tarafder, "Flood Control and Water Resource Development in Bangladesh", Seminar on Flood Control and Water Resources Development in Bangladesh, Ministry of Flood Control and Water Resources, People's Republic of Bangladesh, August 1972, PP 1-19.

of low flow from irrigation. Embankment or levee should also be constructed for the regulation and control of flood in Bangladesh. Channel improvement by dredging, river training and cut-off, may be done only in smaller rivers. He suggested not to construct bypasses or floodways as it would create more flood problem down stream of the channel.

As the implementation of structural measures will take a long time, so he advocated for taking immediately non-structural measures. He is of the view that even after construction of flood control works, need for non-structural measures, such as flood forecasting, warning, evacuation, flood proofing, flood plain zoning, land management, flood fighting, community preparedness and flood insurance would be required.

Planning For Flood Control In Bangladesh By B. M. Abbas¹

This article has been presented by Mr. B. M. Abbas on the 21st August, 1972 in the Institution of Engineers (Bangladesh), Dacca, in a seminar on Flood Control and Water Resources development in Bangladesh, sponsored by the Ministry of Flood Control and Water Resources, Government of the People's Republic of Bangladesh. Though the author advocated for storage reservoir for the control of flood in Bangladesh, yet he is doubtful about the capability of the Indian reservoirs in eliminating the flood in Bangladesh. He

¹ B. M. Abbas, "Planning for Flood Control in Bangladesh", Seminar on Flood Control and Water Resources Development in Bangladesh, Ministry of Flood Control and Water Resources, People's Republic of Bangladesh, August, 1972, PP.69 - 75.

suggested to divert part of the flow of Jamuna through Old Brahmaputra and diversion of the Ganges flood water through its old distributaries.

He said that embankment constituted the most practical method of flood protection. Economic studies would show that embankments are the cheapest form of flood protection work, as they could be raised according to the need and relocated as per requirement of meandering rivers. He also advocated for pump drainage of low lying depressions specially in Sylhet area.

In conclusion Mr. Abbas suggested to implement at least the following programmes in the flood and water control sector in Bangladesh:

- (a) River Control;
- (b) Drainage and Irrigation;
- (c) Estuary Closures and Land Reclamation.

Finally the author advocated to relate the water plans for Bangladesh to a comprehensive land and water development programme for the entire Ganges-Brahmaputra system. He is of the view that long term planning for major rivers basins would take time, so the problem of the smaller rivers could be tackled immediately.

International Water Aspects

Almost all the rivers and streams of Bangladesh have their headwaters outside the country. Furthermore, with the exception of the Maghna river, the main rivers derive only a negligible proportion of their flow from runoff within Bangladesh. In these circumstances it is inevitable that major problems arise in connection with the development of the resources of these international rivers. Although immediate problems relate essentially to the Ganges, in the future other rivers will certainly be involved. This applies not only to major rivers but also to minor rivers and water courses.

Here we considered the international water problems from three points of view.

- a) Legal aspect of water right of international rivers.
- b) Influence that on-going future developments in India may have on the discharge and behaviour of the systems in Bangladesh.
- c) Extent to which Indian development might prejudice future water, navigation and agricultural programmes in Bangladesh.

Legal Aspect Of Water Right Of International Rivers

"The water right is a property right. It is a valuable right. And it is real estate. The holder of a water right in an area in which competition for water is keen need to be constantly on guard to protect his right against infringement or loss. It is said that

'Eternal vigilance is the price of a good water right'.¹ According to international law a State is forbidden to stop or divert the flow of a river which runs from its own to a neighbouring State but likewise to make such use of the water of the river as either causes danger to the neighbouring State or prevent it from making proper use of the flow of the river on its part. Moreover, each basin State is entitled, within its territory to a reasonable and equitable share in the beneficial uses of waters of an international drainage basin.

In international law, as an upper riparian, India has well-defined legal obligation towards the lower riparian Bangladesh. The flow of international rivers is not within the arbitrary power of one of the riparian States. No State is allowed to alter the natural conditions of a territory of a neighbouring State. For this reason a State is not only forbidden to stop or divert the flow of a river which runs from its own to a neighbouring State but likewise to make such use of the water of the river as either causes danger to the neighbouring State or prevents it from making proper use of the flow of the river on its parts.

Influence That On-going And Future Developments In India May Have On The Discharge And Behaviour Of The Systems In Bangladesh

The on-going major projects and medium projects over 50,000 acres in the Ganges Basin of India are listed in Table 8 of the total

¹ Wells. A. Hutching. Irrigation Water Rights in California Circular 452 (Revised). (California, U.S.A.: Division of Agricultural Science, University of California, February, 1967. P.54)

of 13.66 million acres.¹ It is not known what proportion has already been developed. It is understood, however, that in most cases, the land development and hence effective irrigation lags seriously behind the main civil engineering works (dams, barrages and main canals). If priorities are therefore correctly assigned to the development of irrigation distribution system a large growth in irrigated areas will occur in the 1970's. It will be noted that about two-thirds of the total areas of these on-going project are on the lower tributaries - Gora, Gandak, Kosi and Sone. Of these the first three, are believed to contribute a large portion of the dry season flows that still reach Hardinge Bridge. As developments proceed in the basins of these northern tributaries, there is likely to be continual pressure from the local people who will wish to make use of the valuable dry season flows. The scarcity value of water in the dry season will be raised by the poor opportunities to construct storage reservoirs. This situation may not only give rise to conflict of interest with Bangladesh but also with the proposed operation of the Farakka Barrage.

The rate of progress of the on-going and new projects over the next ten years is largely a matter of conjecture but it is not unreasonable to assume that it will be at least one-half million acres per year. If the capacity of the canal head works is designed at about 7 cusecs per 1,000 acres gross, the total diversion capacity would thus grow at the rate of 3,500 cusecs per year or by 35,000 cusecs over the next ten

¹International Bank for Reconstruction and Development. International Development Association. Bangladesh Land and Water Resources Sector Study. Vol. VII. Water Technical Report No. 22. International Water Aspects. (New York: Special Project Department, May 15, 1972, P.3).

T A B L E 8

IRRIGATION PROJECTS IN GANGES
Basin in India

Name of Scheme	River	Storage Capacity of Reservoir MAF (Live)	Potential Irrigation Area '000 acres	Construction Period
<u>UTTAR PRADESH</u>				
<u>Major Projects</u>				
Matatila	Betwa	0.63	410	1952/66
	(including 112,000 acres in Madhya Pradesh)			
Sarda Sagar	Chanka	0.34	185	1959/62
Ramganga	Ramganga	1.60	1645	1961/74
Western Gandak	Gandak	Nil	558	1961/74
Lower Sarda (Improvement)	Groga	Nil	1500	1968/80
<u>Large "Medium" Project (Over 50,000 acres)</u>				
Daiman Pumped Canal Stage I			154	
Bhopanli Pumped Canal			60	
Zamania Pumped Canal			60	
Tons Pumped Canal			130	
Narainpur Pumped Canal (approved project)			60	
Sub-Total			4,862	

Name of Scheme	River	Storage Capacity of Reservoir MAF (Live)	Potential Irrigation Area '000 acres	Construction period
<u>BIHAR</u>				
<u>Major Project</u>				
Badua	Badua	0.89	105	1958/66
Sone Barrage (including high level canal)	Sone	Nil	734 Stabilization 124 New	1966/74
Kosi	Kosi	Nil	2,600	1957/80
Gandak	Gandak	Nil	2,845 (Bihar)	1960/80
Chandan	Chandan	0.11	174	1961/74
Large "Medium" Projects (over 50,000 acres)				
None				
Sub-Total			6,700	
<u>MADHYA PRADESH</u>				
<u>Major Project</u>				
Chandi-Sagar	Chambal	5.61	50 (Via Kotah)	1954/ (Dam completed 1960).
Barna	Barna	0.33	149	1960/74
Medium Projects (over 50,000 acres)				
None				
Sub-Total			699	

Name of Scheme	River	Storage Capacity of Reservoir MAF (Live)	Potential Irrigated Area '000 acres	Construction Period
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RAJASTHAN

Major Projects

Kotah Barrage	Chambal	Nil	50 (Madhya Pradesh)	
			50 (Rajasthan)	
Rana Pratap Sagar	Chambal	1.27	150 (Madhya Pradesh)	
			150 (Rajasthan)	

Medium Project (over 50,000 acres)

None

Sub-Total	1,400
Total	13,661

Sources: International Bank for Reconstruction and Development.
International Development Association. Bangladesh Land
and Water Resources Section Study Vol. VII. Water.
Technical Report No. 22. International Water Aspects.
(New York: Special Project Department, May 15, 1972,
Table 4).

years. Such a potential incremental diversion of flow is small compared with the mean monthly flows from July to November but is about 40% of the mean dry season flow at Hardinge Bridge. Although it does not follow that such a large diversion would be feasible in the dry season, the opportunities for using dry season flows would clearly become potentially large.

Farakka Barrage

Farakka Barrage was scheduled to come into operation by the end of March, 1974. But in the last meeting of the Prime Ministers of both the countries in April, 1974, it was decided that the possibilities of augmentation of dry weather flow by constructing storage reservoirs on the Ganges should be examined by the Joint Rivers Commission. After the completion of this study it will be decided by the Government of Bangladesh and India, the schedule date of operation of the Barrage. The headworks to the Bhagirathi are designed to divert about 40,000 cusecs but the mode of operating the scheme is not yet decided. At one stage, it was claimed that the barrage would merely be used to augment the ebb flow to the tide in the approach to Calcutta by the diversion of water through the Bhagirathi into the Hooghly estuary. In this way, it was claimed, the ebb flow would be augmented by about 10%¹ above its present flow of 40,000 cusecs. The augmented ebb flow would thus approach the flood flow and hence balance the sediment transport in and out of the Hooghly. Now it is understood a more complex mode of operation is proposed whereby the tidal wave transient would be

¹ International Bank for Reconstruction and Development. International Development Association. Vol. VII. Technical Report No.22. Op.Cit.P.4.

modified in a manner that would reduce the amount of inward sediment transport.

Some Indian agencies feel that such large diversion of the Ganges dry season flow should not be allocated to the purpose of sedimentation control in the Hooghly when it might be used to better advantage in the irrigated areas, especially in the Gandak Sub-Basin.

The most important factor on which information is lacking at present concerns the manner of operating the barrage during periods of critically low flow. Although there is some dispute on the flows recorded at Hardinge Bridge, it is recognized that the dry season flow fell as low as 42,000 cusecs at the end of April, 1953 and has been below 60,000 cusecs on nine occasions since 1934 (1935, 1936, 1937, 1941, 1942, 1947, 1953 and 1954). An important aspect of the Farakka Scheme to Bangladesh is the proposed method of operation of the barrage during these critical periods.

The immediate effect by the Indian withdrawals of the Ganges water at Farakka would be a sharp fall of water level in the river in Bangladesh in the low water season reducing the amount of critical fresh water supplies to spill channels like the Gorai, Ichamati, Kumar, Nabaganga, Madhumati, Bhairab, Atharabanka etc. This reduction of flow have a drastic effect not only on inland navigation, agriculture, fishery, forestry but also on the salinity which will creep up further inland.

Brahmaputra Basin

Of the total cultivable area of Assam amounting to 7.72 million acres, it is stated that 1.50 million acres receive irrigation mainly on minor schemes. Medium schemes totalling 162,000 acres existed prior to 1950. Another 40,000 acres was added to the irrigated area by 1969¹.

The potentially irrigable land of Assam has been stated to amount to 4.15 million acres². In this area, if irrigation is practiced at a rate of 60 acres per cusec, than about 70,000 cusecs would be required.

In view of the on-going schemes in Assam it is unlikely that the rate of expansion in the near future will exceed 20,000 - 30,000 acres a year.

The effects of Indian development in Assam on the Brahmaputra flows are less immediate and of small consequence than on the Ganges. They are, nevertheless, important to the long-term planning of developments in Bangladesh for the period beyond about 1985.

It is anticipated that the emphasis on Brahmaputra development in Assam will remain on flood control for some years to come. India is approaching rapidly to the stage when the Brahmaputra and its main tributaries are fully contained within marginal embankments. This will have great adverse effect by increasing the monsoon peak discharges and hence also river flood levels in Bangladesh. Indian flood control

¹ International Bank for Reconstruction and Development. International Development Association. Vol. VIII. Technical Report No. 22 Op.Cit., P.7.

² Ibid. P. 7.

programme will increase the amount of sediment transport reaching Bangladesh. This will cause navigation through Brahmaputra in Bangladesh, specially in dry season more difficult. Any depletion of Brahmaputra flows in the dry season will further accentuate the problem of saline intrusion in the delta area discussed in connection with the Ganges.

Extent To Which Indian Development Might Prejudice Future Water, Navigation And Agricultural Programmes In Bangladesh

Indian developments in the Ganges Basin will seriously reduce the amount of dry season flow entering Bangladesh. Apart from Farakka Barrage, diversion of 40,000 cusecs down the Bhagirathi-Hooghly, there will be strong pressures within India to permit greater use of the dry season flows for irrigation. The proposed Farakka diversion alone represent a potential difficulty for the successful operation and development of the Ganges-Kobadak Project, if India is to abstract 40,000 cusecs regardless of the residual flow. In some years during April and May this would leave only a negligible flow in the Ganges and even if sufficient to supply the Ganges-Kobadak pumping units, there would be problems of maintaining water depth at the pump intakes.

The effect of Farakka Barrage will be ruinous on agricultural crops, cattle production and farm labour in the region. With the withdrawal of Ganges water at Farakka, the river flow which keeps down intrusion of saline water will drastically reduce, thus creating conditions for advancement of salinity further inland. The present cropped areas will suffer and the agricultural economies of the entire

area will be drastically affected. Areas in Khulna, Barisal and Patuakhali districts will be severely damaged and the present unaffected areas of Jessore and Faridpur districts will face crops damage due to ingress of saline water.

The large withdrawals of river supplies at Farakka will lead to an abrupt lowering of the water table not only in the districts of Khulna, Barisal, Patuakhali, Jessore and Faridpur but also in the districts of Kushtia, Rajshahi and Pabna. This lowering of water will have damaging effect on Boro, sugarcane, pulses, oil seeds, spices and seasonal vegetables and fruits. The damages are expected to occur immediately but cumulative long-term effect will be more severe.

Reduction of low water discharge in the Ganges will give rise to another serious problem i.e. lowering of the groundwater table. This will affect the agricultural production specially the robi crops.

The main source of protein for the people of Bangladesh is cattle and fish. Livestock, dairy and poultry products are second only to rice in value if fish is excluded. The cattle population not only supplies protein and other nutritious food but they also serve as work animals in land cultivation. The cattle population of Bangladesh will suffer due to non-availability of fodder due to lowering down of the groundwater table.

The people of Bangladesh earn their livelihood, mostly through cultivation, whether it be in the form of agriculture produces or in the form of farm labour. If the cultivated land becomes uncultivable,

a huge number of farm labour will become unemployed.

Bangladesh is well known for its fish wealth. Fish is of vital importance to the diet of the people of Bangladesh. This region is endowed with vast inland water resources in the form of large rivers, streams, canals, bils, etc. The Ganges system provide an area of about 13 million acres of land, rivers and streams, which is about 37 percent of total area in Bangladesh. This area is dependent on river Ganges for supply of water and abound with more than a hundred species of fish as well as twenty one species of shrimps and prawns, all or most of which provide food for the people. Of the commercially important fish varieties, the most significant and important fish is "Hilsa" which travels up the Ganges for breeding. The catching and marketing of fish provides means of livelihood to thousands of fishermen and dealers¹.

With the operation of Farakka Barrage by India, the hydrographic conditions in the lower reaches of the river Ganges & its distributaries will suffer violent alternations physically, chemically and biologically. These alternations will alter the migration and breeding of the Hilsa very adversely. The Farakka Barrage will stop the movement of Hilsa up the river and will lead to gradual extinction of this very important fish in Bangladesh. The change in the hydrographic condition will disrupt the natural food chains for different aquatic organisms including fish and prawn and lead to their extinction. Large areas of the

¹ East Pakistan Water and Power Development Authority. India's Farakka Barrage and its Adverse Effects on East Pakistan. (Dacca: Water Investigation Directorate, February, 1971. P.26).

Ganges river system in Bangladesh will go dry in winter months, seriously forcing many natural fish and other aquatic population to become land locked and perish.

The increased salinity in the river due to reduction in the up-land flow caused by withdrawals of the Ganges Water by India at Farakka during the low water season will also affect the growth of Sunderban forest lying in Khulna district in the south. It has been established that the quality of density of forest are best in the fresh water areas and the forests become poorer and more open as one proceeds towards more saline soils.

Eight districts of Bangladesh are dependent on the waters of the Ganges river. Of these, four i.e. Rajshahi, Pabna, Kushtia and Faridpur are situated on the banks of the river and their economy is based directly on the water supplies from the Ganges. The other four districts i.e., Jessore, Khulna, Barisal and Patuakhali located in the Ganges Delta get fresh water supplies through the distributaries of the Ganges like the Ichamati, Nabaganga, Bhairab, Kumar, Gorai, Madhumati, etc.

The system of transportation in Bangladesh is largely dependent on its waterways. Water carriers consisting of diesel and steam vessels, barges and a vast number of river country-crafts handle the major part of the cargo movement around the country-side. But a study has revealed that the tonnage moved by country crafts is about three times as much as moved by the mechanised craft¹. The maintenance of feeder boat

¹ Water Investigation Directorate. Op. Cit., P. 28.

routes is, therefore, of no less important for the economy of Bangladesh than that of the main river channels.

The withdrawal of water from the Ganges river by India in the low water period would adversely affect about 700 miles of major waterways in Bangladesh¹.

The natural waterways in the Ganges river (Godagari-Goalundo) during dry season is limited to about 4½ feet craft vessels. If 40,000 cusecs is withdrawn at Farakka in a year with average flow, than it would be hardly possible for any river craft to ply in the Ganges. The Farakka Barrage would thus cut off the existing usage of the channel for public benefit for the districts of Rajshahi, Pabna, Kushtia and Faridpur.

The large variations of flow between the dry and flood seasons would necessitates the creation of a new dredged channel in October-November which would be completely washed off in the ensuing flood period.

Development projects for the Rajshahi and Pabna districts would be adversely affected due to the lack of waterways access from November to April. This region is located away form the major sea ports and heavy equipment for industrial development can only be taken by waterways into the area. Major projects like Rooppur Nuclear Power Plant, Paper Mills, Jute and Sugar Mills would all suffer for lack of the approach facility.

¹ Water Investigation Directorate. Op. Cit., P.28.

Similarly the feeders which get their supplies from the parent river Ganges will dry off and navigation in these routes will stop. It would deny to the people of Rajshahi, Pabna, Kushtia and Faridpur districts their historic riparian rights to navigation on the Ganges. In addition, economic activity in Jessore, Khulna, Barisal and Patuakhali districts would be curtailed due to loss of communications resulting from early fall of river levels.

It is true that there is no immediate problem of irrigation development in Bangladesh, because of rate of development of agricultural in Brahmaputra basin in India is very slow, but in the long run it will have adverse effect on the dry weather flows of Brahmaputra in Bangladesh. There will be navigation difficulties. Navigation on the Brahmaputra is of greater commercial importance than on the Ganges. Any depletion of Brahmaputra flows in the dry season will further accentuate the problem of saline water intrusion in the delta area. This will have similar adverse effect as discussed in connection with the Ganges.

In the 5th Meeting of the Joint Rivers Commission of Bangladesh and India held in Delhi, the Indian Team submitted a report to the Commission on flood control and river training in the Ganges-Brahmaputra-Meghna basin in India. In that report it is stated, "The flood problem in the Assam State is mainly due to spilling of the main river and their tributaries, bank erosion and inadequate land drainage. The instability of the river is the main cause of considerable bank erosion. This instability is the result of excessive sediment brought into it, which is due to the denudation of forests in the friable hills, disturbances

caused by earthquakes and erosion by faulty land use. Similar is the case with North Bengal tributaries such as the Tista, the Torsa, the Jaldhaka etc."

"A Study of the flood in the valley shows that there is no regularity in the cycle of flood. Flood during the last decade have, however, been heavier than in the preceeding decades. High flood in the Brahmaputra valley have occurred in the years 1931, 1935, 1948, 1949, 1951, 1954 and 1964"¹.

"Very heavy flood occurred in North Bengal during the years 1877, 1886, 1892, 1895, 1900, 1902, 1905, 1906, 1926, 1948, 1950, 1952 and 1954. The latest flood havoc in this region was in 1968".²

"The protection works undertaken in Assam before 1954 consisted of only 260 km of embankments in the Brahmaputra basin. But since 1954, considerable progress has been made in the execution of flood protection and anti-erosion measures. The works executed since 1954 are 854 km embankments along the main Brahmaputra, 2162 km embankments along its tributaries, 770 km long drainage channels, and 30 numbers of town protection works. These measures have benefitted an area of 7.23 lakh hectares. Storage reservoirs for moderation of floods are under investigation on Pagladiya, Subansiri and Dihang."³.

"The embankments constructed in North Bengal so far are 44 km along right bank and 42 km in three reaches along left bank of Tista,

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1. Indo-Bangladesh Joint Rivers Commission. Report on Flood Control and River Training in the Ganges-Brahmaputra-Meghna Basin in India. Enclosure 9. JRC 5th Meeting. (New Delhi: Ministry of Irrigation and Power, Government of India, Undated, P.P. 5-6).
 2. Ibid., P.6
 3. Ibid., PP.6-7.

13.50 km in four reaches and 42 km in two reaches along the right and left banks respectively of the Jaldhaka, and 34 km in two reaches and 10 km in five reaches along the right and left bank respectively of the Torsa. The towns protected are Jalpaiguri, Coochbehar, Siliguri, Alipurduar, Mathbhangra, Toofanganj and Mekhliganj. River training works have also been executed on the Mahananda and its tributaries and Jaldhaka"¹.

"The future programme envisages raising and strengthening of existing embankment, filling up of gaps in the existing embankment in the valley, town protection and anti-erosion measures, construction of Pagladiya detention dam and experimental dredging for river training. The existing flood forecasting system will be further strengthened"²

"The Master Plan for flood control for Assam is under preparation. The measures suggested would benefit a substantial additional area of about 0.757 million hectares at a cost of Rs. 600 million (1964 price level). A major portion of the cost pertains to the Brahmaputra Basin. The Master Plan for flood control for North Bengal region is yet to be prepared by the North Bengal Flood Control Commission"³.

From the above informations it can be seen that the Government of India and Government of Assam and West Bengal has constructed huge length of embankments to confine the main river and its tributaries and distributaries in the Brahmaputra river basin. Moreover they have got

¹ Indo-Bangladesh Joint River Commission. Enclosure 9. Op. Cit., P.7.

² Ibid., pp. 7-8.

³ Ibid., P.8.

gigantic programme of embankment construction and river training works in future. Due to the execution of all these works in the upper reaches, there would be following major effects in Bangladesh:

(a) As a result of the confinement of overbank spilling by the embankments huge quantity of flood waters which used to be retained as valley storage in the upper reaches now rushes down to the lower reaches causing more flood damages in Bangladesh.

(b) The silt carried with the flood discharge which used to be deposited on the spill area are now deposited at the down stream causing siltation of the rivers outside the embankment areas resulting in increasing the flood stage affecting more areas.

(c) In a heavy silt laden river like Brahmaputra the system of dyke may cause formation of shoals down stream affecting the meandering pattern of the river regime as a whole.

(d) Farmation of shoals and changes in the river channel downstream creates navigation problem.

Spacing of embankment is a fundamental prerequisite in terms of planning and designing of embankment, keeping in view the less consequential adverse effect. For the interest of all countries it is desirable to provide sufficient space between the opposite embankment so that valley storage within the embankment can cope with situation.

India-Bangladesh Co-operation And Possibility Of TVA Type Of Integrated Regional Plan For Bangladesh.

The successful termination of the transitional phase of the Indus Water Treaty in March, 1970, has inspired many to suggest a

broad canvas of co-operation between India and Bangladesh, as well as Nepal, Bhutan, Sikkim and China in developing the river resources of the Ganges-Brahmaputra-Meghna basin. The central idea appears to be of TVA type to provide storage dam on the Sarda at Pancheswar in Nepal and on Karnali at Chisapani, also in Nepal, so that in addition to producing a huge quantity of power these reservoirs could provide sufficient water to Bangladesh during the dry months. As a consequence there will be ample surplus power in Nepal to export to India and Bangladesh. Thus the entire river basin could be considered in terms of hydro and flood control projects, in an integrated fashion for the entire region to benefit of all concerned. These proposals need not be limited to irrigation, flood control and hydropower development. The development of river navigation could be another major benefit, for instance, shipment of coal to Bangladesh from the Raniganj and Garo-Khasi coal deposits. Industrial development prospects of Bangladesh, Meghalaya and Garo-Khasi and Mizo area would brighten if navigational routes are opened up and hydro power generation increased. Trade would also increase between India and Bangladesh.

These are some of the broad ideas adumbrated in the perspective of development of Ganges-Brahmaputra-Meghna basin, the largest river basin systems in the world. The UN Krug Mission Report on Bangladesh, the UN Japanese Report on the Karnali and other Nepalese rivers, the Snowy Mountain Authority Study on the Karnali Scheme, the Roger Revelle Pugwash Study on the optimal utilisation on the

Ganges-Brahmaputra, provided the factual basis of the constructive pattern of thinking.¹

Some of the political implications of such a large and long-term project are that it can be under taken in the context of general peace in the region, provided the capital investment is not threatened or work halted in the middle. Secondly there has to be a relationship of co-operation and close interdependence between India, Nepal and Bangladesh on a permanent footing. Finally, international finance should be available on a substantial scale in order that the multiple phases in which the project is executed provide substantial immediate benefits. Of course, there would be the problem of setting up the execution authority. But with the example of the Mekong involving a complex political frame-work, it may not be too difficult to arrive at an agreed formula, although the two political settings are not entirely analogous.

Assumptions Made In Preparing The Plan In The context Of Indo-Bangladesh Water Dispute.

It is very difficult to prepare a comprehensive plan of water resources for the regional development of Bangladesh in the context of water dispute between India and Bangladesh. However, as our relationship with neighbouring India is now quite cordial, the following assumptions are made while preparing the comprehensive plan:

¹ Editorial "Ganges-Brahmaputra Basin: The Larger Context", Indian Journal of Power and River Valley Development, Calcutta, April, 1970, P.188.

(a) As an upper riparian country India will not take such steps ignoring our water rights to disturb intentionally, the existing natural condition of our river systems.

(b) There will be close co-operation between India and Bangladesh in the development of water resources of both the countries.

(c) There will be greater exchange of topographical, hydrological, geological, climatological, agricultural, forestry, fisheries, minerals, land use, traffic and other data between the two countries.

(d) There will be free exchange of information between the two countries regarding any water resources development activity in the Ganges-Brahmaputra-Meghna river basin.

(e) In agricultural development, surface water would be preferred to utilize over the ground water, due to economic reason.

(f) For industrial and domestic purposes ground water would be preferred to utilize over surface water.

Defination of Water Resource

Resources is not a thing or a substance itself it is the function which a thing or substance may perform an operation in which a thing or a substance may play a part.

A functional approach has to be adopted while assessing, evaluating, exploring or exploiting, planning or manipulating resource. Resource has to be defined in terms of their uses.

Two variables interact to turn resources positive or negative:

- (a) Demand-Potential uses in a given contest;
- (b) Supply-Cost of making it available at certain level of quantity.

For example-sea water remains to be just sea-water without technology, equipment and management to mine it. Apparently the ability to put use value on a thing or substance is all the more important; i.e. human ingenuity.

Similarly the brackish water of coastal sub-regions of Bangladesh will become a resource when it can be used for agricultural development through constant research.

Though in Bangladesh we have got abundant supply of water, yet we are utilizing only a limited quantity for irrigation, domestic and industrial use. Most of our water is being wasted into the sea. There is a tremendous scope of water resources development in Bangladesh and it can be profitably used in the development of irrigation, navigation, power generation, domestic and industrial use, fish and wild-life management, recreational purposes etc. Our economic regeneration can be achieved quickly by exploiting water and land resources.

"The basic need for water may be compared with that for air and food. Water has also great potentialities for control and utilization for the benefit of man. Wherever the supply of fresh water has been scarce or lacking, as in the arid and semi-arid regions of

the earth, the significance of water as a fundamental necessity of life and as a limiting factor in the utilization of other resources and in the progress of modern civilization has been keenly appreciated. Fortunately, in large parts of the earth the supplies of fresh water are comparatively plentiful. However, in many places the development of our industrial and social economy has created water demands of a magnitude and variety that have exceeded all previous ideas, or expectation. Consequently, supplies which until recently have been considered as essentially inexhaustible are now recognized to have limits, which, either immediately or prospectively, fix the extent of development"¹.

Concept And Application Of Regional Planning

For the proper development of water and land resources of Bangladesh regional approach is essential. Before starting with the plan proposal for comprehensive water resources development, it is better to explain briefly the concept and application of regional planning.

"The concept of regional planning can be found in the Gedidian Philosophy of town and country planning. This philosophy of city survey was not confined to his immediate environs, but to the larger surrounding region. His word subsequently become regional planning and the term "Connurbation" was applied to city

¹ C. E. Paulsen, "Current Concepts in Appraisal of Water Resources" Proceeding of the United Nations Scientific Conference on Utilization of Resources. 17 August - 6 September, 1949, Lake Success, New York. Vol. IV. Water Resources, 1951. P.37

regions. Mackaye was one of the pioneers in the regional planning movement in the U.S.A. His new exploration - a philosophy of regional planning - was the direct product of seven years of regional planning for the Appalachian Trial"¹.

Cyrus Kehr (Resource Planner) was very much concerned with resource development on the basis of balance distribution over the country. It was his efforts that produced the most famous regional plan of Tennessee Valley Region.

"Regional Planning, on the other hand, has grown up under quite different circumstances. 'Regional Planning' wrote the National Resources Committee in 1935, 'should, in the main, confine itself to dealing with the physical resources and equipment out of which socio-economic progress arises'. By this definition, regional planning has one major focus of interest: the development of physical resources. But the control powers of the Federal Government were so restricted that its point of entry into regional planning was the field of water resources where it had primary justifications. Through the development of water resources for a multiplicity of uses it was hoped that social and economic advance in the watershed would be furthered. The watershed, therefore, become rapidly identified as the 'proper' region for planning, and the recognition that land resources are intimately related to the use of water only, strengthened this view, whether it was called the Tennessee Valley, the Columbia Basin, the Missouri Valley, the Central Valley, or the

¹ Golam Rahman, . Op. Cit, P. 94.

Arkansas-Red River Valley, the physical setting was always a major drainage basin organized for comprehensive resources development. Flood control, the development of facilities for navigation, electric power, irrigation, and recreation, stream sanitation, erosion control and reforestation, even mineral development came to be included under development scheme in major river basins"¹.

A plan Proposal For Comprehensive Water Development

The floods of Bangladesh are in fact of much commanding importance in water resources development in the country. As agriculture will continue for many years the most important sector for the economic growth of the country, development of land and water should get the needed priority. Maximum productivity of the land will be achieved by a combination of improved agricultural practices and water development which will protect the lands from an excess of water and supply irrigation water when rainfall is deficient.

Although, the smaller rivers along the eastern border frequently carry destructive localized floods, but the extensive flooding in the country each year is related principally to the three main river systems described before. The entire central area is essentially only the delta end of two long river valleys, and conditions are typically deltaic and that the streams are numerous and unstable, stream and land gradients are flat, and streams are depositing enormous silts.

¹ John Fridmann and William Alonso. Regional Development of Planning A Reader. (Cambridge, Massachusetts, USA: The M.I.T. Press, 1955)

Almost all the water which makes up the major rivers of Bangladesh comes from outside the country and end up in the Bay of Bengal. In an average year, about 1,070 million acres feet (MAF) crosses the border from upper catchments and about 100 MAF is generated by local rainfall runoff. These huge numbers are difficult for the mind to grasp, but an impression of their magnitude may be obtained by saying that if all this water hold up on the land equal to the area of Bangladesh, it would be inundated to a depth of 34 feet¹. Since most of this enormous volume is concentrated in the monsoon period it causes flood. The problem is to take care of excess of the discharge above the safe river level, during the flood period with a view to mitigate flood losses.

The excess inflow discharges above the safe level (3 feet below danger level) during highest flood period in the Ganges, the Brahmaputra and the Meghna in MAF are 64.15, 57.63 and 16.60 respectively. By adding 50% to the inflow discharges above the safe level, the corresponding designed discharges, will be in MAF are 96.23, 86.44 and 24.90 (See Table - 9). The runoff and the designed runoff from local rainfall, storm during flood period are 21.78 and 32.00 MAF respectively (See Table - 10). The problem of Bangladesh in the field of water resources development are: (i) to dispose or to accommodate outside the country 239.57 MAF (the total design discharge of the three rivers above the safe level during the flood plus the design

¹ EPWAPDA. Master Plan. Vol. I. (San Francisco, California, USA: International Engineering Company Incorporated, 1964, P.87)

TABLE 9

IMPORTANT DATA ON MAJOR RIVERS IN BANGLADESH

Sl. No.	River	Station	Maximum Water Level (Observed)		Maximum Discharged (Observed)		Danger Level in Feet PWD	Dis-charge for Water Level 3 ft. Below Danger Level in 100 cfs	100 year Dis-charge in 1000 cfs	Water Volume in Excess of the Discharge 3 feet Below Danger Level			
			Date	Water level in feet (PWD)	Date	Dis-charge in 1000 cfs				Water Level in feet PWD	Year	Volume in million Acre feet	Multiplying by 1.5 a Factor for Long Term Discharge in million acre feet
1.	Ganges	Paksye (Hardinge Bridge)	24.8.60	49.35	29.8.62	2,160*	44.50	900	2,600	49.50	1969-70	64.15**	96.23
2.	Brahmaputra	Bahadurabad	28.7.70	66.25	28.7.70	2,707	63.50	1,300	2,900	67.00	1970-71	57.63	86.44
3.	Meghna	Bhairab Bazar	20.8.55	25.10	13.7.66	521	21.00	345	558	26.30	1966-67	16.60	24.90
Total :												138.37	207.56

* Maximum computed discharge at Paksey (Hardinge Bridge) is 25,45,000 cfs on 1 - 4 September, 1961.

** The Water volume has been calculated from discharge hydrograph of 1969-70 as data of 1961 is not available.

TABLE 10

RAINFALL RUNOFF

Sl. No.	River	Station	Rainfall minus evapotranspiration for the area bounded by roads and railways joining Dacca-Goalunda-Hardinge Bridge-Dacca (a) (Storm period only)		
			Period	@ in acre feet $\times 10^6$	Maximum Expected in 100 year in acre feet $\times 10^6$
1.	Ganges	Paksey	<u>1969</u> July 23 to October 8.	9.201	13.800
2.	Brahmaputra	Bahadura- bad	<u>1970</u> July 17 to August 14.	6.576	9.200
3.	Meghna	Bhairab Bazar	-	6.000	9.000
Total :				21.780	32.000

runoff from local storm during the period) for the purpose of mitigating flood losses, (ii) to supply irrigation water to make up deficiencies in rainfall before, during and after the monsoon rains thereby maximizing food production through intensive and extensive cultivation. In short, to increase the food production in Bangladesh land must be saved from damaging floods and to make provision for the supply of irrigation water, when rainfall fails and (iii) regulate the silt in their proper places on the banks of rivers, low inland depressions and shallow bay areas to reclaim land.

Flood control may be defined as a measure calculated either to reduce the flood flow of a river to such an extent that will not overflow banks to cause damages or to lower the level of the flood flow of the rivers below danger level by some methods. Flood control of a river is possible by the following methods:

- (a) Management of catchment area;
- (b) Construction of storage reservoirs at the upper catchment area;
- (c) Flood diversion and control structure;
- (d) Embankment;
- (e) River training;
- (f) Dredging of rivers;
- (g) Estuary control;
- (h) Absorption of flood water and rainfall runoff in the sub-soil.

In this connection, it may be mentioned that no individual flood control measure will be able to control flood appreciably in Bangladesh. So, all the methods have to be used gradually and simultaneously though it will take long time and require huge expenditure before effective control is achieved. But the sooner a start is made it is better for the country.

Management Of Catchment Area.

Forest and shrubs in the upper catchment area reduce the flow to the stream. Root of the trees and bushes, twigs, dead leaves and even grass blades retard the surface flow over the slopes by creating tiny reservoirs. These tiny reservoirs hold up certain quantity of water for some time and help penetration into the soil. So, the forest and vegetation in the upper catchment area not only reduce the flood flow of the river but also help increasing the dry season flow by releasing sub-soil water in the form of springs. So, the human interference in the upper catchment areas in reclaiming lands for cultivation, habitation or wanton extraction of forest produce or destruction of forest by fire cause serious damage to the river regime. It increases flood flow, depletes the winter flow of the river and causes serious erosion of lands and hill slopes. The rainfall runoff erode the loose top soil and carry it down as silt which causes siltation problem. As an example, it can be mentioned that Jhum cultivations, forest fires and uncontrolled extraction of forest products of Chittagong Hill Tracts are causing serious damage to the river regime of Karnafuli, Sangu and Matamuhuri.

So, proper management of upper catchment area can solve the flood and silt problems to some extent by increasing the infiltration capacity of the soil and decreasing the surface runoff and soil erosion. In return it will reduce the flood and silt problems.

Construction Of Storage Reservoir At The Upper Catchment Area

Reservoirs for storing water in valleys at the head waters of the rivers can be traced back over many countries. A reservoir provides flood control by storing flood water in the basins formed by dams so that it is prevented from contributing to the flood in the river system down stream. Instead of spreading naturally over wide channel or valley bottoms that are of considerable economic use, the water is effectively stored to great depth in artificially constructed reservoirs, located up stream in areas generally of low economic value. To provide full control, a storage reservoirs should have sufficient capacity to store all of the excess water above the safe level in a given flood, and should release the stored water after the flood has subsided in the lower river.

Flood control through reservoirs within Bangladesh is impractical due to the relatively flat terrain of the deltaic region. There are no suitable reservoir site within the borders of Bangladesh except in Chittagong Hill Tracts. Such storage sites on the major rivers would be available at the upper reaches in India, Nepal, Bhutan, Sikkim and China. Such sites are being explored by the Indo-Bangladesh Joint Rivers Commission for flood control reservoirs.

Out of the 96.23 MAF excess inflow above the safe level in the Ganges about 53 MAF may be stored by impounding at the source of its tributaries in India, Nepal and Tibet. In respect of the Brahmaputra river, reservoirs sites are available at the upper catchment areas to store nearly 57.50 MAF out of the 86.44 MAF of excess inflow above the safe level. This would also ensure about 70,000 cusecs of dry flow in addition to the existing flow in the Brahmaputra. It is also estimated that about 15 MAF storage of excess flood of the Meghna may be possible at its tributaries in Assam, Manipur, Hill Tippera, Meghalaya and Arunachal. No storage reservoir is possible at the sources of rivers Tista, Jaldhaka, Torsa and Raidak due to steep slope and high silt content.

It may be noted that reservoirs designed solely for flood control are generally prohibitive in cost. If the reservoirs are developed for multipurpose benefits, the flood control potentiality is much reduced which may be taken as one-third of the live storage capacity. Karnafuli Project of Chittagong Hill Tracts was executed at a cost of about Taka 51 crores. Its total storage capacity, including dead storage of 1.47 MAF for siltation, is 4.35 MAF, with live storage capacity is 2.88 MAF. But the flood storage capacity is 0.83 MAF.

Considering that the hilly catchment area of the Brahmaputra and Meghna in India is highly seismic area, it is not known how many storage reservoirs can be executed there. But the reservoirs on the rivers Sangu and Matamuhuri can protect about 80,000 acres of land and will provide irrigation water for 50,000 acres.

However, the total flood control potentiality of the multi-purpose reservoirs in the upper catchment areas of the Ganges, Brahmaputra and Meghna river systems is shown in Table 11

T A B L E 11
FLOOD CONTROL POTENTIALITY OF MULTIPURPOSE RESERVOIRS

River System	Total Designed Flood Flow in excess of the Safe Level in M A F	Possible Multi-purpose Storage Reservoirs in M A F	Flood Storage Potential of the Multipurpose Reservoir in MAF
The Ganges	96.23	53.00	17.67
The Brahmaputra	86.44	57.50	19.17
The Meghna	24.90	15.00	5.00
Runoff from Local Rainfall in the River Systems	32.00	-	-
	239.57	115.50	41.84

The above mentioned multipurpose reservoirs will have nearly 27,820 Megawatts, in addition to other benefits like flood control, silt control, less bank erosion, recreation and additional winter flow in the rivers.

The following are the limitations of the storage reservoirs in addition to the financial one:

- (i) Reservoir may fail due to earthquakes in the seismic area, as the earthen dams are liable to flow like mud slurry, causing flood disaster in the lower reaches. Rock filled dams can stand to some extent.

(ii) If a rain storm hits the area in quick succession of another storm before the reservoirs are brought down by releasing the water hold up from the previous storm, the runoff from the 2nd storm will flow down stream resulting in flood condition.

(iii) Life of a reservoir varies from 100 to 150 years depending on its size and the silt content of the tributaries. If a reservoir is filled up by silt, there will be no scope to execute another reservoir of same capacity at the same tributary to replace the filled up one.

Flood Diversion And Control Structures

Flood stages of main rivers can also be reduced by diverting certain amount of flood flows in different branches judiciously with the help of structures across the rivers. Such diversion will be much more effective if they are associated with the estuary control. Estuary control will be discussed in details separately.

If control structures like barrages are put on Meghna and Gumti rivers along the section on Dacca-Daudkandi road they will considerably reduce the flood stage of the whole flood plains of Meghna and Gumti through quick disposal of flood water. The functions of such type of control structures have been discussed below:

Let us consider the section of the Meghna river at Dacca-Daudkandi road. At this section a large quantity of water during Flow tide passes upstream upto Markuli even during flood season. At the time of ebb-tide flood water along with tide water passes down the

section. Due to the funnel shape of the tidal reach of the river the quantity of tidal water which passes the section is much more than the flood water which passes down during ebb-tide. So, during the flow of tide flood water is blocked up stream creating higher flood stages.

If the flow of tide upstream is stopped at the section by structures, as soon as the downstream level goes down below the upstream level greater volume of flood water can be discharged quickly having flood control effect upstream. These structures may encourage more flood flow from the Brahmaputra River through the old Brahmaputra. As such uncontrol flow from the Brahmaputra will be dangerous, a control structures on the old Brahmaputra at a certain distance from the offtake will be required.

The type of structure proposed for the Meghna and Gumti river has already proved its success in controlling, flood to some extent in the case of Little Feni River. The proposed control structures will have the following benefits:

(i) To some extent it will control flood upstream during flood season.

(ii) By raising the level of the water during winter, it will facilitate navigation due to higher depth of the river.

(iii) Demand for navigation and fish culture on the perennial winter flow of about 5,000 cusecs will be eliminated as a result of impounding. As such, the total quantity of perennial flow will be available for irrigation through low lift pumps and other methods.

(iv) Due to inpounding at a higher level water can be distributed more inland from the main river through gravity canals and existing drainage channels for irrigation. This will not only help in locating more low lift pumps but also will reduce pumping head of the low lift pumps.

(v) It will facilitate road communication over the structures. To make navigation easier in the upstream region of the river & for equitable distribution of winter flow for irrigation two more control structures will be required at Bhairab Bazar and Itna.

(vi) It will cut off certain amount of tide prism, if similar structures are constructed on tidal rivers including Padma. In future, it will be easier to construct the estuary control structures on big estuaries.

(vii) It will eliminate dredging work for navigational purpose in the upper portion of the river if such structures, one at Bhairab Bazar below the outfall of the old Brahmaputra and other above Itna below the outfall of the old Surma river are constructed.

As the structures are of multipurpose nature benefit cost ratio will be very high and will start giving full return immediately after the execution. Similar control structures may be constructed on other rivers like Karnafuli, Sangu, Matamuhuri, Feni, Madhumati, Rupsa, Dakatia and Kushiya etc.

In general flood in the Brahmaputra arrives much earlier. By constructing a barrage across the Brahmaputra at Bahadurabad below the

offtake of the old Brahmaputra it will be possible to provide certain amount of flood control down stream by diverting some flow through the old Brahmaputra and the Ganges by way of a link Canal. Diversion of winter flow through the old Brahmaputra and the Ganges link will also help in distributing water for winter irrigation.

Similarly, a barrage at Bhagyakul on the Padma will have greater flood control benefits. During the flood season it will cut-off a large amount of tidal Prism which will help in discharging more flood water. By diversion of certain amount of flood flow through Kumar and Arial Khan flood stage at the upstream can be reduced with the help of estuary control which will be discussed seperately.

The following are the benefits of the proposed barrage at Bhagyakul:

- a) It will help in discharging more flood water by cutting off a large volume of tidal prism.
- b) It will make possible diversion of certain amount of flood flow through Kumar and Arial Khan.
- c) It will eleminate the demand on winter flow for navigation and fish culture.
- d) It will distribute winter flow to more interior areas for irrigation purpose.
- e) It will provide road communication.

After the operation of Farakka Barrage without augmenting the present winter discharge, the flow in the Ganges below the barrage will be very low. It will not only seriously effect the existing Ganges-Kobadak Irrigation Project in the districts of Kushtia and Jessore, but fish culture and navigation will be completely stopped in the Ganges river. Salinity at the coast will move further upstream. To utilize the low flow of the Ganges for irrigation, navigation and fish culture it has become very urgent to construct a barrage on the Ganges at off-take of Gorai river. The barrage at the proposed location will also help in diverting certain amount of flood flow of the Ganges and Brahmaputra through Gorai by a control structure. This control structure must be connected with the Ganges Barrage. If the barrage is located further upstream from Gorai offtake either Gorai offtake may be completely silted up or may develop to a big river drawing larger amount of flood flow of the Ganges, in turn it may cause disaster down stream. Ganges Barrage will also help diverting some of the flood flows of the Ganges and the Brahmaputra through Bhairab, Kobadak and other rivers.

Embankment

In Bangladesh the only currently feasible method of preventing vast overland flooding during peak river discharge, which has been agreed to by most of the experts, is by construction of embankments along the river channels. Factors critical for a successful flood embankment protection system, are embankment height, embankment location and the maintaining of an adequate embankment cross-section by proper maintenance.

A well designed and properly located system of embankments would exclude exterior flood waters from the protected areas. Interior flood water resulting from blocked drainage and interior run-off can be removed through the construction of sluices and regulators and in some cases, interior drainage channels and major pumping plants. Soils in Bangladesh for the most part are well graded fine silts and lend themselves well to embankment construction through labour intensive methods. Navigation locks and boats lifts may be provided where traffic volume is enough to justify such construction.

The embankments most of which would be less than 15 feet in height even along the major rivers can be built by human labour. With the large amount of labour force available in Bangladesh, the embankment can be built in a short time, if this labour resource can be properly organized. With the construction of the embankments along the major rivers and secondary rivers, most of the flood water could be confined in the river channels and a large portion of the annually flooded land could thus be made suitable for growing high-yield IRRI paddy by changing the present cropping pattern to suit the changing condition.

In delta areas adjacent to the sea, embankment may be avoided till the land is sufficiently above sea level in accordance with prevailing condition to permit cultivation, drainage and salt water exclusion.

Roads on the embankments prove to be most useful for inspection, maintenance and repair works in emergency cases. In areas where the road system has not yet been developed and whose periodic flooding still

occurs, the embankments offer the most suitable and economic alignments to build roads. If for reasons of stability or convenience of construction, a shoulder or berm is made on the inner slope of the dike, this platform can also be used for road construction. In this case, however, the road cannot be used, if flooding of the protected areas occurs. A road on the embankment increase the total width of the earth body, which may be very desirable to reduce the gradient of the seepage line.

Normally flooded area was determined by superimposing annual flood affected area of Bangladesh one after another from the annual flood reports of the Hydrology Directorate of Bangladesh Water Development Board. The area which was flooded in most of the years is taken as normally flood affected area. For integrated planning, Bangladesh has been divided into four Regions viz North West Region, North East Region, South West Region and South East Region.

Total normally flooded area in Bangladesh was determined to be 15,280 square miles. In North West Region normally flooded area is 3,880 square miles, in North East Region normally flooded area is 7,000 square miles, in South West Region normally flooded area is 2,700 square miles and in South East Region normally flooded area is 1,700 square miles.

It is proposed to construct 604 miles of embankment along the major rivers, 2096 miles of embankment along the minor rivers (Table 12), in addition to the existing embankments that has been constructed by

TABLE - 12

STATEMENT SHOWING REGION-WISE LENGTH OF EMBANKMENT

TO BE CONSTRUCTED

Sl. No.	Name of the Region.	Length of Embankment in Miles	
		On the Bank of Major Rivers.	On the Bank of Minor Rivers
1.	North-West Region	309	952
2.	North-East Region	101	460
3.	South-West Region	150	411
4.	South-East Region	44	273
Total:		604	2096

the Bangladesh Water Development Board. Embankments were proposed to be constructed on both banks of the rivers and whenever possible it was tried to empolder the area by embankment.

River Training

River Training includes bank stabilization, deepening the channel by dredging or other means and cut-offs. River training helps in flood controlling to some extent due to decrease in flood level.

Bank stabilization is done by riverments and groins to combat the tendency of the rivers to change its course which is natural to an alluvial river. Bank stabilization will be very effective, for the meandering and braided rivers of Bangladesh, in developing hydraulically efficient river to discharge the flood flow quickly. By this method river width can be reduced considerably which in turn stabilize the river channel by automatic deepening of the bed due to its increase capacity to transport the bed load into the sea. Bank stabilization and narrowing the shallow and braided rivers to a reasonable width will not only facilitate unobstructed navigation but also reclaim considerable land. The approximate total length of the major rivers and big tributaries in Bangladesh is nearly 700 miles with an average width of 5 miles (taking the Brahmaputra and the Ganges, the Padma as 10, 8 and 12 miles respectively and small rivers as 2 miles). The major rivers and big tributaries can easily be reduced to $1\frac{1}{2}$ miles and $\frac{1}{2}$ mile respectively. Thereby nearly 2,500 square miles can be reclaimed from the river.

In this connection, it may be mentioned that the Government of United States of America took up the training works of Mississippi rivers about 100 years back and which may continue for another century. The flood flow of the Mississippi river is practically $\frac{1}{3}$ rd of the combined flood flow of the Ganges and Brahmaputra. It may take 2 to 3 centuries to train the rivers of Bangladesh but considering the importance and the magnitude of the problem, the sooner a start is made it is better. Start may be made by protecting the towns and commercial centres which can be extended gradually.

There is common belief that by putting ballahs, bamboo mattress and brush wood at the bank, the erosion of big rivers can be stopped. The scouring depth of major rivers at the site of erosion varies from 60 feet to 120 feet. But the maximum velocity of the river is at 0.6 of the total depth. Which means, for a river of 100 feet depth, the maximum velocity will be at a point about 60 feet from the surface. So, ballah piles, bamboo mattress or removal of the shoals will not be able to arrest the bank erosion of the big rivers of Bangladesh. The extent of flood control benefit which can be derived from river training may be obtained by conducting experiments on a large scale models. The effectiveness of economic type of training work and the extent can easily be established through model tests. So, the model tests will surely cut down the cost of river training very considerably and also gives indication of a correct method.

Dredging of Rivers

The utilisation of dredger to reshape the alluvial river channels to increase hydraulic efficiency of the channels and thus effecting

reduction of flood stages, flood control and navigation has often been suggested. However, dredging alone of the big rivers of Bangladesh, except Meghna which carries very little silt has very little chance of being effective. The Ganges and the Brahmaputra bring nearly 1.70 billion tons of silt annually into Bangladesh from upper catchment areas. The very nature of the delta which is in the process of aggrading is such that it still depends on its river systems to provide silts required to raise the land elevation. Therefore, without exception, the main rivers and its branches will over-flow periodically in spite of extensive dredging, whether for flood control or navigation, due to heavy siltation, as enormous quantity of silts are being carried into Bangladesh by its main rivers. Though the Meghna river brings in very little silt its dredging alone will not have any effect either on flood control in monsoon or navigation in winter without control structures. Winterflow of the Meghna above Bhairab Bazar is hardly 5,000 cusecs. So, development of 5,000 low lift pumps for Boro cultivation in the area will have no water for navigation. As such, the dredging of Meghna can not improve navigation but it will adversely affect Boro cultivation by increasing the pumping head unnecessarily. As a result, discharge of the pumps will be reduced and the operation cost will go up.

Further, it may be mentioned that dredging alone in the Ganges-Brahmaputra river system will have no benefit either to flood control or navigation as the bed load of the rivers will fill the dredged portion almost as fast as they are executed. Dredging of shoals and sand bars in rivers for directing the flow from eroding banks will be complete

wastage as it will have, practically no benefit. Dredging will be successful, if done in combination with the river training. It may be mentioned that extensive dredging operation have been carried on in the lower Mississippi river for a number of years with little or no effect, except when used in combination with river training works, though the annual silt load of the lower Mississippi river is only 344,000,000 tons i.e. $\frac{1}{5}$ th of the Ganges-Brahmaputra system.

The dredging requirement will be increased significantly in Bangladesh as the water development programme gets going. Many new channels must be dredged, (MAP 15) old channels deepened and widened with training works and control structures and maintenance of dredging will be required for water supply, flood control, navigation and drainage. At the present time due to limitation of funds the need for channel maintenance by dredging may be pressed in Bangladesh principally for navigation but flood control works and navigational improvements are inseparable and no work should be undertaken for one purpose without considering the effects on the other, as it will do more harm than good. So, dredging for navigation alone should not be considered in isolation. It may also be mentioned that relative dredging requirement for navigations will decrease gradually with the implementation of water development programme.

Estuary Control

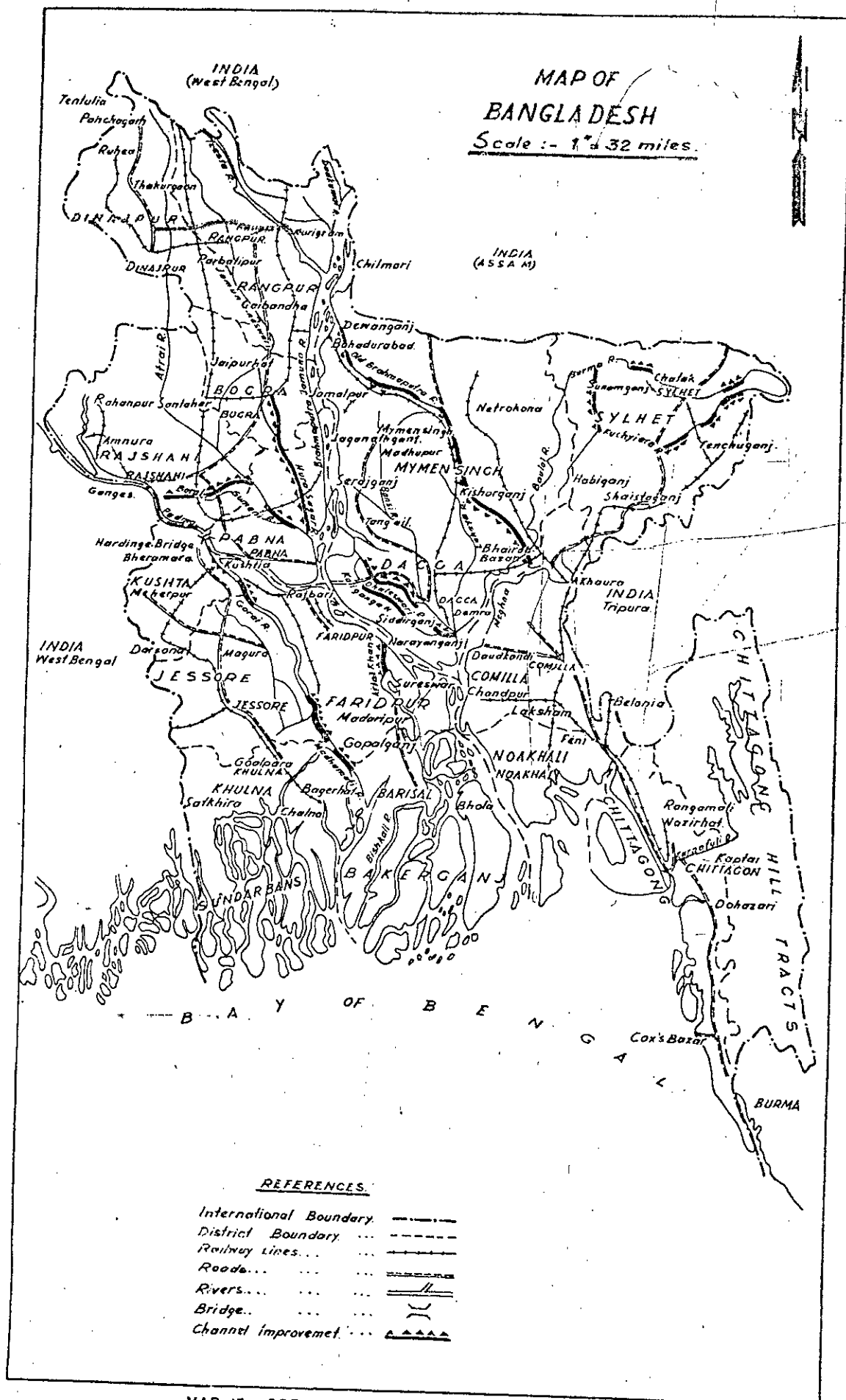
Coastal region of Bangladesh along the shore of the Bay of Bengal comprising nearly 5,400 square miles (excluding forest) is periodically

inundated by salt water during high tides. Saline water inundation not only damage the standing crops but also makes the land useless till the salt is leached out.

The region being situated at the apex of the funnel shaped bay, are particularly vulnerable to severe cyclonic storm and devastating surges. When these storm move inland, only the destructive forces of the wind exists. But the damages caused in the coastal region are due to combined effects of both high velocity winds and extremely destructive tidal surges. Though in the last 177 years, fourteen devastating cyclones hit the region but in the recent past, say in the last twelve years, 6 of such cyclones occurred, which proves that the frequency of the cyclonic storms in the area has increased. But the disasters caused by the cyclone of 12th and 13th November, 1970 is unprecedented in World history. According to the estimate of the Government, made at the end of November, 1970, the loss of lives will be nearly 2,00,000 and the total loss of properties will be approximately Taka 100 crores. This must be worse than any natural disaster in living memory.

It may not be out of place to mention that the loss of properties and living in this area will surely be much greater in future cyclonic surges due to more development and growth of population. Considering the above factors, it has become an urgent necessity to protect the area from the devastation of such cyclonic surges.

As the channels from the Ganges which used to carry upland fresh water to the greater part of the region have deteriorated and the fresh



MAP 15. DREDGING OF RIVERS IN BANGLADESH

water supply in the area has considerably reduced, it is not possible to maximise the development of vast tract of lands for agricultural purpose due to shortage of irrigation water. The suffering of the area will increase in future when the winter flow of the Ganges will be drastically reduced due to operations of Farakka Barrage. The intrusion of saline water more upland will cause greater harm.

Coastal embankments are being constructed around comparatively small islands avoiding closure of big channels at a cost of Taka 136.00 crores. Total length of the embankment will be about 3,000 miles to protect nearly 2.14 million acres of available land of about 5,000 square miles of the coastal area, from monsoon flood and saline water inundation. About 2,077 miles of embankment, protecting 1.8 million acres, have been completed to date. Although the coastal embankments were not designed and executed to protect the area against the cyclonic surges of higher magnitudes, they have, however, provided considerable protection to lives and properties.

Solution of above mentioned problems at the Ganges-Brahmaputra-Meghna estuary is possible through estuary control by high embankments of about 200 miles along the coast (excluding Sundarban forest) and 5 big drainage structures at the coast with ship locks. The proposed estuary control alone can do a miracle in controlling floods of the Ganges and the Brahmaputra. By taking advantage of the average tidal range of about 15 feet, the drainage structures can provide an excellent outlets for additional flood discharge of 100 MAF of 239.57 MAF combined excess flood flow of the Ganges-Brahmaputra basin above the safe level

during monsoon which mean about 42% flood control potentially. Thus estuary control with 5 number of drainage structures west of the main Meghna estuary can handle on an average about 8,00,000 cusecsexcess flood flows. For the effective functioning of the proposed estuary control some of the branch channels such as Mathbhanga, Bhairab, Kapotakshi, Gorai, Kumar and Arial Khan need resectioning with off-take control.

The benefits which can be derived from the proposed estuary control are summarised below:

- a) About 100 MAF of the excess flood discharges, above the safe level of the Ganges and the Brahmaputra can quickly be discharged into the sea. As such, with 42% flood control potentiality, it can easily reduce the flood damages within the Ganges-Brahmaputra basin of Bangladesh.
- b) Future damages due to cyclonic surges in the region will be completely eliminated.
- c) High tidal levels will no longer effect the up-stream land. As such, upstream embankment height can be reduced or eliminated.
- d) Intrusion of salt water will completely be eliminated from the area.
- e) Supply of winter flow through the distribution channels will help in maximising the land development through irrigation of lands of the whole zone south of the Ganges river.

- f) It will conserve the winter flow by controlling the outlet structures.
- g) It will facilitate impounding of fresh water in the lower basin and as such, will considerably supplement the shortage of water for irrigation during March and April.
- h) Improved drainage of the zone will provide the better sanitation through channel rectification and bank stabilisation.
- i) Demand on winter flow for navigation and fish culture will be totally eliminated.
- j) Will facilitate navigation in the zone throughout the year.
- k) Will provide recreational opportunities.
- l) It will help human settlement on both banks of the estuary.
- m) Industries will be established in the coastal belts.
- n) Ports and harbours can be established in the Coastal areas.

Considering all the above mentioned benefits of this particular method of flood control, it may be taken as the most economic one, as it will create opportunities for maximum economic development of a considerable part of Bangladesh.

For further benefit from the closure of Shahbajpur channel with regulator may be taken up in future when the stage of development and economy of the country will permit.

Drainage

During monsoon the internal water from local rain fall must be drained out of the area protected by embankments through sluices by gravity if the out-side water level permits. otherwise, through pumps at flooding stages. Timely drainage of low hills in winter through drainage channels may help winter cultivation. Drainage schemes of unprotected area through channels are inexpensive, can be executed in short time and gives an immediate return. So small drainage schemes should be taken, as many as possible, to increase the food production in the country.

Protection Against Cyclonic Surges

The cause and effect of cyclonic surges have already been discussed in detail. Now, it has become a question how to protect the lives and properties of the coastal region from the devastating cyclonic surges. It is suggested to construct about 80 miles of 25 feet high and 120 miles of 18 feet high earthen embankment along the coast (excluding Sundarban forest) from Indian border to Bhola. Small estuaries are to be closed and five regulators are to be provided in the big estuaries to drain nearly 8,00,000 cusecs of excess flood water. The embankment along the coast will considerably reduce the length of embankments protecting the islands. The big estuaries will provide fresh water lakes for irrigation and recreation purposes. To protect the slope of the earthen embankments against the pounding and suction force of the high velocity cyclonic surges of nearly 20 feet high, some flexible type of materials such as asphalt mat, stone boulders, concrete blocks or

tetrapods may be used. The asphalt mats are extensively used against the storm surge of about 10 feet. But in the case of cyclonic surges of Bay of Bengal having a wave height of nearly 20 feet will try to rise to a higher level by riding on the smooth surface of the asphalt mat and will overtop the embankment and thereby will erode the inner slope unless greater free-board is provided.

Considering the size of the wave generated by the past recorded cyclones and the factors stated above, slope protection of the embankment by big boulders or tetrapods on inverted filters is considered to be more effective. Cyclone protective works of Noakhali and Chittagong districts may be taken up when the land formation between Hatiya and Sandwip islands is completed after the closures of Hatiya and Sandwip channels.

Irrigation By Surface Water

From the discussion made before it will be clear that the problems of Bangladesh in respect of its rivers and related flooding are very big and complex in nature and without any parallel. Considerable amount of investment every year will be required for many decades before any appreciable flood control benefit can be expected. But the gap between the demand and supply of food within the country is ever increasing due to population explosion. To meet the food requirement in the shortest possible time short term measures like flood protection, change of cropping pattern, irrigation by low lift pumps, improved agricultural methods and other inputs may be taken up. Start should also be made for conventional surface irrigation projects of

long gestation period.

Although flood protection and drainage will make the land available for a longer period for more use, but to maximise the yield irrigation water is prerequisite with other inputs to make up the failure of rainfall before, during and after the monsoon. Where immediate flood protection is not possible new cropping pattern may be introduced thus avoiding cultivation during the flood period of July and August. Aus and Aman may be cultivated from March to June and from October to December. More Boro and other crops in winter avoiding flood damages should be introduced depending on the availability of water for irrigation. Similarly, early Aus and late Aman will also require irrigation before, during and after monsoon. Though sufficient water is available in the rivers for irrigation in the monsoon, yet shortage of surface water in winter put a limit to the winter cultivation. Again, most of the winter flow remains within the main rivers, as such, it can not be made available to the interior for winter cultivation, because the source of water and the place of use for irrigation are distantly placed.

At the upper reach of the rivers beyond the tidal zone considerable quantity of winter flow is required for navigation and fish culture. The average perennial flow at present in the main rivers during March and April is about 2,25,000 cusecs. If 1,00,000 cusecs is left out for navigation and fish culture in the Ganges, the Brahmaputra and the Padma, only 120,000 cusecs will be left for irrigation in the Ganges-Brahmaputra basin and 5,000 cusecs in the Meghna. With this available

water about 6.37 million acres may be irrigated during winter provided inland distribution is possible. Another 1.0 million acres may be irrigated in the sweet water area of the tidal zone. With the passage of time more and more area are to be brought under irrigation which means that control structures like barrages are to be constructed on the main rivers along with their tributaries and branch channels. The following are the benefit of such structures:

a) Can control floods to some extent by diverting flood flow and eliminating the tidal prism if the location of the structure is within tidal zone.

b) By raising the water level up-stream during winter, the demand on the winter perennial flow for navigation and fish culture can be totally eliminated.

c) The whole quantity of the average winter flow of 2,25,000 cusecs in April can be distributed in the basin for irrigation by gravity and low lift pumps. About 11.25 million acres of Boro and early Aus can be irrigated by this quantity of water.

d) The pumping head and the cost of operation of low lift pumps will be reduced.

Irrigation By Underground Water

As the surface flow of the rivers in winter is not sufficient to meet the irrigation demand of the lands within the Ganges-Brahmaputra basin which is prime requirement to maximise cultivation of exotic variety of rice crop, alternative source must be found out to irrigate

the rest of the land. Considering the higher rainfall and recharge capacity of the soil of the delta, it is expected that a large amount of water can be drawn from the huge underground sub-soil reservoir which has, so far, practically remained untapped. Though the capital and operation cost of tube-well irrigation is high in comparison with other types of irrigation, but it has to be used in Bangladesh for quick return and to meet shortage of surface water in winter. Tube-well irrigation should be introduced in the country considering the aquifer, recharge capacity, quality of the water and zone of interference in conjunction with surface water irrigation.

Navigation

Since water transport will continue to be a cheap and widely used means of transport in Bangladesh, all development works of water resources should be co-ordinated with the needs of navigation. River training, control structures and drainage work will improve navigational facilities, but withdrawal of water for winter irrigation will hamper navigation. Considerable volume of dredging has always been suggested for navigation only. The effect of dredging in Bangladesh has already been discussed in detail. But it can be said again that flood control works and navigational improvements are inseparable and no work should be undertaken for one purpose without considering the effects of the other, as it will be more harmful than useful.

Accretion of Land

Due to over population and very low agricultural yield tremendous

pressure has been put on the land to support the ever growing populations. In this land hungry country of ours, it will be considered a miracle if by some means we can increase the land area of the country. This type of miracle is possible in Bangladesh due to geographical location of the country and other natural factors like the mighty rivers with enormous volume of silt laden flood flow and the strong flow tide current of the sea.

If the wide and braided channels of the major rivers are trained, which is very costly and time consuming, it will be possible to reclaim nearly 2,500 square miles of land.

But there is a quicker and less costly method also. If the suspended silt of the flood flow of the rivers carried to the sea and part of which is again brought back to the coastline by the strong current of the flow tide is guided and helped to deposit at the selected places, new land will come out of the sea in a short period. Guidance and deposition of silt at the selected places is only possible by creating certain natural conditions for such behaviour of the silt through strong barriers placed at suitable locations. There is no scope to doubt the result of such barriers. The Meghna cross dam No. 1 and 2 executed in 1957 and 1964 across the old Meghna channel passing through Noakhali have already proved the success of such barriers. These two cross dams within 3 to 4 years of their execution helped in building nearly 200 square miles of new land. Now the total land formation in the area is about 300 square miles.

Two further such barriers are now being suggested in the Bay of Bengal between Noakhali mainland and the islands of Sandwip and Hatiya. The area of the Bay between these island has now become shallow due to siltation. But the rate of siltation by the natural process is very slow, as some of the silt deposited in winter is carried away by the strong current of the monsoon. If this natural process is allowed to continue we may get some lands in the form of a group of small islands scattered in the area in a period of 50/60 years. Such natural process will also maintain a large number of ever shifting deep gulties which would not only often erode these new islands but also erode the old and developed islands in a most unpredictable manner. This natural process of the siltation can be accelerated if strong artificial barriers are placed across the present channels. These two proposed barriers if executed will help in building up a vast area of about 600 square miles in a period of 9/10 years as one mass, instead of scattered islands, and thereby reduce the shoreline which are constantly subjected to erosion and salt water inundation by the current and cyclonic surges.

Similar reclamation of land in the coastal districts of Barisal and Patuakhali is also possible by putting such barriers across some of their estuaries. But the selection of location of such barriers will require systematic survey and studies for a considerable period to avoid serious side effect.

Urban Protection

Protection against devastating flood, drainage congestion and

erosion is a must for a developing country like Bangladesh. This protection may be of two principal kinds viz.

- a) Protection of agricultural land
- b) Urban protection.

Discussion has already been made regarding the protection of agricultural land in the para on river training. In the fore going paragraph discussion on urban protection will be made.

Nature of protective measures to be adopted for urban protection primarily depends on the specific needs of the area to be protected and is different for different locations varying according to problems of drainage congestion, overbank spilling due to high flood stage, erosion and scour and in accordance to these, it may be of three types as given below:

- a) Where the problem is one of drainage congestion, improvement of drainage channel and installation of regulator may solve the problem.

- b) In case of overbank spilling, protection is made by embankments with provision for drainage regulators. In both the above measures there may be necessity of drainage pumps.

For protection of embankment from rain water and wave wash, placing of turfs, planting of shrubs and trees, brick mattressing etc. may be necessary.

- c) To fight menace of erosion of river bank protective measures in the form of groynes, spur and revetment etc. are employed.

In case of major river such measures are very expensive and annual maintenance requires colossal expenditure. It is to be emphasized in this context that costly protective measures combined with annual maintenance is absolutely necessary to obtain desired result from the protective measures. Even with all these efforts full guarantee of protection can not be ensured.

Heavy protective measures for urban protection in case of certain major rivers become very costly apart from stupendous procurement difficulties of materials particularly boulders and their transportation because of the necessity of construction of stone groyne in view of the heavy scour depth. Earthen groynes in such situation cannot provide satisfactory solution. Protection of town and commercial centres on major river bank should only be considered when there is ample justification for undertaking such gigantic protective measures from the standpoint of strategic, administrative and social importance and where the urban area demand such measures, otherwise shifting of towns and commercial centres should be considered as an alternative solution. Town protection scheme like Rajshahi (on the Ganges), Khulna (on the Rupsa), Kushtia (on the Gorai) and Bhairab Bazar (on the Meghna) have been taken up in consideration of above perspective.

To provide protection to banks of such towns and cities vulnerable to destructive action of rivers, different identified measures in relation to specific problems have been taken.

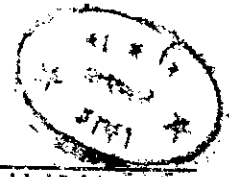
These measures include training of rivers, construction of embankments, dredging where necessary and technically feasible, provision of drainage facilities. Implementation of these measures would go a long way toward urban and rural economic growth and would develop an infrastructure to encourage industrial growth in protected areas.

Important towns like Dacca, Chittagong, Rajshahi, Khulna, Kushtia, Serajganj etc./^(MAPS 16 - 21) are affected by severe erosion and each year large tracts of land occupied by important commercial areas, institutions, factories and other important structures are being devoured in these cities endangering their very existence. Schemes has already been identified for this purpose, by the Bangladesh Water Development Board, out of which several schemes have been taken up for execution and feasibility reports for others are being completed or in progress. Identified schemes are listed in Table 13.

TABLE 13

LIST OF URBAN PROTECTION SCHEMES

Sl. No.	Name of the Urban Centre	Name of the River	Status of Feasibility Report or Construction
A. District Towns:			
1.	Dacca	Buriganga	Feasibility Report prepared and construction started.
2.	Khulna	Rupsa	-do-
3.	Rajshahi	Ganges	-do-
4.	Chittagong	Karnafuli	-do-

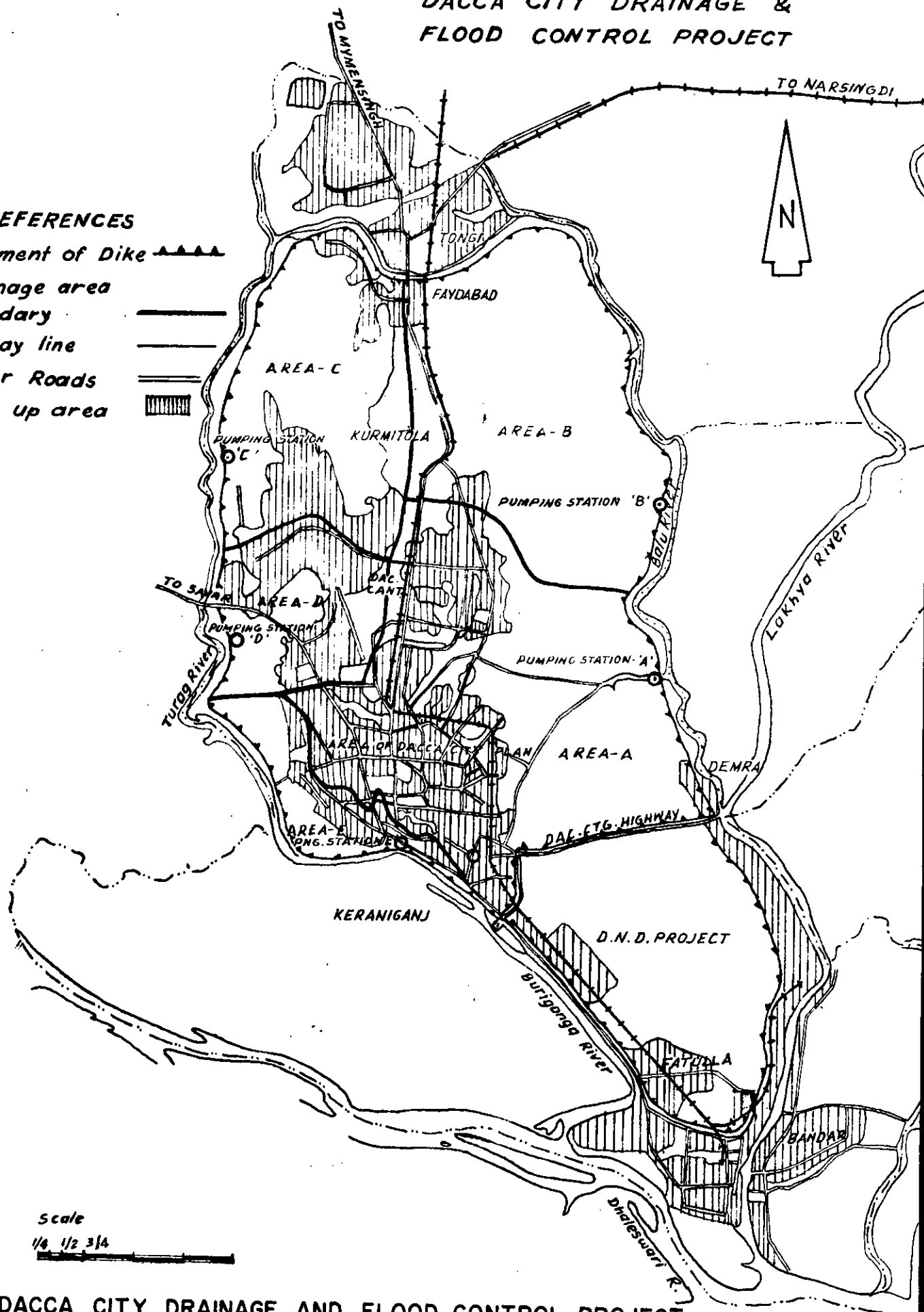


Sl. No.	Name of the Urban Centre	Name of the River	Status of Feasibility Report or Construction
5.	Kushtia	Gorai	Feasibility Report prepared and construction started.
6.	Barisal	Kirtonkhola	Feasibility Report not yet prepared.
7.	Faridpur	Kumar	Feasibility Report is under preparation.
8.	Patuakhali	Patua	Feasibility Report not yet prepared.
9.	Rangamati	Karnafuli	Feasibility Report prepared.
10.	Dinajpur	Punarbhaba	-do-
11.	Tangail	Lohajang	-do-
B. Sub-Division Towns:			
1.	Sirajganj	Brahmaputra	Feasibility Report prepared and construction started.
2.	Chandpur	Meghna	-do-
3.	Kurigram	Dharla	-do-
4.	Habiganj	Khowai	-do-
5.	Sunamganj	Surma	-do-
6.	Moulavibazar	Manu	-do-
7.	Jhalakati	Biskhali	Feasibility Report not yet prepared.
8.	Gaibandah	Ghagat	Feasibility Report prepared and construction started.
9.	Gopalganj	Madhumati	Feasibility Report is under preparation.
10.	Netrokona	Kangsa	Feasibility Report not yet prepared.

DACCA CITY DRAINAGE & FLOOD CONTROL PROJECT

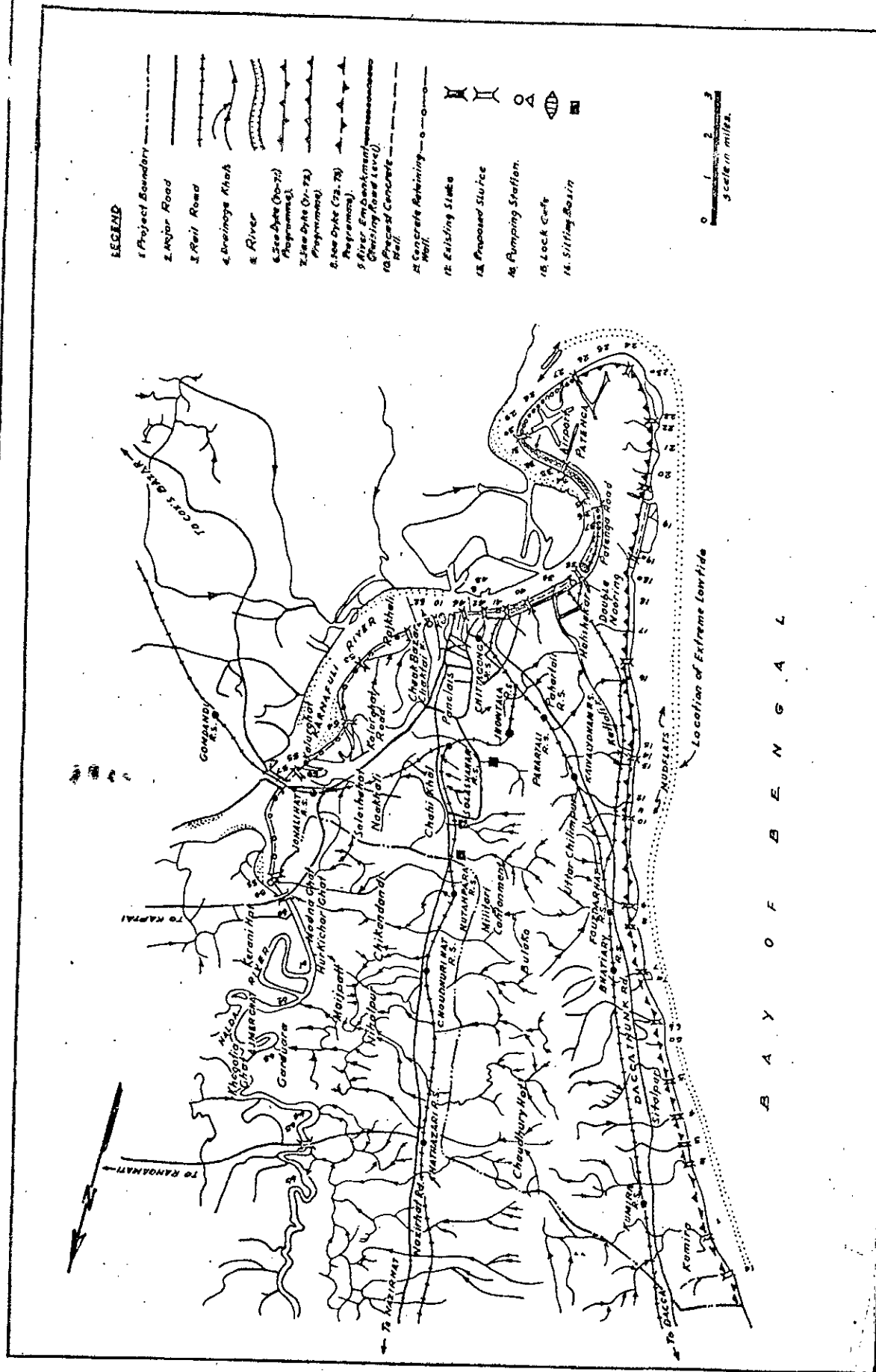
REFERENCES

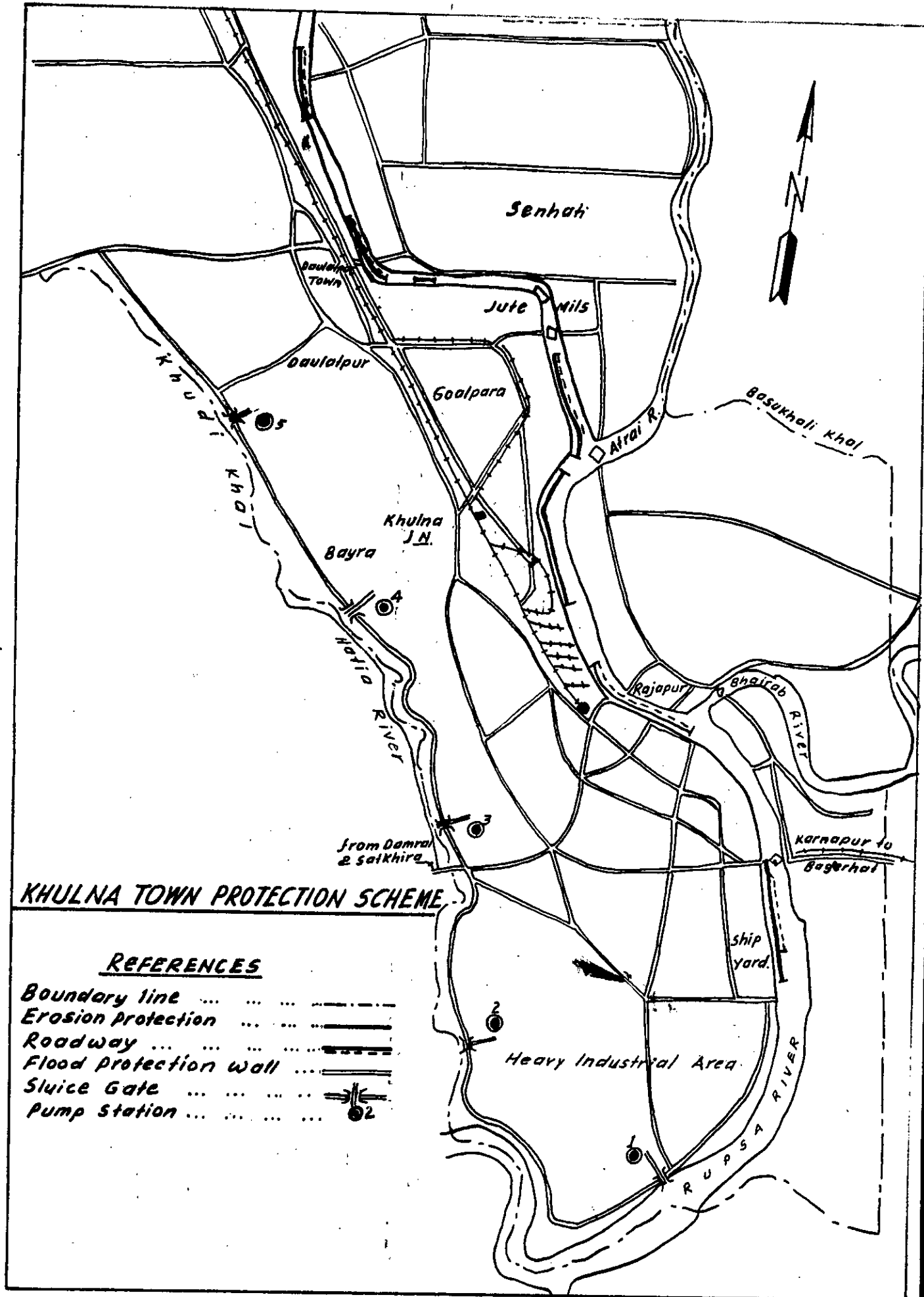
- Alignment of Dike 
- Drainage area boundary 
- Railway line 
- Major Roads 
- Build up area 



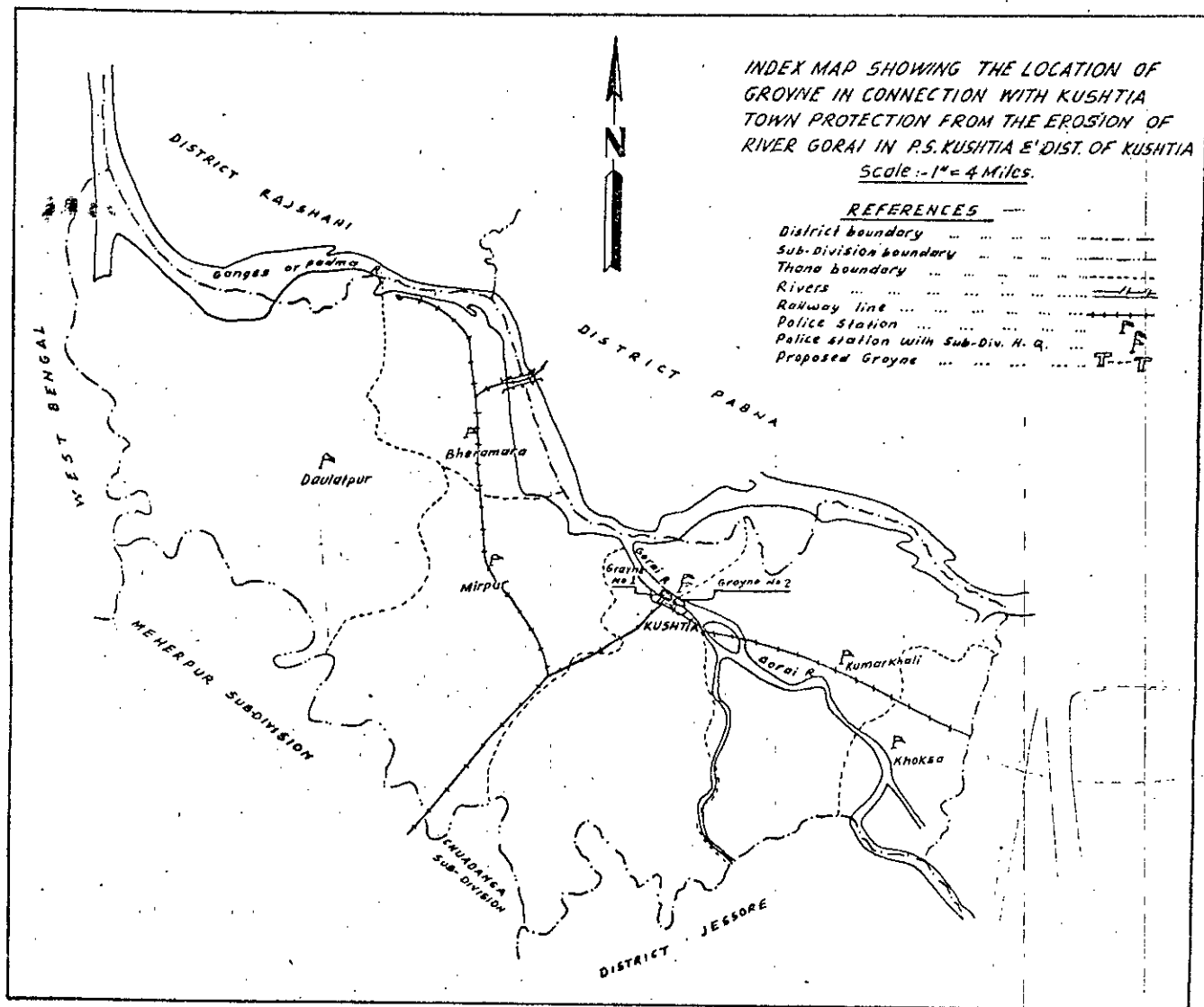
Scale
1/8 1/2 3/4

MAP 16. DACCA CITY DRAINAGE AND FLOOD CONTROL PROJECT



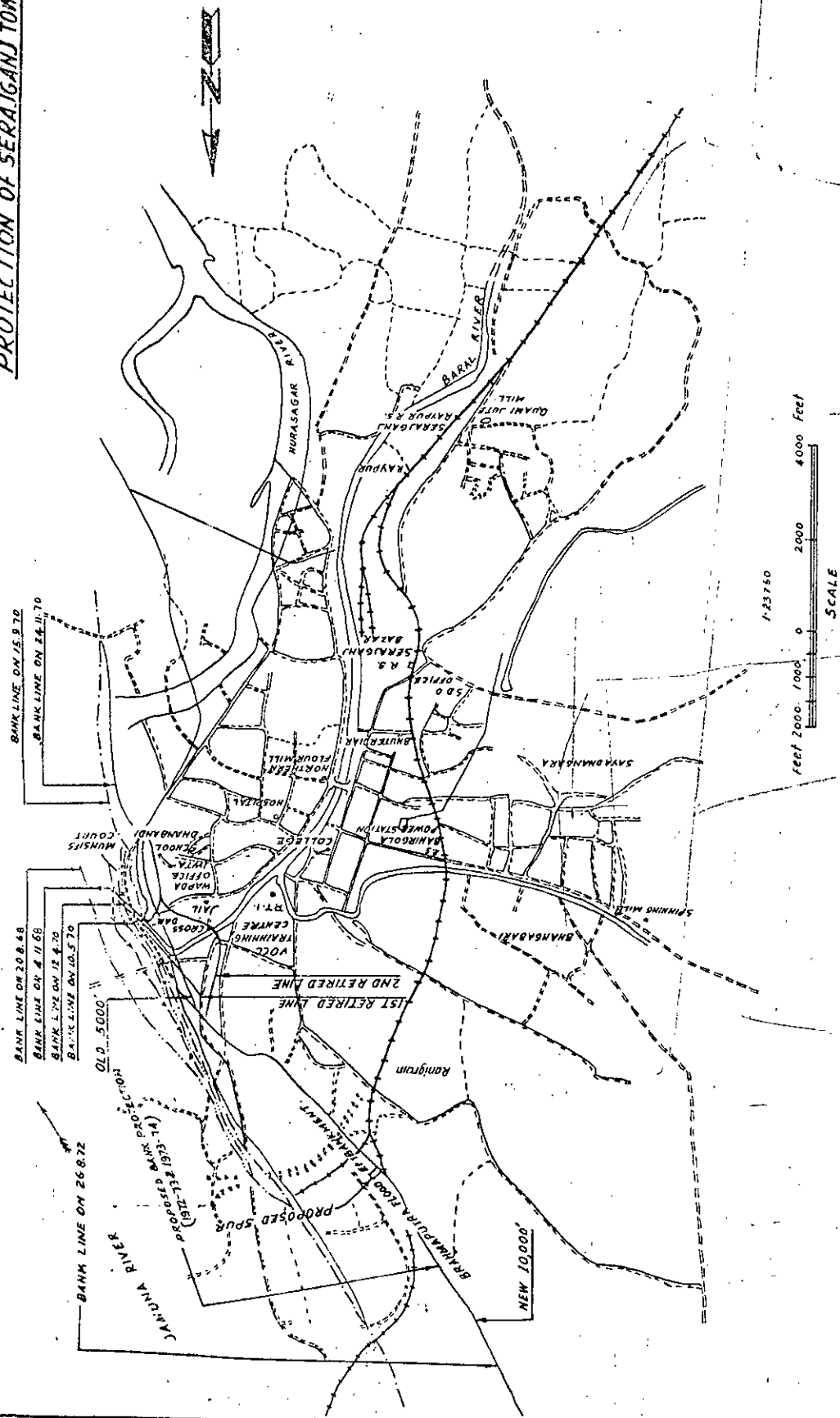


MAP 19. KHULNA TOWN PROTECTION SCHEME



MAP 20. PROTECTION OF KUSHTIA TOWN

PROTECTION OF SERAIGANJ TOWN



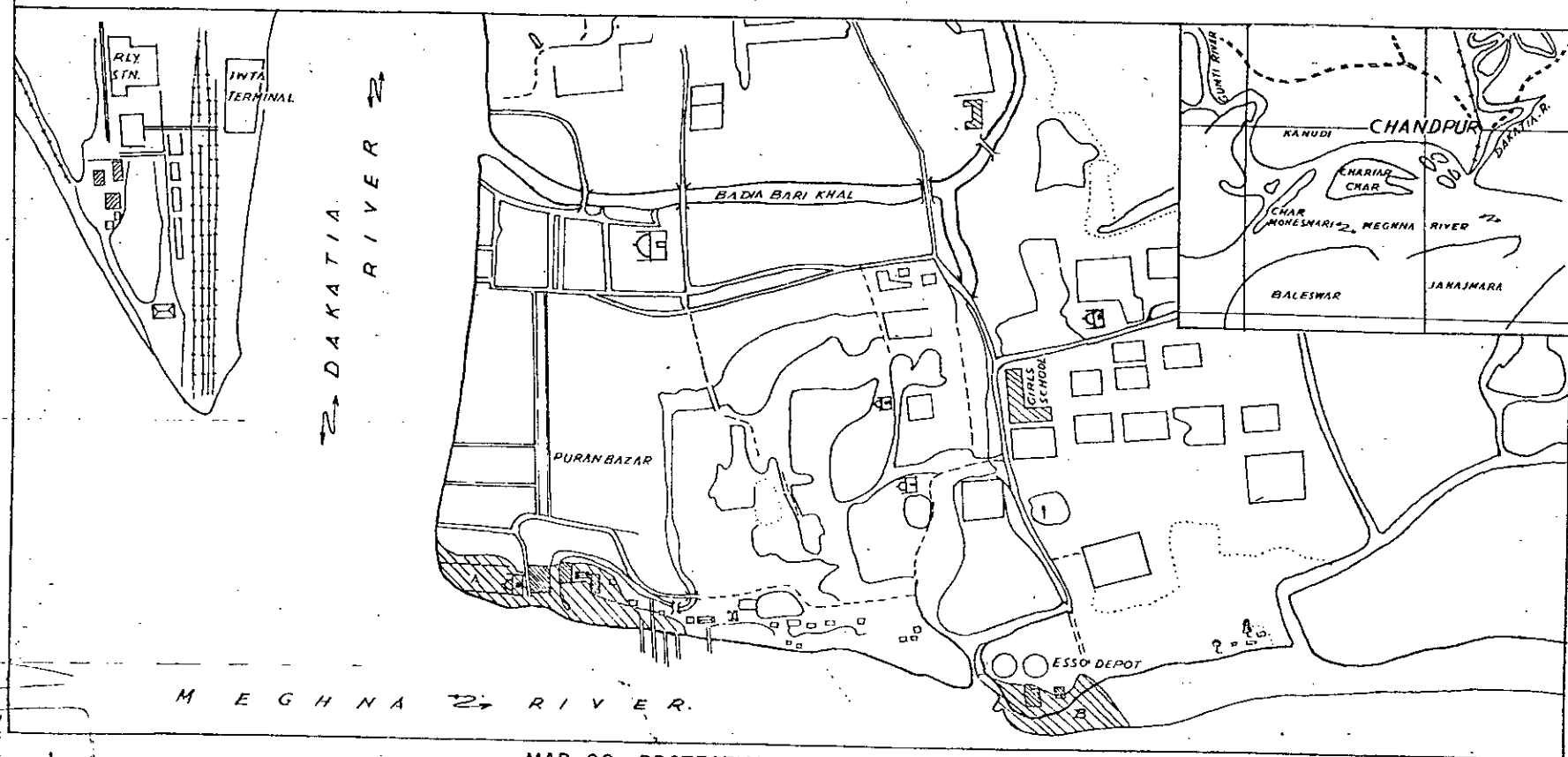
MAP 21. PROTECTION OF SEIRAJGANJ TOWN.



PROTECTION OF CHANDPUR TOWN.

SCALE 1"=500'-0"

LAND ENDED ———— 
 PART A ———— 2.46 ACRES
 PART B ———— 1.14 ACRES.
 TOTAL = 3.60 ACRES.



MAP 22. PROTECTION OF CHANDPUR TOWN.



Sl. No.	Name of the Urban Centre	Name of the River	Status of Feasibility Report or Construction
11.	Madaripur	Arialkhan	Feasibility Report is under preparation.
12.	Jamalpur	Old Brahm-putra.	Feasibility Report prepared.
13.	Ramgarh	Feni	Feasibility Report not yet prepared.
14.	Munshiganj	Dhaleswari	-do-
15.	Manikganj	Kaliganga	-do-
16.	Chapai Nawabganj	Mahananda	-do-
C. Commercial Centres;			
1.	Haragacha Bandar	Tista	-do-
2.	Chilmari Bandar	Brahmaputra	Feasibility Report prepared and construction started.
3.	Dewanganj Bazar	Old Brahma-putra.	Feasibility Report not yet prepared
4.	Bhairab Bazar	Meghna	Feasibility Report prepared and construction started.
5.	Kumarkhali	Gorai	Feasibility Report prepared and construction completed.
6.	Shambhuganj	Old Brahma-putra.	Feasibility Report not yet prepared.
7.	Manumukh	Kushiyara/Manu	-do-
8.	Wazirpur	Dawarika river	-do-
9.	Sikarpur	Sikarpur	-do-
10.	Banoripara	Swarupkati	-do-
11.	Morrelganj	Baleswar	-do-

Sl. No.	Name of the Urban Centre	Name of the River	Status of Feasibility Report or Construction
12.	Maltab Bazar	Dhonagoda	Feasibility Report not yet prepared.
13.	Dhonagoda Bazar	Dhonagoda	-do-
14.	Durgapur	Someswari	-do-
15.	Amua	Bishkhali	-do-
16.	Badarganj Bandar	Chikli/ Jamuneswari	-do-
17.	Sardah	Ganges	-do-
18.	Bera	Hurasagar	-do-
19.	Godagari	Ganges-Mohananda	-do-
20.	Gaforgaon	Old Brahmaputra	-do-
21.	Kazipur	Mathabhanga	-do-
22.	Belonia	Mohuri	-do-
23.	Baidyer Bazar	Meghna	-do-
24.	Chhatak	Surma	-do-
25.	Nazirhat	Halda	-do-
26.	Balia	Banshi	-do-
27.	Kaliganj Bazar	Lakhya	-do-
28.	Dacope	Daki Nadi	-do-
29.	Assasuni	Marichapa	-do-
30.	Paikgacha	Sibsa	-do-
31.	Zakiganj	Kushiyara	-do-
32.	Ballah	Khowai	-do-
33.	Fenchuganj	Kushiyara	-do-

Sl. No.	Name of the Urban Centre	Name of the River	Status of Feasibility Report or Construction
34.	Kanairghat	Surma	Feasibility Report not yet prepared.
35.	Ashuganj	Meghna	-do-
36.	Lacharipara	Feni	-do-
37.	Roazerhat	Ichamati	-do-
D. Communication Links:			
1.	Fulcharighat	Brahmaputra	-do-
2.	Bahadurabad	Brahmaputra	-do-
3.	Jagannathganj	Brahmaputra	-do-
4.	Nagarbari	Brahmaputra	-do-
5.	Arichaghat	Brahmaputra	-do-
6.	Goalundoghat	Padma	-do-
7.	Siramdighat	Padma	-do-
8.	Dohazari	Sangu	-do-
9.	Chiringa	Matamuhuri	-do-

Development Of Water Fronts Of Urban Centres

River fronts of urban centres in Bangladesh are being used for commercial purposes. Most of the river fronts are not properly developed. There is tremendous scope for development of river fronts.

River front of an urban centre must be very beautiful and attractive to look at. Besides commercial activities there may be facilities for recreation such as boating, angling and other sports.

There may be some good eating places. River fronts must be kept very neat and clean, so that it may attract even the foreign tourist.

Development of Ports And Harbours

In Bangladesh there is tremendous scope for the development of ports and harbours. Chittagong and Chalna are the two important sea ports. With the closure of estuaries, there will be more scope to establish more sea ports and harbours. At the moment except a few inland river ports which were developed by IWTA, such as, Dacca, Narayanganj, Chandpur, Barisal and Khulna, condition of other inland river ports are precarious. Even these ports have got no other facilities except the terminal buildings.

Development of Fisheries

Physiography and climate of few countries of the world of comparable size enjoy such vast fisheries potential within their boundaries and territorial waters as Bangladesh. Although there is no reliable information, it is estimated that more than 30 lakhs acres of different types of water bodies constitute the inland fishery resources, whereas the territorial water cover an area of over 25 lakhs acres. In addition to these, sixty to seventy lakhs acres of paddy field which remains under water for three to six months may be used as seasonal fish rearing ground.

"Fisheries sector plays a significant role in its contribution to Gross Domestic Product, foreign exchange earning, employment and nutrition of the people of Bangladesh. It is estimated that

approximately 8 percent of the population of Bangladesh derive their livelihood directly or indirectly from the fisheries sector. Prior to 1965, fish exports accounted for about Tk. 5 to 8 crore a year. The role of fisheries in supplying animal protein is even more vital as evident from a past Nutrition Survey which shows that more than 80 percent of the animal protein comes from fish alone¹.

Some of the problems and constraints inhabiting and retarding development of fisheries resources in Bangladesh are:

(a) Profit oriented catching and revenue oriented management system without due regard for future conservation (b) destruction of many important natural fish habitats due to the withdrawal of water by low lift pumps for crop production, (c) indiscriminate use of pesticides and fungicides which prove to be toxic to fish population and (d) construction of coastal embankment and estuary enclosures interrupting natural breeding, and causing discontinuity in the life cycle of fish.

Unsatisfactory achievements in production, and development of fisheries can also be attributed to (i) poor socio-economic condition of fisherman, (ii) multiple ownership of the private ponds, (iii) lack of facilities for preservation, quick transportation and efficient marketing of existing catch of fish.

¹ Government of the People's Republic of Bangladesh, Planning Commission, the First Five Year Plan 1973-78 (November, 1973) P.112.

Production in the inland fisheries should be intensified by proper fish culture. As many derelict water areas as possible should be reclaimed, developed and brought under scientific fish culture and management. Optimum fish production in all water bodies including Kaptai Lake which are already under fish culture, may be ensured. The owner of the private ponds should be given all necessary assistance in the form of technical know-how, fingerlings and fertilizers at subsidized rates, so that they get sufficient incentive to bring their ponds under scientific fish culture. Additional powered boats with engines should be provided for operation in the estuarine and other inland waters.

To expand fishing in the Bay of Bengal increased number of mechanized crafts and trowlers should be provided. For catching fish in the shallow regions of the sea, large number of country boats should be introduced. It is necessary to conduct a systematic survey on various aspects of inland fisheries to obtain reliable information for future planning and development. The programme should include comprehensive studies on resources and stock assessment and management, survey of fisherman, types and efficiency of fishing gears in use, fish consumption rate, handling, transportation and spoilage; survey of fish markets and study of the economics of the inland fisheries industry.

Protection should be given to the small fisherman from exploitation. The present system of fish exploitation from public waters and marketing of the fish should be changed so as to render the fisherman free from the grip of the lessees and other middlemen in the fishing.

Co-operative organization of fisherman should be encouraged for providing them material inputs including credits more easily.

Any water resources use should be given due consideration for fisheries and all possible measures should be taken to eliminate or minimise harmful effects on fisheries.

Rules already promulgated in the past or to be promulgated in future to prevent the destruction of undersized and brood fishes both marine and inland should be enforced by the Government with all earnestness and vigour.

Development of Forest

Forest occupy only 8,486 square miles,¹ about 16 percent of the area of Bangladesh. For a balanced economy, a minimum of 20 percent of the total area should be under forests. With 63 percent under forests in Japan, 51 percent in the USSR, 34 percent in USA, 28 percent in Germany, these countries are in a happy position. Forest conservancy in Bangladesh started in 1864, when the Forest Department came into existence.

There are only four main forested areas, parts of the Chittagong Hill Tracts and Chittagong districts, South Khulna, North and South Sylhet, and the Madhupur area in Dacca and Mymensingh districts. This makes the regional distribution of forests rather uneven. Most of them lie either in the extreme south-east or south, the only exception being the Dacca-Mymensingh forests which are the most centrally

¹ Nafis Ahmed, Op. Cit., P.199.

situated but cover the smallest area.

The forests of Bangladesh are of great economic value. Of the total area under forests (8,486 square miles), a little less than half i.e. 4,441 square miles are classed as Government Reserve Forests, 137 square miles as Protected Forests, 3,453 square miles as unclassed Forests and the balance 455 square miles as Private Forests.

Close observation will reveal that in Bangladesh practically two different forest areas can be distinguished: forests in the North-Eastern districts and the forests in Chittagong Hill Tracts. In the former region the pressure on the meagre Sal forest of the district of Dinajpur and Rangpur is excessive. This forest should be conserved and improved in order to meet the timber famine existing in this part of the country. Their accessibility has given these forests a special value, and because even the smallest stick can be utilized they will lend themselves, more than almost any other forests, to an intensive system of management.

The forest bearing areas of Dinajpur and Rangpur were not brought under the Private Forests Act till 1952. In the meantime, the owners continued the destruction of the forests uptill the partition of the country and the creation of Pakistan. As a result most of the present forest is clear-filled with coppice growth varying from one to eight years of age. In addition, forests were subjected to excessive grazing and annual burning of the undergrowth to provide fodder for cattle.

A high forest system could be extended into this area. Scientific forest management requires that felling be restricted to annual coupes and that regeneration following fellings be scrupulously protected against grazing. In order to cause minimum inconvenience to the rightholders, it is the practice to lay out coupes at a short distance from their villages. In large blocks of forest, fairly effective protection against grazing can be secured by vigilance on the part of the protective staff and a little consciousness on the part of the local people. In small, isolated patches surrounded by habitations, protective fencing against cattle must be maintained for some time. In many cases even areas of 30 to 40 acres are being afforested and fenced, it will obviously render planning quite useless if forests already existing are allowed to be destroyed merely for lack of fencing.

In some areas in the past a considerable part of the local land-less population was dependent for its living on the forests. The people removed forest produce from these forests and sold it in the adjoining markets. Sometimes they had to pay the landlord a nominal price for the produce removed. Today no amount of protection can save these forests unless the people are provided with alternative employment.

As the private forests have now been taken over, the responsibility of supplying local market with forest products devolves upon the Forest Department. Arrangements must be made for supplying these markets either departmentally or through coupe purchasers. In most

areas forest management becomes a sociological rather than a technical problem. The average villager is not interested in long-term policy. What is required is not so much the development of techniques as the inculcation of a new outlook.

Local people must become associated with the management of the forests. The protection of forests adjoining villages, distribution of product from the rightholders, coupes, apprehending forest offenders, and even their trial can be given over to the local union councils. Once the people start looking upon the forests as their own responsibility many of the difficulties will be solved, even though the details of management must still be subject to control by the Forest Department.

The forests might be classified into two categories - commercial and community forests. Commercial forests would be predominantly worked for maximum financial yield and the revenue collected by the Forest Department. In the remaining forests, which are essentially meant for supplying the local people, the community can be brought to share the responsibilities of management.

In the Chittagong Hill Tracts more than nine-tenths of the forests is being managed on a "care and maintenance" basis. In the district of Chittagong, no more than a quarter of the area is under a system of concentrated regeneration. The difficulties are two-fold problems of extraction and utilization of the standing crop, and problems of regeneration in the felled areas. The produce, consisting

of sawn timber, is extracted and shoulder-borne for considerable distance, because good roads and navigable streams are lacking. Because of high cost of labour only selected pieces are removed and much is wasted. In the Chittagong Hill Tracts, the difficulties are even greater-labour is scarce, the climate unhealthy, and the terrain hilly.

Large-scale mechanized logging operations in the Kassalong valley forest are being done by the Forest Department Corporation. In other parts of the Chittagong Hill Tracts, e.g., in the valleys of the Rangkhiong, the Subalong, the Sangu and the Matamuhuri, no large-scale logging operations are contemplated just now. With the completion of Kaptai hydro-electric dam, the water level in the Rangkhiong and the Subalong has risen appreciably and this would facilitate floating down of big logs. The possibilities of constructing dams in the Sangu and Matamuhuri valley are also worth investigating. Besides supplying hydro-electric power, such dams would open up these inexcessable forests.

The forests in the district of Chittagong are too scattered to plan any large-scale mechanized extraction. Development of a network of roads in the region and encouragement in the use of portable power saws should go a long way towards solving the problem.

Once logging problems are solved, the Forest Department will still be confronted with problems of regenerating the felled areas. Where labour is available a system of clear-felling with Taungya

plantation seems appropriate. The custom of roving agriculture (or jhum) is widely prevalent amongst the tribal population in this region. In Taungya plantations field crops are grown between rows of trees which the tribes plant and tend in exchange for the agricultural crops. When the trees are established, the cultivation moves on to new areas. The Forest Department supplies the nursery stock, does general supervision and usually gives some cash reward after the plants are established.

While labour for Taungya is plentiful in the Chittagong Hill Tracts, it is inadequate in the district of Chittagong. Over three-quarters of the 800 square miles of forest in the district of Chittagong must be worked on a kind of selection system because of the lack of regeneration methods. To find a practicable means of naturally regenerating these evergreen forests with a reasonable degree of success still remains a challenge.

There are many possible ways of producing the amounts of wood and naval stores required in the future if these are the only products required from the river basin. Production could easily be increased by increasing the number of acres devoted to forestry or by land-use changing that would utilize the better lands for tree growing. The number of acres must be established at the beginning of the studies. Production increases from the basins, therefore, would depend mainly on the management and protection of the land that would be devoted to forestry.

Using the fixed woodland acreages, estimates of the timber growth that might be achieved in Bangladesh for the selected target years were made under assumptions of (1) prospective changes in forest management and (2) high-level management. High-level management is defined as the application of measures now being applied on the best-managed lands in the basins. Prospective management level is based on current trends in forestry.

"Certain modification of forestry-measure needs required under high-level management assumptions were made. It was recognized that all forestry owners would not participate in the plan and that some would only engage partially. To account for this lack of participation, a reduction of 25 percent was made for those measures requiring general participation by all woodland owners. It was thought that the loss of projected annual growth due to non-participation would be offset by the gradual application of research findings. The forestry committee agreed that improved utilization, superior trees, and improved harvesting techniques could make up the deficit that might be anticipated if all woodland owners did not carry out the programmes indicated as being needed for high-level management"¹.

The increased salinity in the river due to reduction in the upland flow caused by withdrawals of Ganges water by India at Farakka during the low water season will also affect the growth of Sundarban

¹ Food and Agriculture Organization of the United Nations. The Appraisal of Agricultural Fishery and Forestry Resources in Relation to needs in the Lower Ganges-Brahmaputra Basin. Rome, September, 1959.

forests lying in Khulna district in the south. It has been established that quality and density of forest are best in the fresh water areas and the forests become poorer and more open as one proceeds towards more saline soils. The increased salinity will, therefore, affect the revenue from these forests considerably (Map 23).

As the results of functional studies on forestry began to take form, it was necessary to determine the interrelationships. Most recommendations for one function invariably affect one or more other functions, either beneficially or adversely. For forestry, special studies were made to determine the effects of recreation, grazing, flood protection, and wildlife management proposals on commercial woodland production. The effects of these other programmes on forestry were evaluated in monetary terms if the magnitude of the change was sufficient to warrant such analysis. Although the benefit and cost analyses of interrelationships were often critical factors in the justification of small projects or programme, the overall effect of all other functional recommendations on wood production was not great enough to necessitate revising the overall forestry programme.

National Parks

National Parks for recreational purposes can be established in forests of Bangladesh. Government has already started developing a National Park at Madhupur Forest in Mymensingh district.

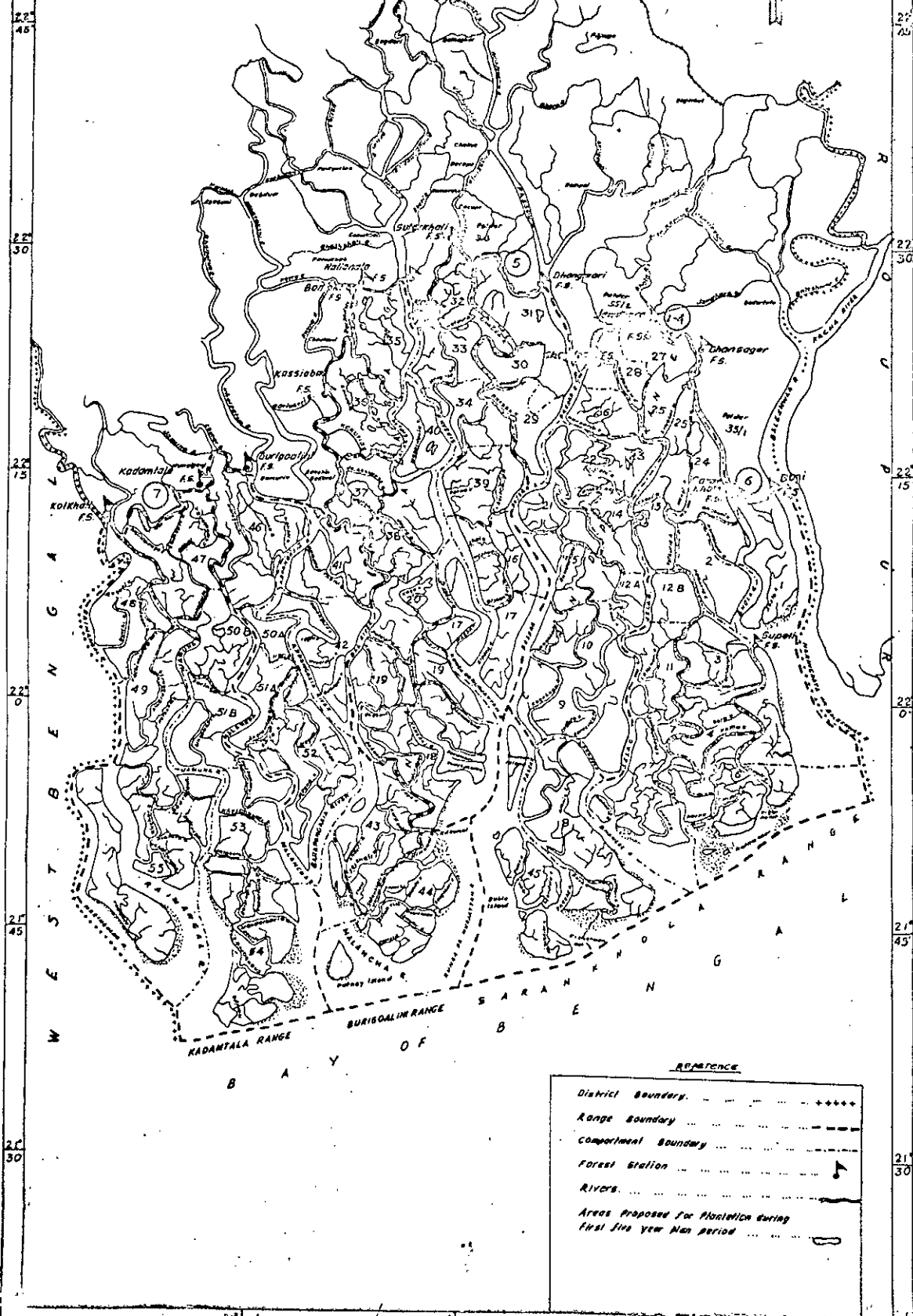
National Park lands are usually mapped on aerial photograph in the field in four categories: (1) Residential, (2) Commercial,

(3) Camp and Trailer sites, and (4) Parks proper. National Park "residential" lands include permanent and winter home tracts within primary recreational areas. The estimated density of home per acre is also indicated in the course of the survey. National Park "Commercial" lands include those containing motels, resorts, hotels, stores, restaurants and similar commercial establishments in primary recreational areas. Lands mapped in the "camp and trailer sites" category include those areas so used within primary recreational areas but outside the boundaries of public parks. The entire area within the boundaries of parks is included in the "parks" category without regard to the extent of development thereon. Obviously, nearly all of the mountainous, seashore, and water surface areas are suitable for some use such as hunting, fishing, hiking, picnicing and other recreational activities of this nature. For the purpose of this land use survey, however, except for parks, consideration must be given to those lands where some fairly intensive development requiring water service was located.

In the United States, National Parks has developed significantly for recreational purposes.

"The United States has set aside a number of areas as National Parks and National Monuments to be preserved for the education and enjoyment of the people. The National Parks are remarkable chiefly for their scenic beauty or grandeur, and many are also sanctuaries for wildlife. Some contain buffalo, mountain goats, elk, bears and other

Scale 1:40,000



creatures which might otherwise become extinct. These parks, twenty-nine in number, total more than nineteen thousand square miles in area. The National Monuments, eighty-five in number, total over fourteen thousand square miles in area. In addition, five Historical Parks, eleven Military Parks, two Battlefield Parks, ten National Cemeteries,¹ ten National Memorials and several miscellaneous areas are under the Department of the Interior. The National Forests, formerly called Forest Reserves, are administered by the Department of Agriculture, both to protect and develop timber resources and also to protect watersheds. The parks, monuments and forests receive every year thousand of visitors from all parts of the United States"¹.

"A National Park is created by congress for the sake of developing and perpetuating it for the public enjoyment, and a National Monument is proclaimed by the President to conserve some restricted area of unusual scienic or historic interest. A National Forest, on the other hand, is administered by the Federal Government for the service of the public, in part to conserve the timber crop and in part to protect the watersheds and so prevent floods and resultant drought and aridity. There are 151 national forests with a total of 180,758,433 acres or 282,435 square miles. The size of each of the National Parks ranging from over 3,000 square miles to only a few acres. Most of the National Monuments are small, though some include large areas. It is

¹ The Grolier Society. Lands and Peoples - the World in Colour. Vol. VI. (Toronto: The Grolier Society Incorporated, 1951). P. 377.

probable that there will soon be a reclassification transferring some from one list to the other. The present arrangement has grown up without much plan, and some in each group logically belong in the other. Parks, Monuments and forests welcome hundreds of thousands of vacationists every summer¹.

Wild Life Preservation

The approach followed in conducting wildlife studies is in accordance with the concept that the ultimate aim is to satisfy human needs and desires. The principal needs for wildlife are for hunting, and for food, furs, oils, and other industrial products. In considering these needs, wildlife studies are oriented toward the people.

Use of wildlife resources for hunting is measured in terms of "man-days" or "user-days", which are synonymous. Either one of these terms is defined as any part of a day spent hunting or fishing by an individual. The total user - day expended by the hunters residing within a specified area was expressed as the hunting effort. The impact of this use on a specific resource or area was referred to as the hunting pressure.

Demand is defined as the total user - days expended by all the people in a specified area if wildlife resources are developed to relatively high levels. It is difficult to apply this concept, however, since distribution, abundance, availability, and costs of

¹ The Grolier Society. Lands and Peoples - the World in Colour. Vol. VI. (Op. Cit., p. 377)

wildlife resources are often the dominant factors influencing utilization.

Bangladesh's natural scenic beauty, its mighty rivers, its ever-green corn - fields and forests, its hills and hillocks of red alluvium have spread out a fascinating scene of beauty for everybody. Like the people and their cultural heritage, the picturesque tribal races and their way of life, varied wildlife that inhabit hills and forests have also unequal attraction for the out-siders.

Royal Bengal Tiger is an awe-inspiring name known to every part of the world. Forests of the Sundarban, located in the southern part of Khulna, Barisal and Patuakhali districts is the home of this King of the jungles. The Royal Bengal Tiger lives in the deep of the forests, but there are plenty of deer and ducks that live in the outskirts of the jungles. Besides in the creeks which intersect the area, crocodiles in abundance can be found. A tourist passing through these creeks on boats, can see hundreds of these ducks and crocodiles on the water front and if he is fortunate, sometimes even a tiger. Tiger generally live on these deer and ducks, hares and other animals, but occasionally a wood cutter or honey collectors is also killed by a man-eater. Annually several such cases occur. Various kinds of snakes, particularly the big python weighing several pounds is another attraction of the Sundarbans.

The forests of Chittagong and Chittagong Hill Tracts are stocked with various kinds of wildlife including the herds of elephants,

tigers, panthers, deer, wildbears, monkeys and big python. The trapping of wild elephants through a local method known as "Khida" is very exciting. A large tract of land is first fenced with big tree trunks securely bound together and then the stockade is planted with banana trees and long grass. Within a short-time the stockade turns into a tempting "dish" for the grass eating animals, particularly the elephant. A wide path-road is then made planted with grass and sometimes tame elephants are released to mix with the wild elephants and lead the herd into the stockade within a few days. When the wild elephants are inside the stockade the pathway is closed by a hanging door which remained concealed so long with two big trees on both sides of the pathway. When the wild elephants can perceive that they were caught in a stockade, they try to break the fencing. But frightening noise is produced by means of drums and tomtoms all around the stockade and a great number of people armed with spears are also posted around to protect the fencing wherever necessary. Within the first few days the banana trees and all the grass inside the stockades is eaten up by the elephants and shortly they are faced with a "famine of food". Continued fasting make them weaker within a week or two and they are claimed gradually one by one with the help of the tame elephants and taken out of the stockade. The process of tamping the wild elephant takes several months. The whole process of the Khida operation, though risky and dangerous, is pleasantly exciting. Generally one such Khida operation is held annually in the area between Cox's Bazar and Ukhia or in the deep forests of Chittagong Hill Tracts.

Forest areas of Madhupur in the Tangail and Mymensingh districts and those of Bhowal near Dacca have also many wild animals including the panther, wild bear etc. National Park at Madhupur is a charming place to go and roam about. Tourists Organisation of Bangladesh has luxury coach service to take the tourist to this park. It is to be noted that previous permission ought to be taken from the Forest Department for hunting or to visit in any forest area.

Now discussion is made, about the game birds in Bangladesh. There are extensive Bil and Haor areas in Bangladesh, specially in the Sylhet district and also in the eastern parts of Mymensingh where all sorts of wild ducks, storks and other gamebirds are found in abundance. In the big Chalan Bil of Pabna and Rajshahi district also such gamebirds abound. There are bils in other parts of the country where plenty of gamebirds can be bagged. These bils and haors may be called the paradise of the hunters.

Unfortunately there is hardly any statistical data available in the country regarding the wildlife population in the country. Reliable data regarding the visitors are also lacking in Bangladesh. But there is a feeling that due to uncontrol hunting wildlife is diminishing gradually throughout the whole country. To preserve the wildlife of Bangladesh, the Government has imposed a ban on killing and capture of wildbirds and animals.

Wildlife occurs directly in relation to the type, condition and amount of habitat available. Habitat is controlled by soil types,

climate, latitude and attitude etc. Many habitat types are encountered ranging from Chittagong Hill Tract region in the south-east, north-eastern hill areas, agricultural land in the flood plain, and the marsh lands in Sundarban forest. The usefulness of these lands for wildlife is influenced by the availability of water and the effects of human activity in modifying such logging, agricultural and marsh lands. As the wildlife resource in Bangladesh is very limited, the Government should take positive action to preserve the existing habitats of wildlife. New habitats should be allowed to grow and wildlife be restricted to suitable habitat.

Development of Bils and Haors

The plains of Bangladesh contain a large number of bils, the characteristics of which have been described in a general manner. The mode of their origin, however, has certain interesting geological and hydrographic aspects. The bils of Bangladesh, as a part of the natural physical environment, are not all of the same origin. They were formed principally in two ways:

- (a) The largest number of them, which vary in size and are most commonly spread over the surface of the plain, are scars and "left out" of old river beds, now deserted by the streams which once occupied them. They especially abound in the area of the so-called dead and dying

~~rivers.~~

- (b) There are, however, a number of bils of vast size, which include some of the largest ones. These are actually basin areas. The basin areas are usually not discernible as low lying, though they become obviously so during the rainy season and present a vast sheet of water. Some are of enormous size and retain water permanently, though its extent varies during the seasons.

"As regards the origin of the basins of the bils, Fawcus held that some amount of subsidence was implied, as the area covered by them is large. Apart from geological opinion with regard to subsidence mentioned already, support was lent to this view by the occurrence of coastal erosion and evidence of subsidence by a comparison of Rennells surveys in 1770 and the survey work of 1906. The origin of these bils may be attributed to earth subsidence, as they could not be merely natural pockets due to silt-laden rivers building up their own banks and thus enclosing vast areas of lowland. Jack lent support to the explanation based on subsidence by mentioning the discovery of brick foundations, skulls and coins, etc. in these bil areas in Swarupkati and Bhandaria (Bakerganj). He also pointed out that the bils have actually grown larger since Rennell's time"¹.

The eastern part of Mymensingh district, and western part of Sylhet district and northern part of Comilla district comprise a vast low lying area of about 1700 square miles known as "Haor Area". The area extends over the drainage basin of the Meghna river and its

¹ Nafis Ahmad, Op. Cit., P.31.

tributaries within Bangladesh. Some of the Meghna river tributaries that flow through the haor areas originate in India.

The area is primarily a large flat alluvial basin with several haors scattered here and there. The elevation of the area varies from R.L. 0.00 to 15.00. There is apparent geological evidence that the northern portion of the area is Meghna valley which has subsided 30 to 40 feet during the past 100 years to the extent that the subsidence has equally or exceeded the rate of sedimentary fill of the basin. The physical characteristics of the area are complex in that they have been the site of sedimentary deposition by the large rivers viz. the Old Brahmaputra and Meghna. Like other deltas, it is composed of a number of overlapping sub-deltas. There have been many changes in the courses of the rivers. These changes coupled with subsidence have left a large number of haors and other low-lying areas throughout the Meghna river basin.

The average precipitation is exceptionally heavy and varies from 70 inches in the southern side to about 200 inches in the northern side of the bil and haor areas.

Boro is the main crop of the areas. Very little broadcast, Aman, Aus and rabi crops are grown in fringes of the area. The Boro crops are grown in November and December and harvested in April and May. But if early flood occurs it damages about 50% to 75% of the Boro crops. Also drought condition damages about 20% to 30% of the Boro and other rabi crops. The whole area usually goes underwater to a depth of

10 to 20 feet and very often the area goes under water so rapidly that even long stem Aman cannot cope with the rise of flood.

In order to solve the problems of development of bils and haors throughout Bangladesh the following measures should be taken:

- (a) Inventory of water bodies of bils and haors should be prepared for the whole year.
- (b) Bils and Haors may be developed for agricultural purposes.
- (c) Bils and haors may be developed for recreation purposes.
- (d) Bils and haors may be developed for fish and wildlife preservation purposes.

Recreational Uses Of Water In Bangladesh

Recreation studies are conceived and applied mainly on the basis of a use concept. Use is expressed in terms of user days. Recreation is defined as public, outdoor recreation activities which dependent upon land and water resources, exclusive of playground-type recreation. Hunting and fishing are recognized as forms of recreation.

To treat recreation on a basis comparable with other functions in a plan, recreation developments must stand the usual tests and be subjected to the same types of analyses as are ordinarily applied to the other functions. Thus, recreation must consider both tangible and intangible benefits and costs.

To make an estimate of user-days a review is made of available data primarily to define the significant and controlling factors which influence outdoor recreation. While many factors are known to have an

influence, the following are the most significant:

(a) population, (b) mobility, (c) income, and (d) leisure time. Other factors noted, but not singled out for detailed study, include the users' age, sex, occupation, place of residence, paid vacation, race, and education.

In Bangladesh multiple-purpose projects should be considered for recreation purposes in the regional plan. These studies should be based in developing a comprehensive plan for the land and water resources. Because the goals remained the same, the impact upon all recreation resources involved continual review. The following list represents the major types of outdoor recreation activities based on water resources that may be used in the recreation studies:

(a) Sightseeing - Generally those activities related to relaxation and leisure driving, such as viewing scenic areas, visiting lookout towers, structures, and scenic viewpoints.

(b) Picnicking - Those activities related to picnicking at a specific site, such as wayside areas, National Parks, by river, lakes, and coast.

(c) Swimming - All water-contact sports, which includes fresh-water swimming (lakes and rivers), salt-water swimming, surf bathing, skin and scuba diving.

(d) Boating - All boating activities such as surf boating, canoeing, row boating, white-water canoeing, outboard-motor boating, inboard-motor boating, sailing and water skiing.

(f) Camping - Includes all types of camping - organized group, individual, family, tent, cabin camping and trailer.

(g) Hiking - Includes all walking - related sports whose purpose is to get outdoor for out-of-door activity - specially, hill climbing, trail hiking, horseback riding, wilderness and beach strolling.

(h) Cultural - Includes viewing historical sights; viewing archeological sites; viewing geological sites; viewing fish and wildlife; viewing plant life; collecting plants; rocks, shells, and related items; bird watching; natural walks; and photography.

Marina

In Bangladesh thousands of country boats and hundreds of launches are anchored just in the rivers without any harbour facilities. Therefore, during storms, cyclones and tidal bores most of them are damaged. Moreover, at present there is no provision of collecting the gurbages and human excreata from these anchored vessels. As a result, all these things are thrown into the river, which pollute the water. In western countries, specially in the United States, Marinas are constructed for safe hurbouring of boats and for pollution control. Such measure can easily be taken in Bangladesh by constructing marinas, specially in urban areas.

Sea World

For recreational purposes, now a days, every Western City has a sea world. There wonderful funs are exhibited by means of fishes

water and ducks etc. There is tremendous scope of development of sea world in the urban centers of Bangladesh to give recreation to the people.

Aquarimum

Aquarimum are also providing recreation to its people in the Western Cities. Thousand of city dwellers visit the aquarimum of a city daily. It is also inviting foreign tourist in large number. In Bangladesh there is enough scope of constructing aquarimum in the urban areas to give recreation to its urban population and also to attract foreign tourist.

Development of Tourist Resorts Based On Water

Tourism is as old as civilisation. It is not only the world's largest industry, but also one which has the scope of tremendous growth. It is one of the most promising and enterprising industries of the present era. The vital contribution of tourism industry need not be over-emphasised. It goes without saying that tourism makes valuable contribution to the national economy.

Unfortunately, the tourism industry in Bangladesh has continued to remain like an unexplored gold-mine. This is mainly due to the step-motherly treatment of the pre-independence regimes. No commendable effort was made to develop this valuable sector. Therefore, the tourist inflow into Bangladesh had dwindled to a negligible few. It remained unknown to the outside world that this region has so much to offer.

Nature has been very careful and kind, bounteous and generous, in making Bangladesh a land of bewitching beauty and superlative surroundings. This lovely land of nature is dotted with majestic hills and dales, meandering rivers and rivulets, colourful creeks with tortuous twists and turns, sands and foams, all rolled into one-blissful Bangladesh - a place for tourists and travellers, visitors and vacationers. Such a land of breath-taking beauty, of rich culture and old history is after all so very rare. It is a land of lovely landscape and scenic splendour. Besides, the temperate climate of Bangladesh is truly very welcome to all tourists.

Tourism like any means of raising revenue for the country, has to be considered not as a haphazard evolution of disconnected ideas which can be put together in the best possible or earliest manner in the shortest period of time. A good deal of market research is required, followed by the allocation of available funds, distribution of valuable expertise and the exploitation of every available resource of the country. There is tremendous scope of development of tourist resorts in Bangladesh based on water. In order to do this, the first and foremost task is to organise the means that facilitate travel, that is, transport and accommodation.

The necessity of an efficient tourist infrastructure can in no case be overlooked. Comfortable hotels and efficient transports go a long way to encourage this industry. An expeditious system of immigration and customs formalities should be inducted to facilitate quick travelling and lessen the tension of the tourists. After all,

human nature reacts adversely to restrictions on free movements.

Bangladesh has got huge potentialities in her natural resources. It can easily be harnessed to convert the land into a veritable paradise for the tourists. Our country can be proud of possessing the world's largest sandy beach, Cox's Bazar. For those who wish to ski, swim or get tanned, this place has got so much to offer. It should be of great attraction to tourists. Hunting is also easy, as green pigeons and jungle fowl abound in plenty in this area. The most favourable hunting ground, however, exists in the Sunderban jungles, which is a curious amalgam of land, sea and dense forests. The endless variety of birds, deer and the renowned Royal Bengal Tigers should be of great interest of all. There is an extravaganza of wildlife. Sylhet, which is located in the north-eastern part of the country, is another place which should be of concern to tourists. Its' terraced tea gardens are eye catching and seductive. It is a Mecca of migratory birds and young hunters should have all their fun.

Other captivating places in Bangladesh includes Rangamati, Kaptai, the Chittagong Hill Tracts, etc. All these places have varied qualities and novelties of their own. All these places may be made more attractive to the tourists, if facilities such as travel guides are readily available. Necessary steps should also be taken from time to time. Among the cities, Dacca and Chittagong are modern and gradually developing. There are many historical things to see in both the cities, and lovely picnic spots dwell in the surroundings of

the cities. The night life of the cities must, however, be improved to attract more tourists. More recreation facilities should be available and if necessary, to develop the cities in the line of other advanced cities of the world, night clubs, theatres, and so on, should be established. The most urgent requirement now is to ensure security to the night travellers. Law and order situation is of great value to tourists. Various other tourists resorts can also be developed in Bangladesh based on water resources, but this will depend primarily on the adequate exploitation of the vast untapped tourist potential.

Domestic And Industrial Water Uses

Domestic and industrial uses of surface water are small at the present times as most of the supplies come from groundwater, but this may change in the future due to the low yield of many aquifers. This is evidenced by the fact that additional water for Chittagong is to come from the Halda river northeast of that city, and for Dacca from the Lakhya river. Water for the fertilizer factory and its environs near Fenchuganj is pumped from the Kushiya river. Another industrial use is cooling water for present and future thermal power stations although the cooling water is returned to its source without loss. Water is presently taken from the Karnafuli and Passur rivers for use in paper manufacture at plants where expansion is being planned.

In areas converted from irrigated farming to housing and industry, water originally used for irrigation can be reallocated to domestic and industrial use without conflict. In other areas

competition for the water will develop to some extent during the dry season. Resolution of this conflict should be worked out with those agencies responsible for domestic industrial supplies.

Water supply problems do exist, however, particularly in the coastal areas where fresh water generally occurs both at very shallow depths - upto 70 to 80 feet (so called Ghyben Harzberg Linzes) - which makes use of high capacity tubewells impossible and at great depth - below 700 feet. Consideration should be given for installing desalination plants in the coastal area especially at Khulna for municipal and industrial water supply. Requirements of future industrial development should be carefully accounted for in planning allocations of the surface and groundwater resources.

Salinity Control

Encroachment of salt water from the Bay of Bengal up the rivers of the deltas is another consideration in planning water use. The position of the salt water front is a function of tides and the supply of freshwater to the tidal streams. An increase in river discharge moves the line of excess salinity toward the Bay and lengthens the reach of river from which water can be taken for irrigation and other uses. Decrease in river discharge reverse this process.

The effect of salt water intrusion have long been recognized as a limiting factor to full development of agriculture in the southern regions of Bangladesh. The Coastal Embankment Project of BWDB has been undertaken to reduce saline inundation of agricultural lands by direct tidal flooding.

Further expansion of agriculture requires irrigation development but withdrawals upstream may cause further saline penetration in the coastal estuaries. A survey was carried out in the coastal region of Bangladesh on the inter-relation between discharge, tidal variation and salinity penetration. This study revealed that with decrease of upland discharge/through the Ganges, the Gorai, the Arial Khan the Lower Meghna rivers, salinity will penetrate further inland towards Jessore and Faridpur districts. Salinity will also invade Barisal and the eastern part of Khulna districts, where water is now fresh for most of the year due to the flushing effects of the tidal rivers by upland discharge through the above rivers.

Withdrawals at Farakka would result in a sharp fall of water levels of the Ganges in Bangladesh in the low water season reducing the amount of fresh water supplies to spill channels like the Gorai, Ichamati, Kumar, Nabaganga, Madhumati, Bhairab, Atharabanka etc. during the critical months. Augmentations of low water flow of the Ganges is another practical solution of salinity control in the southern parts of Bangladesh. India and Bangladesh should work together to find a reasonable solution of this problem.

Pollution control

Pollution abatement should be an objective of legislation and control measures taken to prevent the pollution of rivers and streams.

by sewage and industrial wastes. Much progress has been made in the field of sanitation, but as the urban population increases, sewage disposal plants will be required to prevent pollution of the streams.

Although pollution by industrial waste is not presently a major problem in Bangladesh, the danger of chemical pollution of the water also increase with industrial development unless industries from the beginning are required to treat the industrial water properly before discharging them into streams or tidal waters. As preservation and expansion of the fishing industry is of vital importance to the economy of Bangladesh, and the disposal of any industrial wastes and uses of excessive fertilizer in the agricultural land, which are harmful to fish, should be controlled to prevent contamination of fishing waters which include all surface waters of Bangladesh.

Action Against Cyclone And Tidal Surges In Bangladesh

The cyclone and tidal surges of violent intensities have revaged the coastal areas of Bangladesh on many occasions during the past centuries while in the past decade it has become a regular event occurring at least once a year. On the 9th of May, 1961, the southern parts of Khulna and Barisal districts were revaged. Besides during the violent cyclones and accompanying tidal surges on the 28th of May, 1963 and 11th of May, 1965, the coast of Chittagong and the coast of line of Barisal were heavily affected.

"The November, 1970 cyclones took several hundred thousand

lives and caused an estimated Tk. 8,400 million of damage"¹. It was said to be the biggest catastrophe of the world in living memory.

Protection against these two menaces is building coastal embankments sufficiently high to prevent sea water entering land. Afforestation in the coastal area helps considerably to reduce the flood height of the water surge within a short distance from the coast and it helps in reducing the intensity of cyclones.

"Most of the population in the coastal area are either cultivators or fisherman. It is not difficult for them to work in the field in the coastal area from a distance of a mile to a mile and a half. We consider that it will be inadvisable to build any dwelling houses of permanent nature within this distance which may be termed as the danger zone. Temporary hutments only may, however, be built within this zone if at all necessary"².

The water surge is also responsible for many buildings collapsing due to standing water at the plinth. A prevention against this is the construction of "Chang" type of buildings as are done by the Mug's in the coastal area of the Bakerganj district within a zone of 3 miles from the coast. In this area double storied houses are preferable to single story.

¹ International Bank for Reconstruction and Development. International Development Association. Land and Water Resources Sector Study Bangladesh. Vol. III. Op. Cit., P.5.

² Institute of Engineers, Pakistan. Report of Institute of Engineers Sub-Committee on Cyclone Disasters in East Pakistan. Op. Cit., P.11.

Ecological Aspects Of Water Development

Water resources development in Bangladesh has got great ecological impact on plant, animal and fish. The effects of the creation of a man-made lake on forestry are either direct or indirect. Direct effects are represented by changes in the water table, including the drowning of trees, and possibilities for irrigated forest production. Indirect effects include improved transportation and labour resources which can make economically possible the afforestation of an area otherwise too inaccessible or lacking available manpower.

Groundwater has got great effect on plant. If excessive groundwater is exploited for industrial and domestic purposes, than vagitation of the entire area will be affected. Over exploitation of groundwater is harmful to plant.

In Bangladesh there are large number of bils and haors. During winter season specially during harvasting of crops, these bils and haors abund with various kinds of birds. But if these bils and haors become completely dry due to improvement of their drainage system, than there will be hardly any birds in these areas. Similarly if any reservoir is constructed, then due to impoundment, its animal life will be affected.

A river system plays a vital role in the life cycle of migratory species of fish - it is a route up or down thourgh which spawners reach their spawning grounds, and fish in their young life reach their feeding grounds. For such species an obstruction like a simple dam

can spell doom. For, not only may the dam prevent migration up-stream, but fish migrating down-stream may not survive due to the effects of passage through the turbines, or, if led into irrigation ditches, they may be stranded and die.

Dams alter water flow characteristics down-stream and thus may affect aquatic stocks in many different ways and cause changes in water velocity and volume of discharge, water chemistry, temperature and turbidity, and the stream ability to purify its waters. There may also be alteration in the amount of living space for fish, including the extent of spawning, nursery and feeding grounds. In the estuarine tidal zone in Bangladesh, a chemical change of potentially vast significance may be effected in salinity, probably in the form of an overall net increase due to reduction of stream discharge.

These effects and changes obviously include elements of danger vis-a-vis the maintenance of aquatic production. If a fishery scientist is called into advise early enough in the planning and feasibility studies on a dam some unwanted direct effects of a dam as a barrier may be overcome, often at surprisingly low additional cost. In such instances the fishery expert may determine the need, feasibility and characteristics of appropriate fish passing devices and fish-guidance structures. Thus, in carefully planned and executed dam systems uneconomic barriers to migratory fish stocks may be minimized if not completely overcome.

Man-made lakes, ecologically cataclymic though they may be,

often afford unusual opportunities for economic gain and for increasing demand for the development of wildlife resources and outdoor recreational facilities. Altering ecology as they do, and often isolating islands or long peninsulas, such new lakes also offer an opportunity for the conservation of open spaces and natural beauty, and the preservation of natural areas for study and enjoyment. In addition, forests with these areas may often be managed for multiple use including wildlife utilization, recreation and tourism. Controlled harvest of wildlife within conservation area is sometime desirable from a management point of view at the same time, it provides an immediate economic return in meat and skins and ensures future returns from hunting, viewing and photographic wildlife.

Family Planning

Any consideration of family planning in Bangladesh must take into account the socio-cultural setting of the people and their attitudes towards family planning. A number of studies undertaken to analyze this question in Bangladesh indicate that economic as well as social and psychological factors play a role. Among these factors are: income, level of physical and social infrastructures; social mobility, availability of arable land; child labour; minimum age of marriage education laws; status of woman; availability of social security and medical care; life expectancy of infant and child; and availability of contraceptives. Many of these factors are directly affected by policy; others imply long-term social-economic changes and are more difficult to influence directly.

Any family planning programme must take into account the long standing traditions of a country where purdah is still common practice and where girls are usually given in marriage at puberty. The extended family is the common social pattern with a wife joining the husband's family. If mothers-in-law could be convinced of the need for reducing family size, they might have considerable influence on the acceptance of family planning.

Experience shows that families accustomed to social and economic changes are more receptive to family planning techniques. Therefore, future programmes for family planning should focus on segments of the population and areas of the country where other economic development programmes are successful. The small-scale farmer living in a densely populated district where new technology is being introduced should be a prime target.

Monetary incentives for vasectomies have been quite successful and should be expanded. This simple operation, which provides permanent protection, has the advantage of being wholly the decision of the male. Female contraceptive devices have had more limited effect partly due to health complications arising from malnutrition. The oral pill, though not part of previous family planning programme, should be considered as a possible alternative. Moreover, ways need to be found for producing the tablets locally at a reasonable cost.

The strategy for expanding family planning particularly in densely populated areas of the country should include: health services

for mothers and children; incentives for families and entire communities to practice contraceptives; an information programme to motivate both potential recipients and policy makers; a change in the legal age for women to marry; and promotion of the oral pill.

Open space specially water bodies in Bangladesh can be used for recreational purpose. People can enjoy the natural beauty and wide open space during leisure time and holidays. These has got tremendous effect on family planning.

Nutrition - Blanced Diet

The only major nutrition survey of Bangladesh to date was made in 1962-64¹. After studies of approximately 15,000 persons from all geographic and economic sectors, the survey demonstrates that malnutrition affects the health & well being of at least half the population of Bangladesh. Growing children, especially those of pre-school age, and women of child-bearing age are most serverly affected, but no age group escapes the effects of malnutrition.

The general pattern of food intake is based heavily on rice. Over two-third of the dry weight of the daily diet consists of rice, which is supplemented by curries, primarily of vegetables or fish, and pulses in the form of bean soup. Milk and meat products are consumed in small amounts and fruit intake is almost entirely seasonal. Intake

¹ University of Dacca and the Nutrition Section, Office of International Research, National Institute of Health, U.S. Department of Health, Education and Welfare, Publid Health Service. Nutrition Survey of East Pakistan, Ministry of Health, Government of Pakistan, May 1966.

of cooking fats and oils is scanty. Most foods are taken in their natural unrefined forms, but cooking practice often lead to considerable loss of certain nutrients, such as vitamin C.

Apart from the shortage of staple food grains produced in the country, the diet itself is very unbalanced. The nutrition survey carried out by the Health Division of the Government of Pakistan as stated earlier shows that the total intake of food in calories per head in Bangladesh is only 2,202, on an average, against the recommended average requirement of 2400 calories. The present intake of calories is supplied by the intake of 56 grams of protein, 461 grams of carbohydrate and 18 grams of fat per head per day.

Thus, of the total intake of the calories supplied by those nutrients 82.70% is from carbohydrates or starchy foods including sugars, 10.04% is from protein or foods such as meat, fish, milk, eggs or pulses and 7.26% is from fats or foods of animal or vegetable origin containing oils and fats. After the liberation of Bangladesh, due to destruction by the Pak Army and frequent natural calamities, internal production of food and other agricultural products has gone down substantially. This has resulted in further deterioration of the total intake of the calories by the people of Bangladesh. Therefore earnest effort must be made to increase food and other agricultural products by properly utilizing the available water resources of Bangladesh in combination with other inputs and management facilities. It is suggested that balanced diet of an adult of Bangladesh based on height, weight, age, sex, climate, temperature and environmental condition

should be such that the calories supplied by carbohydrates, proteins and fats are 66.67%, 12.26% and 23.07% respectively.

Changing Of Eating Habits

It is aparent that with the increase in population, the demand for cereal is increasing. This demand may be met with intensive application of various inputs necessary for increasing production and by increasing the scope of cultivation during winter. In future, however, tremendous efforts will berequired to meet the cereal requirement of the entire population by rice alone. This will not only strain our economy but also make difficult to provide for the balanced diet needed for the people unless the population explosion is kept under control.

Therefore, diversification of food habits of people is of two-fold necessity: first, to provide a balanced diet as far as possible; and secondly, to ensure that there is no significant increase in the daily per capita intake of rice. Additionally, diversification will contribute to the level of farm income, thus providing more purchasing power which should assist in stimulation of economic development. Emphasis will be placed on increased production of vegetable, fruits, fish, sugarcane, groundnuts and pulses. As rice yield increases and technology become available, the farmer will turn more to these crops. It is evident that the shift to diversification has already started in many areas of Bangladesh. It is believed that the production of food crops mentioned above will lead to stabilization of the per capita daily consumption of rice and this might gradually lead to an actual reduction of per capita rice consumption.

Programme should be undertaken by the Government of the people's Republic of Bangladesh to modify and change the dietary habits of the people in order to remove the pressure on cereal intake particularly rice, by producing more wheat, maize, potato, vegetables, fruits with particular reference to banana, edible oil, fish, meat etc. To store the perishable foods, sufficient number of cold storage facilities should be provided through out the country.

Change Of Cropping Pattern

Cereals constitute the main portion of the national diet in Bangladesh and 93 percent of the cereal consumption is rice. A crucial test of agricultural policy in the years ahead will be to meet the staple food requirements of a population growing at over 3% a year.

The first high yielding variety IR-8, suitable only for Boro¹ crop, was introduced in 1966. The variety was dramatically successful and has spread over 700,000 acres. Its further spread has been limited by the expansion rate of irrigation. IR-20, first introduced in 1970 for transplanting Aman² has already spreaded to 500,000 acres. Suitable varieties (IR-176 and IR-272) have been successfully tested for the Aus crop and another variety (IR-422) is under going tests for areas flooded upto 5' deep.

Numerous other varieties are in the research pipeline, including a few of them close to be released for cultivation. This would

¹ Boro - Winter rice crops.

² Aman - Rainfed summer rice crop.

give further improvements in grain quantity and yield through better pest and disease resistance and better ecological adaptability. Further more new varieties may open up areas for high yielding variety now under low potential varieties because of drought, flooding or salinity.

Changes will occur in the traditional cropping patterns with the development of irrigation, flood protection, and drainage. These changes will take the form of increased cropping intensities by growing more winter crop during the dry season, and by practicing more double cropping during the Aus or jute and Aman season. Essentially the same crops will be grown as at present except a few new crops. However, the relative proportions of each will vary depending on preferences, prices, Government policies and water requirements, as well as changed physical and socio-economic conditions in the project area. Cropping patterns for specific projects should be carefully selected to fit the conditions that will actually exist on a particular project.

Introduction Of Inter Cropping

Inter cropping is defined as the raising two or more crops in a piece of land simultaneously. In Chittagong Hill Tracts this type of cultivation is in practice by the tribal people on the hill slopes in non-irrigated lands. But it is practiced extensively in plain land in China : Taiwan where population density is very high and demand for food also naturally high. Though inter cropping is not as yet practiced in the plain land of Bangladesh yet it can be profitably practiced in the irrigated and non-irrigated lands of this country.

This will help tremendously in over coming food shortages of this country within a few years.

Development Of Vegetables And Fruits

Regarding vegetables, the present intake of 135 grams per head per day as compared with U.S.A. need to be further increased. This increase can be brought about by the normal extension activities, supply of improved seeds of vegetables and by utilising the inputs such as fertilizers, irrigation and pest control measures.

The estimated acreage under fruit cultivation is 3,19,390 which is expected to produce 16,16,000 tons of fruits against 3,11,575 acres and 15,76,420 tons of fruits grown in 1966-67. This will be made possible by the rapid expansion of the cultivation of quick growing fruits like Banana, Pine-apple and Papayas. Banana plantation in Bangladesh is changing from the few plants for home consumption to commercial operation. Blocks of improved Banana production are now operating.

Horticulture schemes such as establishment of Horticulture Centres, pilot Orchard-cum-Nursery for quick growing fruits should be under taken by Bangladesh Agricultural Corporation. All these would contribute to increase the supply of vegetables and fruits in the country.

Uses Of Inputs

Each of the inputs like irrigation, fertilizer, improved seeds and plant protection measures play a vital role in increased agricultural production. Irrigation in this country will be specially helpful

in two ways : firstly, it can bring large areas under winter crops and, secondly, it can save agriculture in Bangladesh from vagaries of nature. Fertilizer and improved seeds help in the increase of yield, whereas plant protection measures protect crops from pests and diseases. To attain self-sufficiency in food none of these inputs can be neglected and as such Government should take all possible steps to provide extended facilities to farmers to avail of these inputs.

Rural Electrification And Development Of Cottage Industries

Owing to a severe shortage of power in the past, very little has been done in the way of rural electrification. The need for extension of electricity to rural areas has been realized in an increasing measure during recent years. After the completion of Karnafully Hydro-electric Project, Bangladesh has some surplus power to be diverted to rural areas for the use of irrigation pumps and small and cottage industries.

The existing pumps and tube-wells for irrigation are powered mainly by diesel. It has been established that electricity is a cheaper and more reliable source of power which, inter alia, reduces the enormous distributional problems implicit in the diesel based motive power in the countryside. For this reason use of electricity in low-lift pumps and tube-wells has been identified as a key factor for the rapid agricultural development of the country.

In rural areas if electricity is introduced for irrigation, cottage and small scale industries can be simultaneously energised.

This rural electrification will revolutionise the rural economy and also go a long way to modernising the habits and social activities of the people and will thus contribute to bridging the gap between urban and rural life. Therefore accelerated programme for rural electrification should be taken up by tapping all the sources of production of power for rapid development of the country.

Solving Unemployment Problem And Proper Utilization Of Human Resources

The most socially distressing form of unemployment in Bangladesh is seasonal unemployment of the labourer classes. Although difficult to document, there is probably also substantial disguised unemployment among the wealthier rural classes. This unemployment arises from social custom and economic decisions which are a product of the economic and physical environment. The existence of disguised unemployment is important to labour policy because a change in production ^{condition} / might bring that labour on the market for additional productive effort or in displacement of existing employment of lower income persons.

Rapid expansion of productive employment in Bangladesh requires vigorous policy efforts in each major employment absorption sector. These are: (1) the agricultural sector, (2) the non-agricultural sector; (3) public works programmes. Each of these has a substantial potential to provide employment and requires appropriate policies if the targets are to be met. All are so interrelated that failure in one will reduce potentials for success in the others.

The high yielding rice varieties are highly variable in their

The high yielding rice varieties are highly variable in their labour requirements. "If we see the increased labour requirement of high yielding varieties and increased double cropping as part of an intensive irrigation package we define a massive potential within agriculture for increasing employment and production. With a shift from single cropping to double cropping, a 60% increase in yields, and 30% increase in labour use per cropped acre, as above, per acre production would increase 3.2 times and employment 2.6 times¹".

In choosing irrigation systems for their employment impact, the longer run potential for continuous steady employment through the system which is more capital intensive in construction must be compared with one with less capital intensive in construction but which provide less potential for long-run absorption of labour in operation.

Development of large employment potential in agriculture also assumes a well-developed infrastructure of fertilizer and other input supply, including a highly developed transport, communication and power system, educational services to cultivators and, most important, a research system designed to provide the crop varieties and practices suited to accepting the full potentials for intensification of agriculture.

A rapid rate of growth of non-agricultural employment in Bangladesh is most likely to be achieved if a favourable environment

¹ International Bank for Reconstruction and Development. International Development Association. Bangladesh Land and Water Resources Sector Study. Vol. III. Sector Economics. Technical Report No. 5. The Special Problem of Employment in Agriculture. (New York: Asia Project Department, December 1, 1972-P.9).

is created for production of manufactured consumer goods, such as textiles, light electronics and plastic articles, which are in substantial demand by lower and middle income consumers. Production of such goods can be performed in small to medium scale firms, which operates with relatively low amount of capital per worker and tap widely for capital and entrepreneurship. It is here that a crucial interaction develops between employment policy in the non-agricultural sector and rapid, yield increasing technological change in food grains production.

In the long run, labour absorption must occur largely in the non-agricultural sector. To prepare for that, Bangladesh must give highest priority to developing an industrial structure oriented towards export commodities and goods. Thus unemployment problem in labour force can be solved in the country.

For the proper utilization of human resources proper man power survey must be made. Right people should be placed in right places. This will bring efficiency in the organization and productivity in both agriculture, management, administration and industry will increase. This will help in bringing co-ordination among the various institutions of the Government and helping in properly utilizing human resources for the betterment of the country.

Development Of Livestocks And Poultry Firms

There is practically no commercial livestock production in Bangladesh. Cattle are kept mainly for draft with meat and milk mere by-products. Goats, sheep and poultry are kept by many smallholders

mainly for subsistence. Because of land pressure and the need for cash and food crops, there is no land devoted to stock feed production. Cattle feed is mainly rice straw, some roadside grazing and small amounts of barm and oil cakes.

Livestock, dairy and poultry products are second only to rice in value, if fish is excluded. The percentage contribution to the individual farm income is small, but they provide much needed animal protein.

Government Livestock services are responsible for improving animal health and nutrition. They should shift the emphasis from curing to preventing diseases. The expansion of veterinary hospitals and clinics should give way to strengthening the field services with trained staff, equipment and adequate transport. Provision of animal husbandary advice, not available to farmers at present, is also important and this should be the duty of the Agricultural Extension Directorate. The Livestock Directorate must have central disease diagnostic facilities and a large supply of vaccines.

Under existing condition, the extreme pressure of population on the land resources makes any expansion of the livestock industry unlikely. Meat is a luxury, few people can afford it. The same is true for dairy products. The almost complete dependent on animal power and the resulting requirement for a large number of work animals imposes an additional heavy pressure on the land. Good livestock management, involving breeding, better feeding, and disease and parasite control,

would make it possible to produce more livestock products and productive work with few animals.

The livestock makes an important contribution to human nutrition. Although mostly sick or old cattle are slaughtered beef is a most important source of meat. Cattle improvement, while primarily aimed at increasing draft power, would also provide extra meat and milk. Little could be done for sheep and goats other than improving their health but an important increase of eggs and poultry meat may be possible.

With irrigation expansion and some degree of flood protection, it will be possible to greatly increase the production of high quality forage crops which will provide the foundation for an expansion in the livestock industry. Some increase in the poultry population is also possible. Adequate professional training in this field is provided by the University of Mymensingh, but research may have to be stepped up considerably to sustain the development effort.

Development Of Research Stations

The lack of a centralised organisation in Bangladesh responsible for research in agriculture and broadly concured to cover crops, soils, water requirement, horticulture, crop protection, livestock, agricultural engineering, forestry, fisheries and economics and social studies is a definite handicap in effective development planning. This affects both the collecting of specific and dependable information regarding the feasibility of setting certain development goals and

also the development of new technology in achieving such goals. The real need in the country is to strengthen research capabilities. The need was recognized by the Government in establishing the Rice Research Institute and the Jute Research Institute. To co-ordinate the activities of various research institutes, it has been decided to establish a consolidated "Bangladesh Agricultural Research Council".

Like agricultural research institutes and council, Flood Control Research Station, River Research Institute and Hydraulic Research Stations are essential for the proper study of flood, river morphology, sedimentation problems, hydraulic structures, ground water hydrology etc. The existing Hydraulic Research Laboratory of BWDB is poorly equipped and poorly staffed. Therefore more vigorous efforts should be made in establishing the above mentioned organization immediately.

The main objective of setting up of such stations is to provide facilities for carrying out model tests of major river and minor river system of Bangladesh in connection with the study of problems of flood, drainage, irrigation and specific project needs. These would be well equipped with facilities for applied research and basic studies.

Merely establishing of various research institutes, stations & councils will not solve the problem of the country, if these are not properly staffed. What is actually needed in various research organizations in Bangladesh, is the research minded dedicated people. Unless such personnels are picked up and trained properly to run these research organizations, it is sheer wastage of countries scarce

resources in establishing such institutes or stations. Therefore effort should be made to put proper man in proper place and to train the people of such research organizations at home and abroad as quickly as possible.

Regional Plan Of Bangladesh On The Basis Of Hydrological Unit

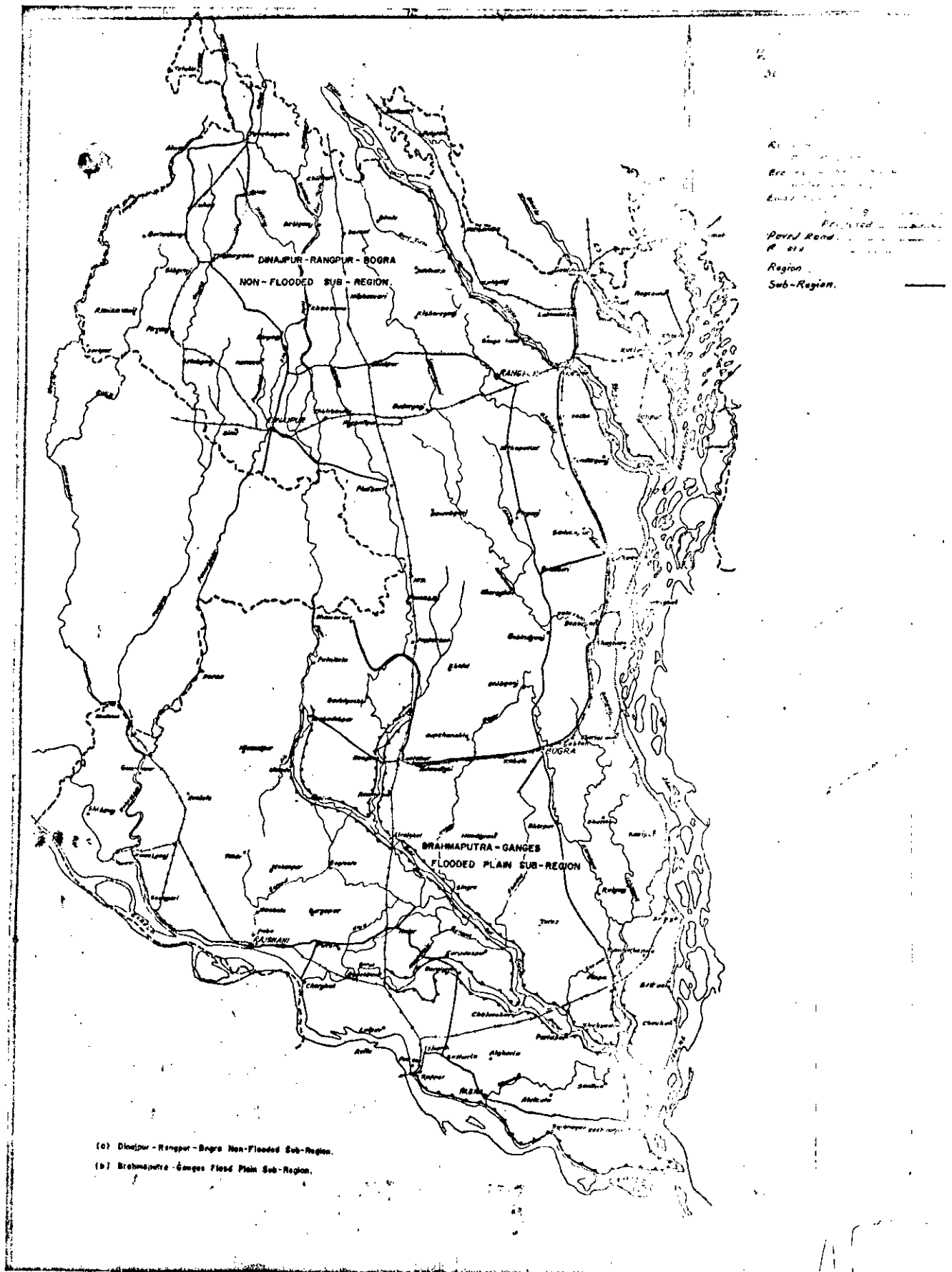
On the basis of hydrological unit and divisions made by the major river systems of Bangladesh, the country is divided into the following regions:

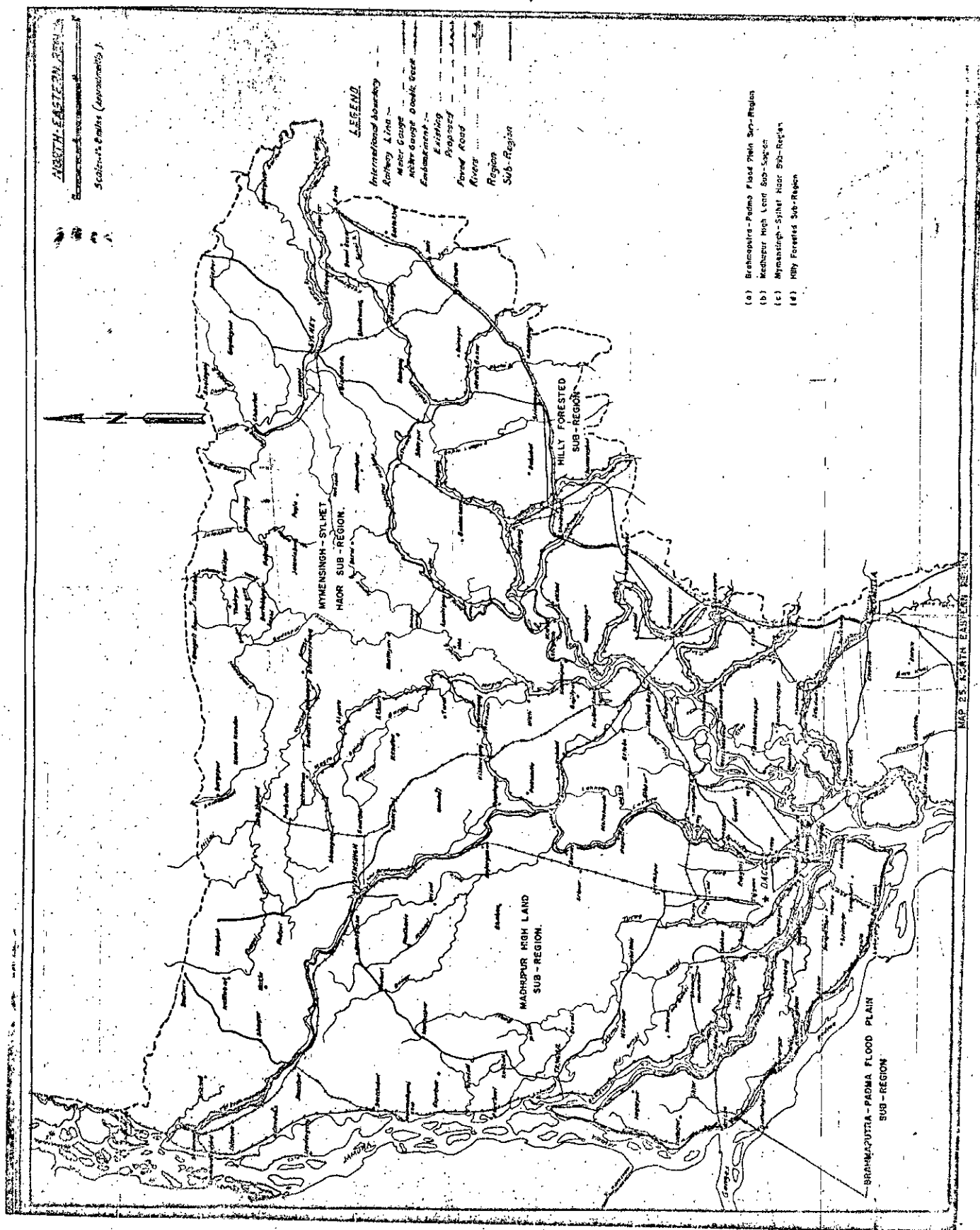
- a) Northwest Region;
 - b) Northeast Region;
 - c) Southwest Region and
 - d) Southeast Region.
- a) Northwest Region is again divided into two Sub-Regions: (Map 24)
 - i) Dinajpur-Rangpur-Bogra non-flooded Sub-Region;
 - ii) Brahmaputra-Ganges Flood Plain Sub-Region;
 - b) Northeast Region is again divided into four Sub-Regions: (Map 25)
 - i) Brahmaputra-Padma Flood Plain Sub-Region;
 - ii) Madhupur High Land Sub-Region;
 - iii) Mymensingh-Sylhet Haor Sub-Region;
 - iv) Hilly Forested Sub-Region;
 - c) Southwest Region is again divided into four Sub-Regions: (Map 26)
 - i) Jessore-Khulna Moribund Sub-Region;
 - ii) Faridpur-Barisal Active Delta Sub-Region;

- iii) Coastal Saline Sub-Region;
 - iv) Sunderban Forest Sub-Region.
- d) Southeast Region is also again divided into: (Map 27)
- i) Comilla-Noakhali Non-Saline Flood Plain Sub-Region;
 - ii) Noakhali-Chittagong Coastal Saline Sub-Region;
 - iii) Chittagong-Chittagong Hill Tracts Forested Sub-Region.

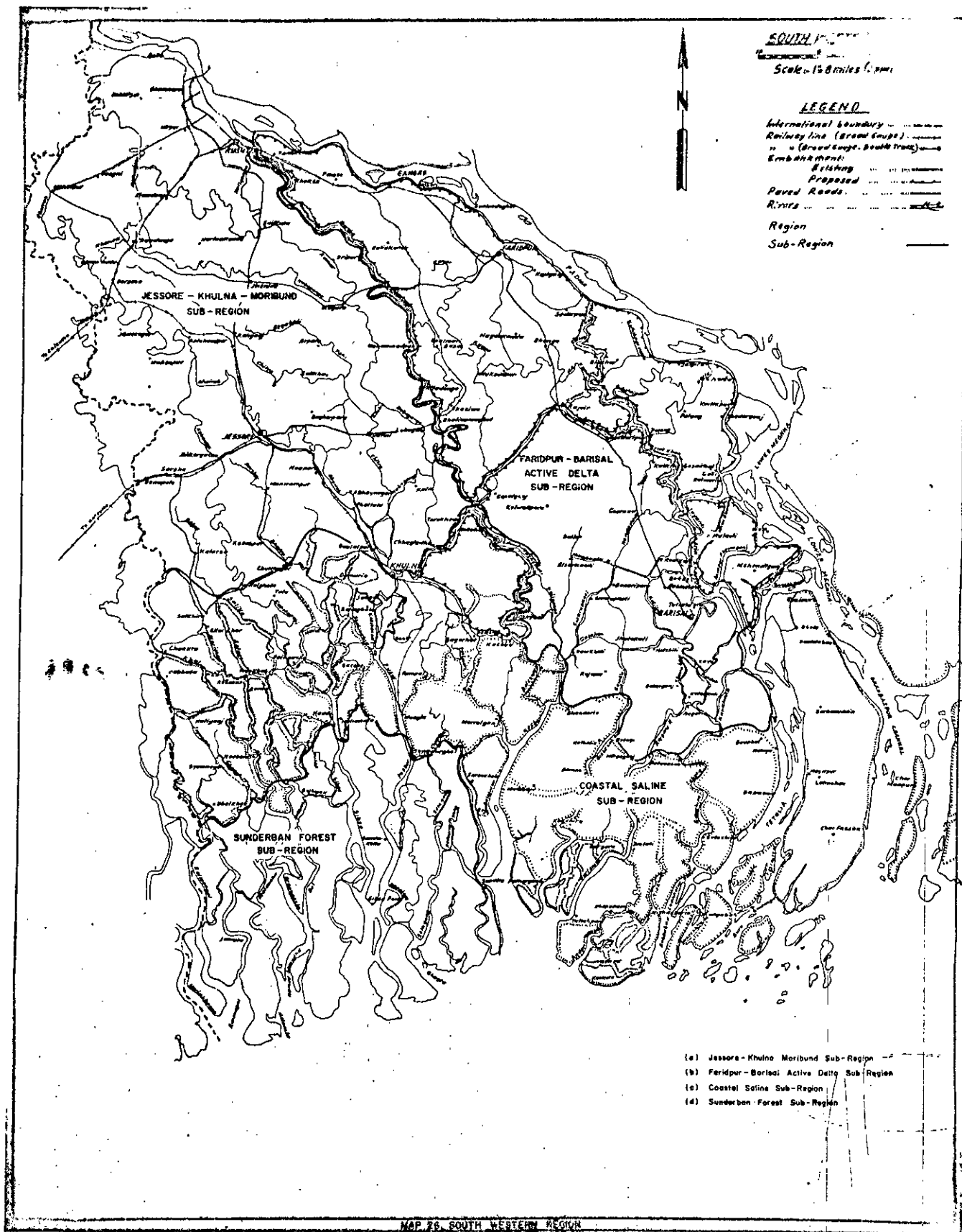
Regional approach to water resources planning in Bangladesh is very urgent and absolutely necessary. Regional planning would provide the most suitable frame of reference for a balanced integration of development projects of national significance and those based on local initiative. Such comprehensive regional planning would apply to the development of metropolitan areas, to areas in which Natural Resources are being developed, as well as to rural reconstruction programmes and to the location of industries. Regional planning has already demonstrated its value in guiding the development of areas where natural resources are being exploited. Regional planning techniques applied to rural development programmes could be used to assist in the development of areas and is establishing a better urban-rural balance.

"With this background, planners in Bangladesh of to-day and to morrow will have to equip themselves with the art and technique of regional planning. The broad framework of the physical planning should conform to economic, social and administrative conditions. The citizens participation should not be neglected. For its success, the objectives of planning should be understood by the unsophisticated villagers. Thus





- (a) Brahmaputra-Padma Flood Plain Sub-Region
- (b) Madhupur High Land Sub-Region
- (c) Mynenshing-Sylhet High Sub-Region
- (d) Hilly Forested Sub-Region



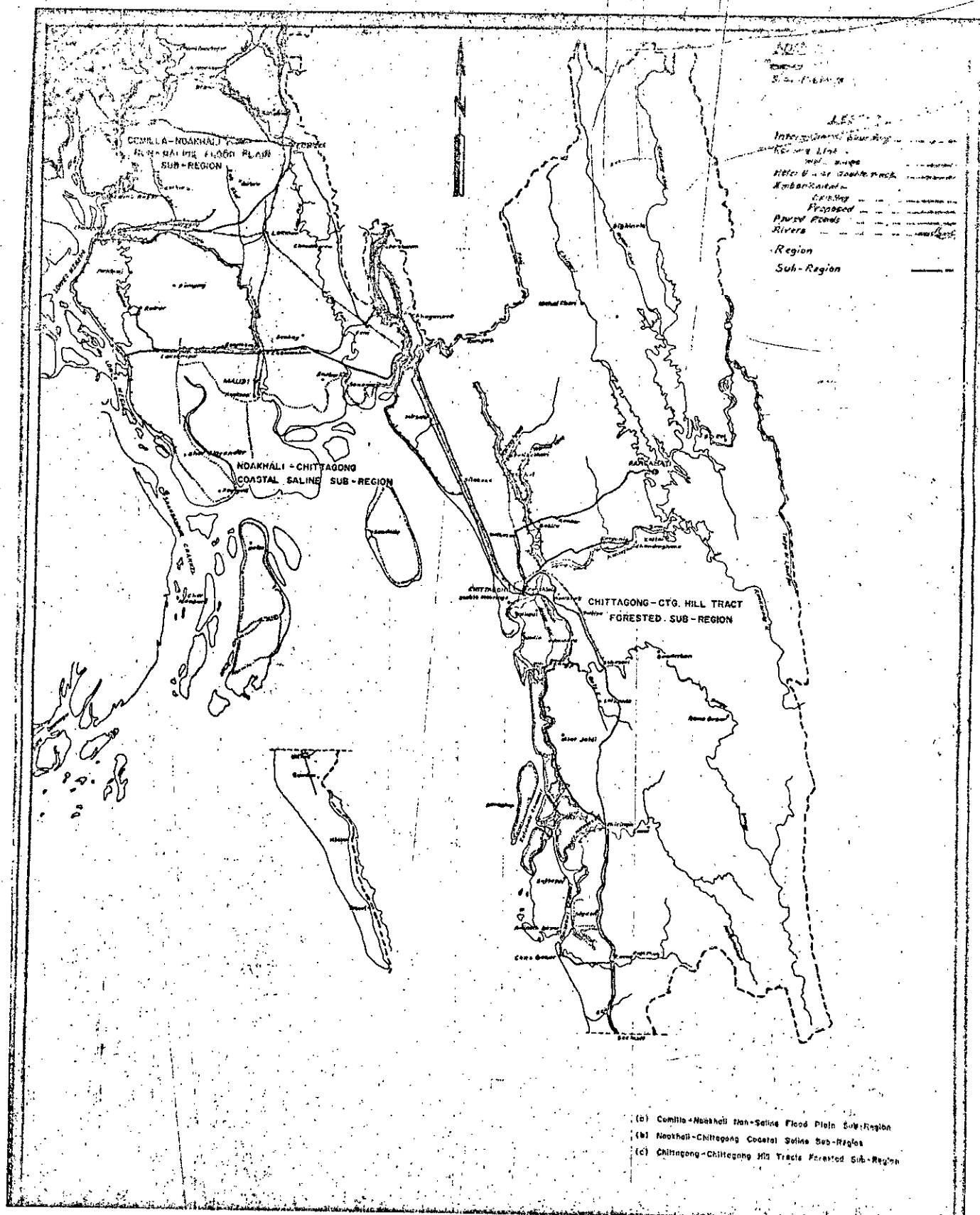
- (a) Jessore-Khulna-Moribund Sub-Region
- (b) Faridpur-Barisal Active Delta Sub-Region
- (c) Coastal Saline Sub-Region
- (d) Sunderban Forest Sub-Region

it would create conditions and environment for its success¹".

The above thirteen Sub-Regions contain nineteen districts, fifty-four sub-divisions, 410 thanas. For water resources planning what would be a workable area for a planning region is very difficult to delimit. For better administrative control a big thana may be taken as regional planning unit. Where the sizes of the thanas are very small, there two or more thanas may be grouped together to form a regional planning unit. For planning purposes, an area which is large enough to enable substantial changes in the distribution of population and employment to take place within its boundaries, yet which is small enough for its planning problems is to be comprehended as a whole. Resource development is the primary objective of regional planning. The physical boundary should provide easy access. Therefore, it is essential that the physical size of a region should not be too great for to make it possible to reach all parts of it from the center and to return to the center within a day (Figure 2).

"The rural population which is becoming more uprooted from the soil is looking to cities for an economic salvation which the cities at the present are not capable of providing. Several factors are responsible for the growth of population, immigration and influx of refugees into Pakistan. Can we halt this growth, migration and influx of refugees? Has any approach to eradicate these problems ever been sought? It is true that our cities are producing more unhealthy living condition and slums. What will help at this stages? One need

¹Golam Rahman, Village Planning in East Pakistan, Op. Cit. P. 100.



- (a) Comilla-Noakhali Saline Flood Plain Sub-Region
- (b) Noakhali-Chittagong Coastal Saline Sub-Region
- (c) Chittagong-CTG. Hill Tract Forested Sub-Region

is to divert the flow of migrants to small, medium and big cities by providing opportunities and job facilities. Therefore we need good roads to link rural areas with the central city, district towns, small and medium size towns and central villages. The systematic construction of roads is therefore needed. Feeder or rural roads are necessary to stimulate the agricultural production, give the peasants fair price and easy communication facilities in the small and medium size towns. Such plans will help in rebuilding and revitalizing the broad hinterland and the rural villages¹".

Big towns enjoy some social and economic advantages than the small and medium size towns. The role of big towns versus small and medium size towns will always continue to exist. Small towns cannot compete initially with large towns. It is essential to provide assistance for the development of the small and medium size towns in the early stage through some economic concessions to industries and housing in the field of taxation and other similar facilities. This type of development of district towns, subdivisional towns. Thana Head Quarters would tend to attract the flow of migration from big urban centers and rural villages. This would help to create a balance in rural and urban migration. People are lured to the big cities because they provide a wider economic opportunity than a small town. Living conditions are more complex and congested in big cities. The migrants would prefer to settle in smaller towns if proper facilities and job opportunities are provided.

¹ Golam Rahman, Village Planning in East Pakistan. Op. Cit., P.106.

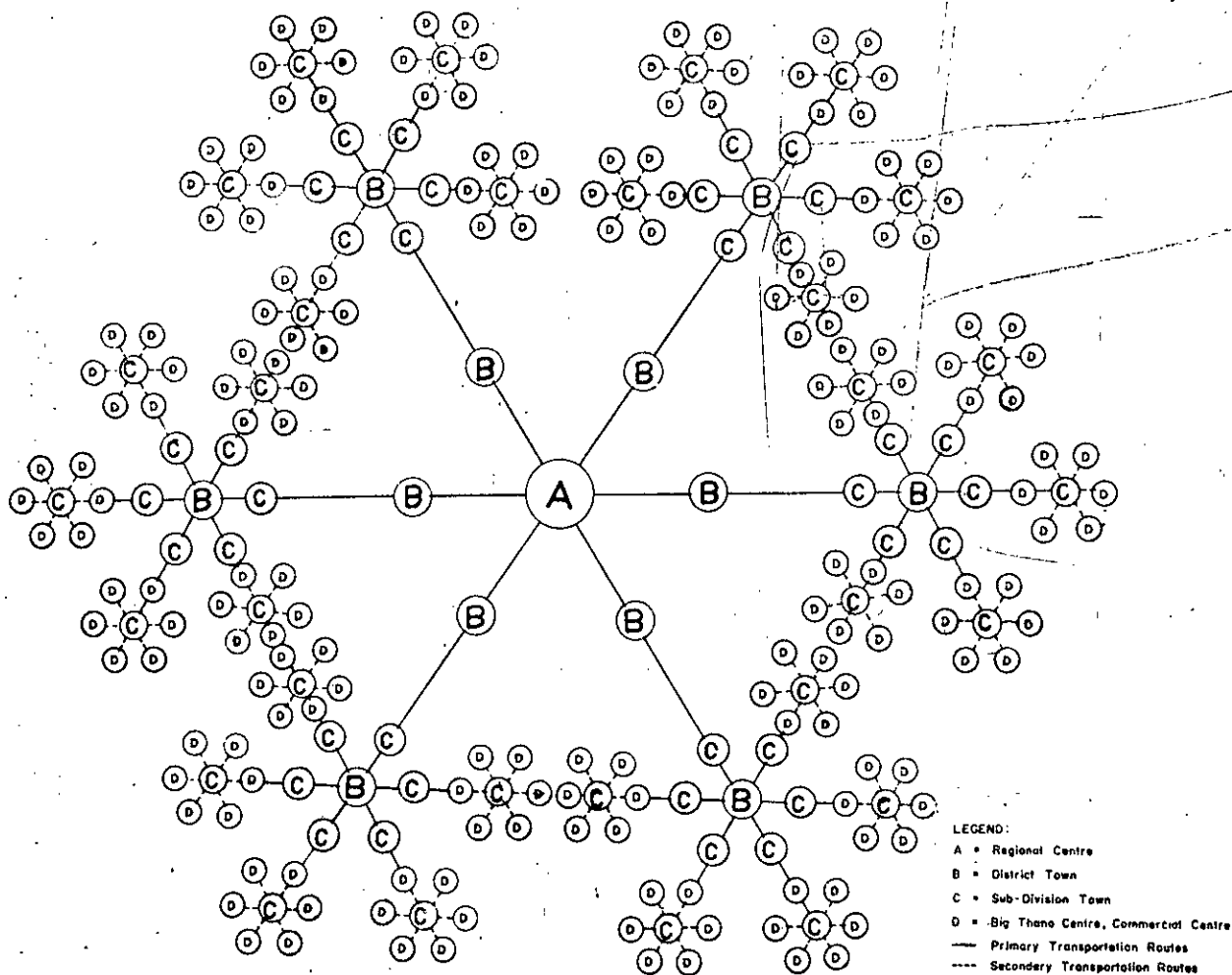


FIG. 2. MODEL OF A REGIONAL PLANNING PROGRAMME
FOR A REGION OF BANGLADESH.

"Therefore the emphasis on regional planning should be emphasized to create "Push" and "Pull" factors in rural-urban settings. Surveys and investigations should be made on resources development to provide more opportunities for rural migrants created by the urban "Pull". The major emphasis should be placed on rural agricultural production, proper utilization of resources through industrial establishments, creation of new towns, revitalisation of old towns, employment opportunities, transportation and education. Villagers are gradually adopting new techniques in the fields of cultivation. However, the pace of progress is still slow, but advanced agricultural methods must come to enable, stimulate and sustain urbanization."¹

"The real problem which faces them is again to consider the optimal long-term distribution of population and the balance between rural and urban growth. Their plans must be concerned with the progressive improvement of communications between the various Thana centres and with the district or other major industrial townships within them. Here, unlike the links between village and Thana, the emphasis must be on metalled roads and the improvement in river communications, particularly the ferries. The location of higher educational centres, major industrial estates and possibilities for the development of tourism or holiday centres should also command attention but the plans

¹Gomal Rahman. Village Planning in East Pakistan. Op. Cit. P. 108.

should not sink into the detail required by the Thana Area Plans. Where plans for agricultural development require a greater labour supply than which can be provided locally the district should assist in the voluntary movements of population from surplus areas. They should therefore, set the population targets for the Thana areas within their jurisdiction, based upon regional considerations and national policies".¹

Public Participation

During execution of any regional plan, planning Authority faces difficulties due to lack of co-operation and support from the local people. This condition emerges from the ignorance of the planning objectives by the local people. The ignorance of the local people can be removed by forming several institutions to explain to the people the salient features and objectives of the regional plan. The people will take keen interest if they realise that the plan is beneficial to them. Public participation is essential for the success of a regional plan.

Local Water Rights

Local water right is a right, granted by law, to take possession of water occurring in a natural source of water supply and to divert the water and put it to a beneficial use.

Water rights may be impaired or lost because of certain processes that are recognized by law. In the following designations it

¹ John R. James. Some Aspects of Town and Country Planning in Bangladesh. (Dacca, May 14, 1973. P. 29).

is assumed that the water right came into being unimpaired and that it suffered no impairment or loss after it was acquired. The principal types of irrigation water rights are given below and discussed in more detail in later sections.

Riparian Right

The owner of land that is contiguous to or borders a natural stream or lake is entitled to take water from the source for use upon that contiguous land. This right is called a riparian right. The land to which it relates is called riparian land. The riparian right exists solely by reason of location of the land with respect to the water supply.

Appropriative Right

A person may acquire a right to the use of water for the irrigation of a particular tract of land, or for other beneficial purposes, by performing certain acts required by law. These acts include taking or diverting the water from a stream or other source and applying it to use on or in connection with the land. If the source of water is a surface or underground watercourse, certain formalities for acquiring the right are prescribed by statute.

The person who performs these acts appropriates the water or makes an appropriation of the water. Such person is an appropriator. The right that he acquires is called an appropriative right. The land to which the appropriative right relates may either be contiguous

to the stream, or may be located at a distance from it. In some instances it may be in a different watershed.

Correlative Right

A person who owns land over lying a body of percolating ground water is entitled to extract water from the ground for use upon his overlying land. This right is called a correlative right.

The correlative ground water right exists solely because the percolating ground water in question underlies the land of the holders of the right.

Prescriptive Right

A person may possibly divert to his own uses water to which riparian or overlying landowners or appropriators have prior claims, thereby depriving them of the use of water to which they are entitled. If he does this without interruption for a period of five consecutive years prescribed by the state statute of limitations, and if he fulfils certain other legal requirements, he gains a prescriptive right against the parties whose rights he has invaded.

The prescriptive right gives the holder a valid right, so far as the parties he has dispossessed are concerned, to continue diverting and using the water to the extent that he has been doing throughout the five-year period. Under the usual circumstances prescriptive rights can be acquired against downstream parties only.

In Bangladesh at the moment there is no problem with water

right. With the spread of irrigation and industrial development, demand for pure water will increase gradually. Then every body will become conscious about their right of water.

Public Hearing

If any dispute arises regarding the rights of water, then the case is disposed off by public hearing. In the United States, where water is a very scarce resource, there are always disputes regarding the riparian rights of water. There the disputes are settled in a court of law by public hearing. Both the parties plead their case and ultimately the judge gives his judgement in favour of any one of them. In this way water disputes are settled in the United States.

In Bangladesh at present there is small use of water in industrial, domestic and agricultural purposes. But with the increase of population, industrial, domestic and agricultural uses of water will increase. Then there will be disputes among the various users of water. At that time one shall have to settle his water dispute by public hearing.

CHAPTER IX

IMPLEMENTATION OF REGIONAL PLAN

Present Government Organizations

A Regional Plan, however well designed, is only as good as the seriousness with which its discipline and policy prescriptions are observed, the extent of political commitment behind it and the efficiency with which it is implemented. History of planning in many countries indicates that a Regional Plan easily degenerates into an academic exercise if political leadership and administrative machinery are not seriously committed to its implementation. Present Government Organizations responsible for the implementation of the Regional Plan are as follows:

- a) Bangladesh Water Development Board;
- b) Bangladesh Power Development Board;
- c) Bangladesh Agricultural Development Corporation;
- d) Agricultural Department;
- e) Bangladesh Fisheries Development Corporation;
- f) Fisheries Department;
- g) Forest Department;
- h) Department of Livestocks;
- i) Bangladesh Tourist Bureau;
- j) Department of Integrated Rural Development;
- k) Urban Development Directorate;
- l) Inland Water Transport Authority;

LEGEND:

Barrage



Recreation Centre



Estuary Closure



Wild Life Preservation



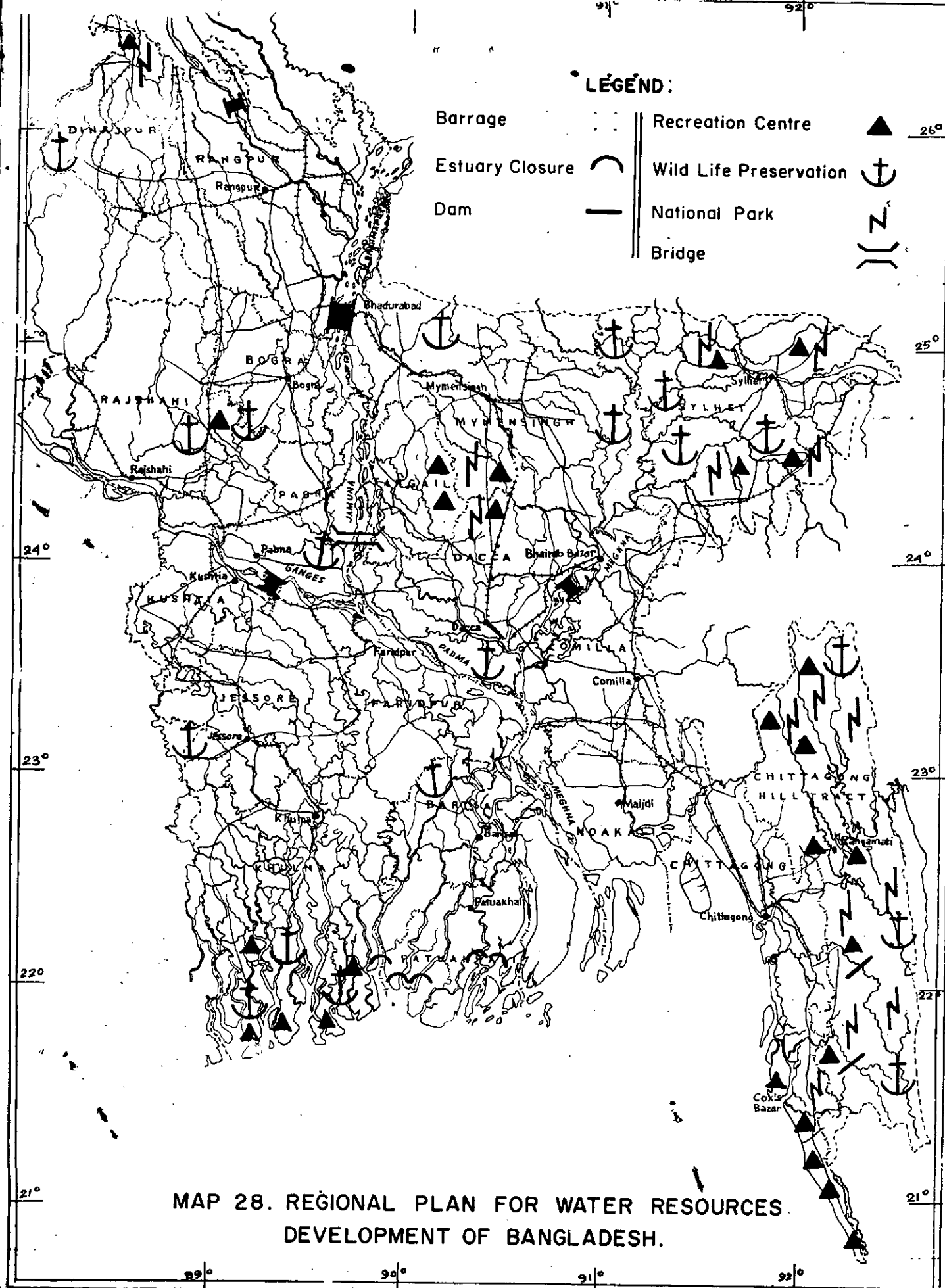
Dam



National Park



Bridge



MAP 28. REGIONAL PLAN FOR WATER RESOURCES DEVELOPMENT OF BANGLADESH.

- m) Road and Highway Department;
- n) Railway Department;
- o) Public Health Department;
- p) Family Planning Department;
- q) Chittagong Port Trust;
- r) Chalna Port Authority;
- s) Department of Horticulture.

Proposed Additional Organization

For the implementation of the Regional Plan a few additional organizations are required and these are as follows:

- a) Department of Park and Recreation Services;
- b) Department of Wildlife Preservation;
- c) Department of Land Reclamation from River and Sea;
- d) Marine Fisheries Department;
- e) Environmental Protection Agency.

Every body is aware of the status and functions of the present Government Organization. Therefore status and functions of the proposed additional organizations are described below:

Department Of Park And Recreation Services

This will be a similar organization as the Department of Park and Recreation Services in the United States. This department will be responsible for the operation and maintenance of open spaces in the urban as well as rural areas. It will also be responsible for

the development of National Parks in Bangladesh, and for the maintenance of picnic spots, hiking and other recreational areas.

This department will make necessary arrangement to attract foreign tourists. This department will be responsible to provide necessary implements to the urban and national parks for recreational facilities.

Department Of Wildlife Preservation

This should be an organization, similar to the Wildlife Preservation Department of the United States. It will be a law enforcing agency against the killing of birds and animals especially in the forest.

Department Of Land Reclamation From Rivers And Sea

The responsibility of this department will be to reclaim low lying land near the banks of the rivers. Dredged fill can profitably be used for the purpose. By properly regulating the sediments by cross dams, coastal areas and shallow sea can be reclaimed.

Marine Fisheries Department

This department will make survey in the shallow as well as deep sea to catch sea fishes by trollers.

Environmental Protection Agency

This should be a similar type of organization as of the United States Environmental Protection Agency. It will enforce the

laws so that urban and rural areas of Bangladesh can remain free from air pollution. Control of disposal of industrial waste in the river water and saving the water systems from pollution will also be the function of this organization. It will also help other organisations to maintain the saline limit to the present positions in the coastal areas of Bangladesh. Ecological balance should also be maintained.

Plan Implementation

The Regional Plan can be implemented in phases. Implementation should be taken up on a long term basis. The period of implementation should be on the basis of availability of internal resources, and external aid. Implementation should also be based on the basis of implementation capacity of the country such as availability of trained man power, material and equipment etc.

For the balanced development of the country in each Sub-Region development of two or more thanas should be taken up in each phases. Development of these areas should be incorporated in the Five Year Plan and Annual Development Programme of the country.

Plan Financing

In Bangladesh resources are very limited specially relatively due to critical land-man ratio. Financing of the projects will be met out of the resources available in the country. Foreign Aid giving Agencies may be approached to finance the Regional Plan. Raising and allocating the necessary funds are critical factors in plan and is

generally held in abeyance until financing is assured. The plan would require both domestic and foreign capital. The estimated cost should be adjusted periodically for price escalation and other factors. No other feature of the entire effort deserves more intensive and persistent head work or will be more conducive to final success than financing.

Design And Procurement Of Materials

As soon as funds are made available, detailed design should proceed with concurrent planning for required local materials and purchases of long delivery items to be imported such as metals, machinery and control equipments. Special care should be taken to use as much as possible local construction materials and labour to save foreign exchange. Effort should be made to develop and exploit local materials. Construction scheduling should be made and construction specifications and bid documents should be prepared accordingly. All available Bengalee technical personnels should be utilized in order to reduce the needs of foreign assistance. This should reduce the total cost of the plan.

Training Of Man Power

For the implementation, and operation and maintenance of the Regional Plan large number of trained man power would be required. To save foreign exchange training should be made available locally. For special type of job, where local training is not available in the country, trainee may be sent abroad. After his return to the

country, he should be put in a place where his services would be better utilized. This will help in getting maximum out-put from the trained man-power.

Economic Analysis

The design of a water resources plan depends on an intimate interplay of economic and engineering considerations. Questions of what can be done and how much it will cost, and questions of what is worth doing and how worthwhile it is, are mostly within the competence of a planner. "The resources employed by water development project (their inputs) are naturally available water, land, construction materials and man-power, and a variety of machinery and equipment. The resources produced (the output) are water at the times and places required for irrigation, industrial and municipal water supply, hydroelectric power, navigation, waste-water transport, low-water regulation, vacant spaces behind dams for flood control, and a variety of recreational and aesthetic facilities".¹

The economist is in the habit of expressing the relationship between the inputs to a system and its outputs by means of a "Production function". It will be helpful in introducing this concept to distinguish between "short-run" and "long-run" production functions. In the short-run production function the durable plant and equipment

¹ Arther Maass and Associates. Design of Water-Resource Systems. Macmillan, London 1962. P. 80.

are assumed to be in place and unalterable, so that the relationship required connects outputs with readily variable inputs. The long-run production function applies to situations where the physical plant can be altered, that is, where the problem includes the design as well as the operation of a water resource project. The resources required to build or alter the plant are then counted among the variable inputs, and the plant is not regarded as an established fact conditioning the relationship between inputs and outputs. The short-run production functions simpler although are less relevant to design problems.

With the implementation of the Regional Plan for water resources development of Bangladesh, there will be tremendous economic activity in the country. It will strengthen the economy of the country. Standard of living of the people will be raised and environmental condition of the country will be improved. Population explosion will be checked and people will be saved from the vagaries of natural calamities. This will pave the way for further development of the country for generations to come.

Benefit-Cost Analysis

The general economic problem is to use available water resources to maximize resultant human welfare. The maximization means alternative configurations of resource use among types of uses, over space, and through time that must be compared in terms of the net benefits that the resources will generate, the benefits being

interpreted in the broadest possible terms. The real cost of any particular configuration of resource use consist of the benefits that would be realized through other patterns of resource use.

Different types of benefits and costs are generated by a given pattern of resource use. Some benefits and costs are correctly registered in markets by prices, some are incorrectly registered by market prices, some are registered in no markets although simulated market values can be computed, and for others it is nearly impossible to think of any kind of adequate market valuation process. Examples of the above possibilities in terms of benefits might be the market values of free market-irrigated crop, the price of sugar-cane, the value of recreation on publicly provided reservoirs and the value of a beautiful landscape or view.

The brief discussion above of scarcity and the making of socially optimal decisions was cost in terms of getting the greatest project benefits from a given construction budget. An extremely important part of the economic problem concerns who gets those benefits and who pays the costs. There are three main reasons why one should be interested in these questions. First, society, partly through government at different levels, takes an interest in the distribution of economic welfare among different groups of persons. Concern over poverty and a willingness to tax incomes at progressive rates are sufficient evidence of this point. Some water projects have been built as much to change the distribution of economic welfare as

to increase aggregate economic welfare. The water projects of Bangladesh : Dacca-Narayanganj-Demra Irrigation Project, Thakurgaon Tube-well Project are evidence of this perspective.

Secondly, even when a project is designed without any overt intent to affect the distribution of economic well-being among groups, the project and its methods of financing nonetheless always have some impact on this distribution as well as on the overall magnitude of economic well-being. Since society generally have preferences regarding the distribution of benefits and costs, the projects distributional implications should be spelled out, although doing so will generally be a complicated task.

Third, the kinds of support and opposition that the water manager can expect for particular projects will depend very heavily on who gets the benefits and who bears the cost. Hydropower projects elicit in a very predictable way the backing of some groups and the opposition of others, not only on the basis of the perceived magnitudes of over all benefits and cost, but also very much on the basis of who receives the benefits and who pays the costs.

Thus one must be and should be alert to the implications of project selection or design for the distribution of economic well being among groups as well as for the overall magnitude of economic well-being generated.

Benefit-cost ratio of the Regional Plan will be very high due

to multifarious benefits of the projects. The plan being multipurpose in nature, its aggregate benefits are enormous.

Conclusions

The intention of writing this thesis on water resources planning for regional development of Bangladesh is to attempt a systematic analysis, as to how the water resources of Bangladesh can profitably be utilized for the benefit of its people. In pursuance of this, the objectives of this research work have been to delineate (i) the different aspects involved in the question of water resources planning for regional development of Bangladesh and (ii) to formulate planning and development guide lines on a comprehensive basis.

The methods suggested for the development of water resources in the thesis for the solution of the existing problems of flood control, irrigation, flood protection, drainage improvement etc. and thereby the overall development of water resources in Bangladesh have already been used individually or in combination in other countries of the world with success. So, it is honestly admitted that none of the methods is a new invention. But point is that what has been tried in this thesis is to present the problems in their true perspectives for general understanding of their magnitude and to suggest measures with relative priorities in consideration of a large area of diverse physical, economical and social factors in Bangladesh.

Considering the existing acute food shortage as one of the consequences of flood problem in the country, emphasis may be given on short term water development schemes with the promise of immediate returns. These short term schemes (of flood control, irrigation, flood protection, drainage etc.) will help change the socio-economic infrastructure which in turn will help to increase the mobility of the productive factors. The execution of the short term scheme will not only minimise the gap between the demand and the production of food but national economy will also get a boost to finance more development activities. The implementation of the short term schemes should not preclude planning and execution of medium and long term water development projects. Otherwise in absence of those short term schemes economic stagnation can easily be expected. So, it is suggested to prepare a set of suitable water development programme for each plan period, both for execution and preparation of new projects. The projects will include irrigation, flood protection, flood control, drainage improvement etc. But proper weightage to particular method may be required in consideration of the prevailing conditions of the area concerned.

Due to the constraints imposed by the nature and scope of work of the thesis in the academic framework given to do the work, planning and development proposals could only be formulated in outline form without much elaboration.

As a result there are no blue prints for projects nor any scheme in this thesis. However, the emphasis has been laid on

identification of the various important aspects concerning the question of water resources development in Bangladesh in a comprehensive manner. The emphasis has also been give to look into the dimensions and implications of each of these aspects. The work presented in this thesis, thus, should not be considered as a complete one by any means. It may rather be viewed as a broad based analysis of the various aspects of the vast problem under study. Modest efforts have been made to difine the probable areas for further studies and investigation. For any in-depth investigation of the problems dealt with in the thesis, the present work will hopefully be of some use as an introduction to the investigators.

It is expected that from the efforts made in this thesis, the future researchers may draw some help in formulating appropriate goals and development planning strategies for water resources in Bangladesh.

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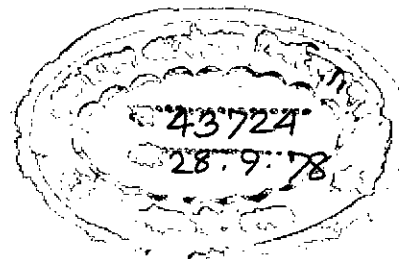
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