Government of the Peoples Republic of Bangladesh
Flood Action Plan

North West Regional Study (FAP-2)

DRAFT FINAL REPORT

VOLUME 4

THE REGIONAL PLAN - INITIAL ENVIRONMENTAL EVALUATION

October 1992

CONTENTS

VOLUME 4
THE REGIONAL PLAN

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This Initial Environmental Evaluation (IEE) and impact assessment examines the environmental impacts of the water resource development proposals of the North West Regional Study (NWRS) under the Flood Action Plan (FAP) Study FAP 2. This study falls under the contracts with the UK Overseas Development Administration and Japanese Aid - JICA. The FAP is coordinated by the FPCO under the Ministry of Irrigation, Water Development and Flood Control.

The total area of interest to impact assessments is shown in **Figure 1.1** and would include the total catchment areas of the three river systems. The continuing development of water control structures, new resource use patterns and pollution sources in India do affect some aspects of long-term planning and impact assessment. The main structures and schemes involved are indicated in **Figure 1.1**. However, little data is available to allow proper assessment of all the cross-border issues. Although not a part of the direct planning of this study irrigation influences are closely tied to the outcome of FCD projects and are assessed accordingly.

The removal of drainage constraints was identified as a potentially important development option by the studies which preceded FAP 2. The Interim Report review of options and impacts of four major drains concluded these to be impractical. These are not commented on further in the IEE. One shortened interceptor drain - the Bengali Floodway- was selected for further study in this second phase of study. Impact assessment on the options for this are carried out.

1.2 Aims and Objectives

This study establishes a holistic framework to assess the impact of the projects and whether these are environmentally sound and sustainable given the various tactical and strategic options involved. During the planning period the impact process has tried to find ways of minimising the number of people disadvantaged and to enhance positive effects which might result from project options. It aims to identify and give priority to the most important impacts, quantifying and valuing these wherever feasible. Proposals for mitigation, resource management planning, monitoring and further investigations are also detailed.

1.3 Scope of Studies

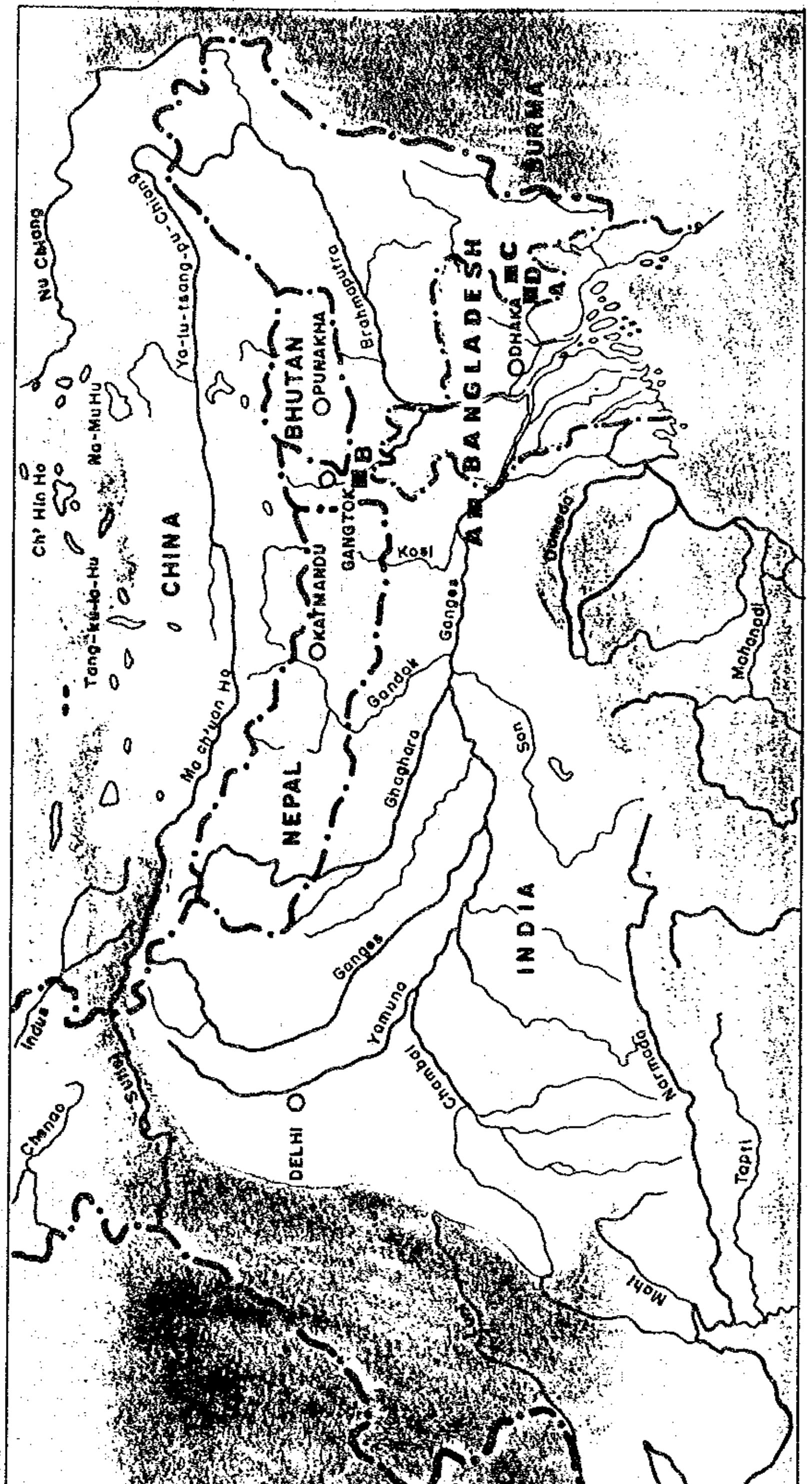
The National Environmental Management Action Plan (NEMAP) has specifically allocated the survey and planning for the nation's major floodplain wetlands to the FAP. Although this responsibility is nowhere mentioned in the FAP proposals or the TOR, this need has been taken into account, but only at the most general level. Some initial proposals for conservation and a protected areas network are identified. A separate study under FAP 16 may undertake a more comprehensive approach.

As the FAP is temporary in nature it cannot take any meaningful or accountable responsibility for the future management and status of the nation's floodplains and wetlands. The allocation of responsibility needs to be clarified, both in relation to FAP and the NEMAP. This must occur soon if key floodplain resources remaining are not to be left in a precarious and uncertain situation.

Figure : 1·1

GANGES-BRAHMAPUTRA-MEGHNA CATCHMEMENT AREA

N ←



LEGEND :

BARRAGES IN INDIA	■
FARAKKA BARRAGE	A
INDIAN TEESTA BARRAGE	B
KHOWAI BARRAGE	C
GUMTI BARRAGE	D

0Km ——— 500

Km

The IEE study area was based on administrative, project, socio-economic, hydrological and ecological areas of influence. The study covers most of the key elements and interactions of the physical, biological and human environment. The components assessed have include the major structural works, supporting facilities, access roads, sources of construction materials and the operational area affected by the interventions inside and outside of the target area project boundaries. The pre-feasibility level of detail has been maintained throughout, except for the Gaibandha area where a separate EIA has been prepared at a feasibility level - see Volume 9. Detailed information on the individual specialist surveys and analysis are available in the respective volumes listed at the beginning of this report.

1.4 Policy, Procedures and Guidelines

National environmental policy is managed by the Ministry of Environment and Forest (MOEF). The Department of the Environment (DoE) acts as the implementation and enforcement agency. A National Conservation Strategy (NCS) has been drawn up with assistance from the International Union for the Conservation of Nature (IUCN). The stated aims of the NCS can only be regarded as a statement of intent until sufficient legislative and enforcement controls have been introduced. Until sufficient basic financial and trained manpower resources are made available, the implementation and institutional arrangements do not exist.

In May 1992 the first official Environmental Policy was adopted by the GOB. This has introduced a new responsibility for work under FAP. Under the policy clear directions are given in relation to FCD/I projects but very little guidance is available as to the criteria by which these objectives are to be met. The most important objective which directly affect the planning for the study are to:

- remove the adverse environmental effects of previous water resources management and flood control projects.

- adopt and extend environmentally and ecologically sound land use practices and conserve soil fertility.

- maintain ecological balance, conserve wildlife and biodiversity and conserve and develop the national wetlands and the migratory bird sanctuaries.

- protect, conserve and develop fish habitats.

- re-evaluate FCD/I projects known to cause adverse effects on fisheries.

Section V and Appendix 8 of the Guidelines for Project Assessment (GPA) provide the approach expected of FAP environmental assessments. These refer to EIA Guidelines and a Manual drawn up by FAP 16. These documents have been under continuing revision since the study started and the version of May 1992 has been worked to. These generally follow international standards.

These documents were not accessible when the TOR were drawn up. The understanding on the role of environmental assessment has changed considerably since, and led to some additional resources being made available for the second phase of the study. Overall, the ability to complete the credible EIA has not been achieved. The minimum criteria of one year of data collection (where no existing data base exists) is the most critical deficiency. The study has also been limited by the lack of reliable models; the disrupted phasing of the FAP supporting studies; scaling problems when trying to appreciate project interventions in the complex landscape and environment characteristic of the floodplains; and problems of indivisibility of analysis (see chapter 4).

1.5 Study Approach

The resource and development profile derive from the work of the Interim report and subsequent NWRS surveys and review of secondary sources. The ongoing or completed work of other FAPs and the National Conservation Strategy have been particularly useful. The NWRS has contacted a large number of people and made considerable use of existing research sources and the literature. These sources are given in Appendix I and J. These have all helped establish the major trends and issues.

The additional surveys undertaken for the second phase of this study included studies mainly concentrated in Gaibandha and the Lower Atrai. These covered:

- water quality (regional sampling)
- geotechnical and seismic evaluation (GIP only)
- flora, fauna, wildlife and ecology studies (regional sampling)
- human health and nutrition surveys and links to the surveys under FAP 16 on disease and disease vectors (regional sampling)
- archaeology and cultural site surveys (GIP only)
- navigation surveys (GIP and Chalan Beel polders only)
- public participation rounds and surveys (regional sampling)
- agricultural and socio-economic surveys (regional sampling)

These studies were carried out with limited time and resources and can only be regarded as the first phase in ecological research particularly. They have provided a baseline from which to assess directly the likely context of project impacts. Figures 1.2 and 1.3 show the location of the main ecology and health related surveys.

In assessing the impacts discussed in chapter 4 the following approach was taken. Impacts are identified as positive or negative as they affect aspects of both the natural and human environment. They can also be immediate, medium or long term. Some are likely to become apparent very quickly and can be easily rectified, others may be only temporary, but severe, as with some construction impacts. Others could be very long term and potentially irreversible. Many processes in natural environment can be slowly changed causing gradual decline in status or capability for key life support functions. These can be difficult to identify and even harder to reverse. There are often critical threshold levels which when exceeded can trigger sudden irreversible declines. Some impacts are the direct result of a change in the existing situation where as others are secondary and may often be harder to identify and predict possible outcomes. A major consideration are those impacts which are felt in, or emanated from, outside of the project area.

Awareness of the temporal and spatial distribution and variability of any effects is crucial to place significance and give priority to the interactions under study. Whether in the physical, biological or human fields the response of the environment to the project, and the project to its wider environment, will always lead to checks and balances, equal and opposite effects, winners and losers, competition and complementarities. The selection of both flood alleviation tactics and their formulation into a FCD strategy needs sufficient knowledge of the likely outcomes of implementation, as well as how the

Figure 1.2

REGIONAL ECOLOGY SAMPLING SITES

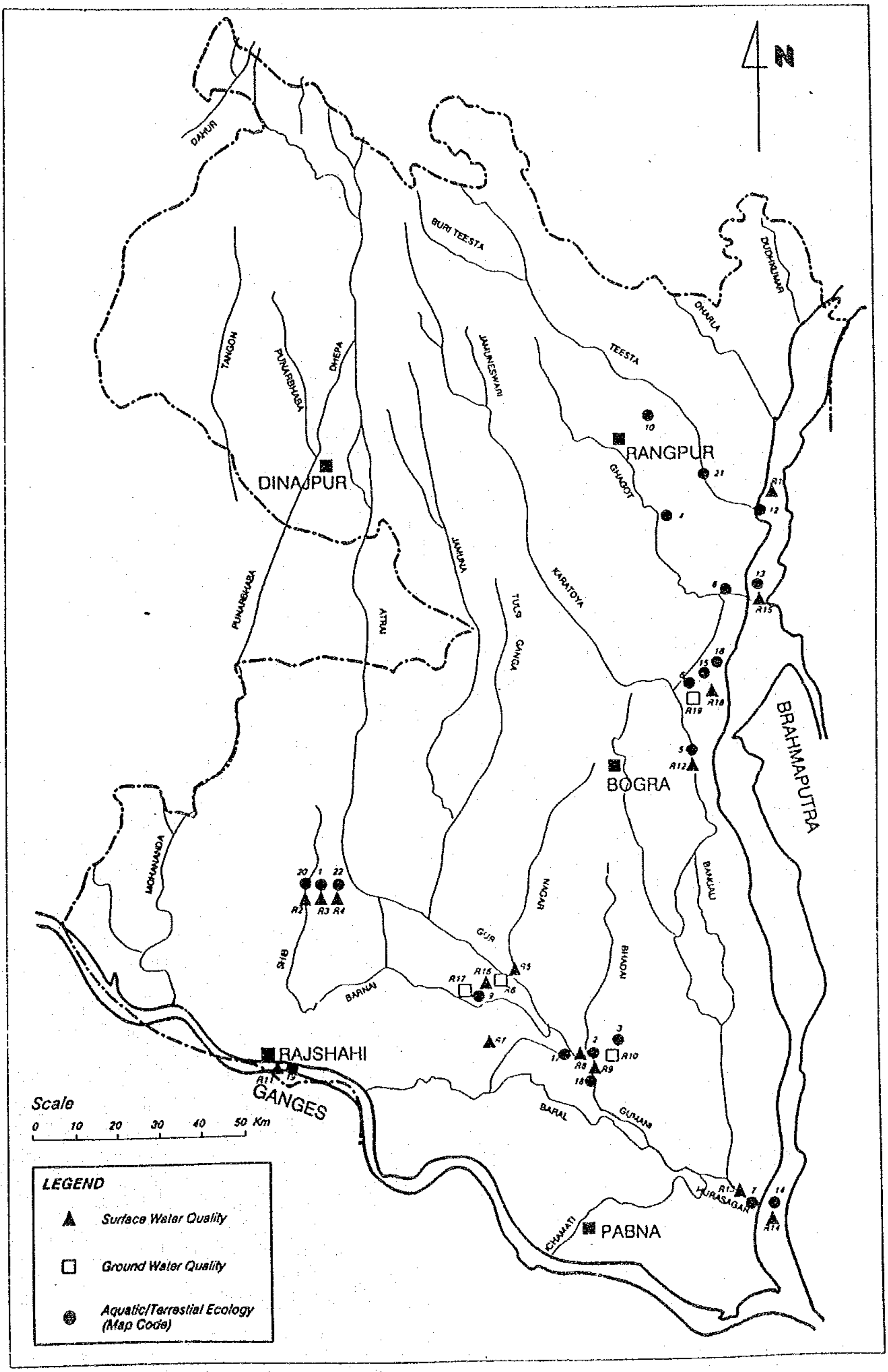
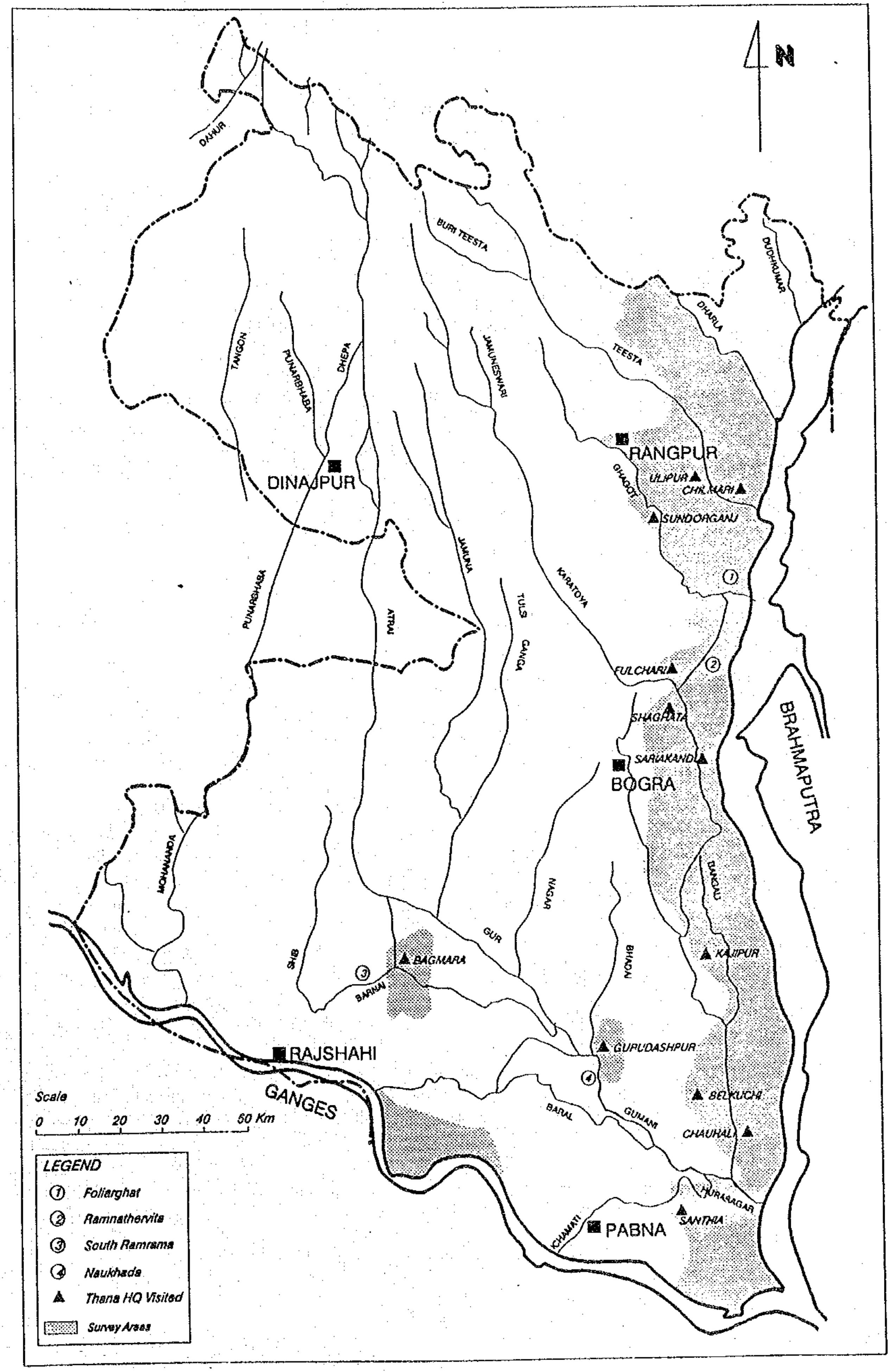


Figure 1.3

HEALTH SURVEY LOCATIONS



scheme fits with policy aims at national, regional and sub-regional levels, and how it squares with and involves local people's priorities and aspirations.

To achieve this awareness the public participation rounds and the MIKE 11 model output have been relied on. The public responses have helped understand the spatial, physical and human dimensions. The MIKE 11 output of hydrographs has allowed a temporal view to be gain on changing flood peaks, depths, duration and timing. Both form a basis for the indicative mapping of impact areas.

A wide range of tactical and strategic options were considered at various stages of the planning. These are described in more detail in Volume 1. Only those final options which were considered likely feasible options are assessed here. This approach was both iterative planning and the final process of impact assessment. The identification of Important Environmental Components (IECs) has referred back to the most likely key issues established in 1991 phase 1 studies, and re-ordered priorities as information was fed back from the field studies and public participation.

With the limited resources it was not possible to survey all the project areas considered. Therefore, for those schemes in the Mohananda and Teesta left and right bank proposals reference has been made to the rapid rural appraisals carried out in mid-1991 and secondary sources.

Where possible quantification or selection of proxy information has been tabulated to help value the likely impacts for different options and the comparison against the present and "future without project" situation. A scaling of impacts between -5 and +5 has been used as requested by the Guidelines.

1.6 Public Participation

The need for effective public participation has become a feature of the FAP. What it means and how to do it has been an area of exploration and uncertainty. It can vary greatly from simple consultation through to the total involvement of local communities in formulating plans and policy and implementing the strategy themselves. The institutional frameworks required for each are very different. No consensus has been achieved while this study was in progress.

In this relative vacuum of guidelines and policy the sociologist, in consultation with a number of interested parties, developed an approach that is described in Volume 11. This work proved vital in confirming that local people are experts in understanding their environment. It also provided valuable feedback to, and raised awareness amongst, the study technicians responsible for design. It also provided important feedback to help assess the output of the MIKE 11 hydraulic model. Thus, considerable benefits have accrued to the planning as a result of the small start in this most important field of public involvement. The results and coverage must still be viewed as very preliminary and more of a pilot approach to be taken up in the next phases of planning.

Non Government Organisations (NGOs) play an increasingly prominent role in development work. Their active involvement will be important in the future programme. Most work actively at a local level and some pioneered important development achievements. For instance Service Civil International (SCI) and the Mennonite Central Committee (MCC) have pioneered an integrated self-help programme for flood proofing in the north central region. NGOs will likely be the core of any future flood response strategy and should be central to planning disaster preparedness. Others are undertaking basic applied research amongst communities of new technologies that relevant to sustainable development strategies. The CARE programme at Rangpur into paddy-fish and pest management is an example.

A number of prominent NGOs, including Gono Kallayan Kendra, Nijera Kori, Chinnaya Mul Unnayan Sangstha, Rural Development 9, Gono Unnayan Kendra, Bangladesh Rural Advancement Committee, Grameen Bank and CARE, are some of those active in the northern part of the region. As part of the public participation exercise they were interviewed in situ about their work in floods in particular and their approach to development in general.

CHAPTER 2

THE PHYSICAL AND BIOLOGICAL ENVIRONMENT

2.1 Systems Analysis

Interventions in the floodplain and delta of Bangladesh have to deal with a particularly complex network of interwoven political, social, economic, ecological and physical sub-systems. It will take many years of basic data collection before the details of these linkages and inter-actions can be worked out to produce meaningful predictive models of either a qualitative or a quantitative type. A generalised systems diagram of some of the key features is given in Figure 2.1.

2.2 Physical Environment

2.2.1 Atmosphere and Climate

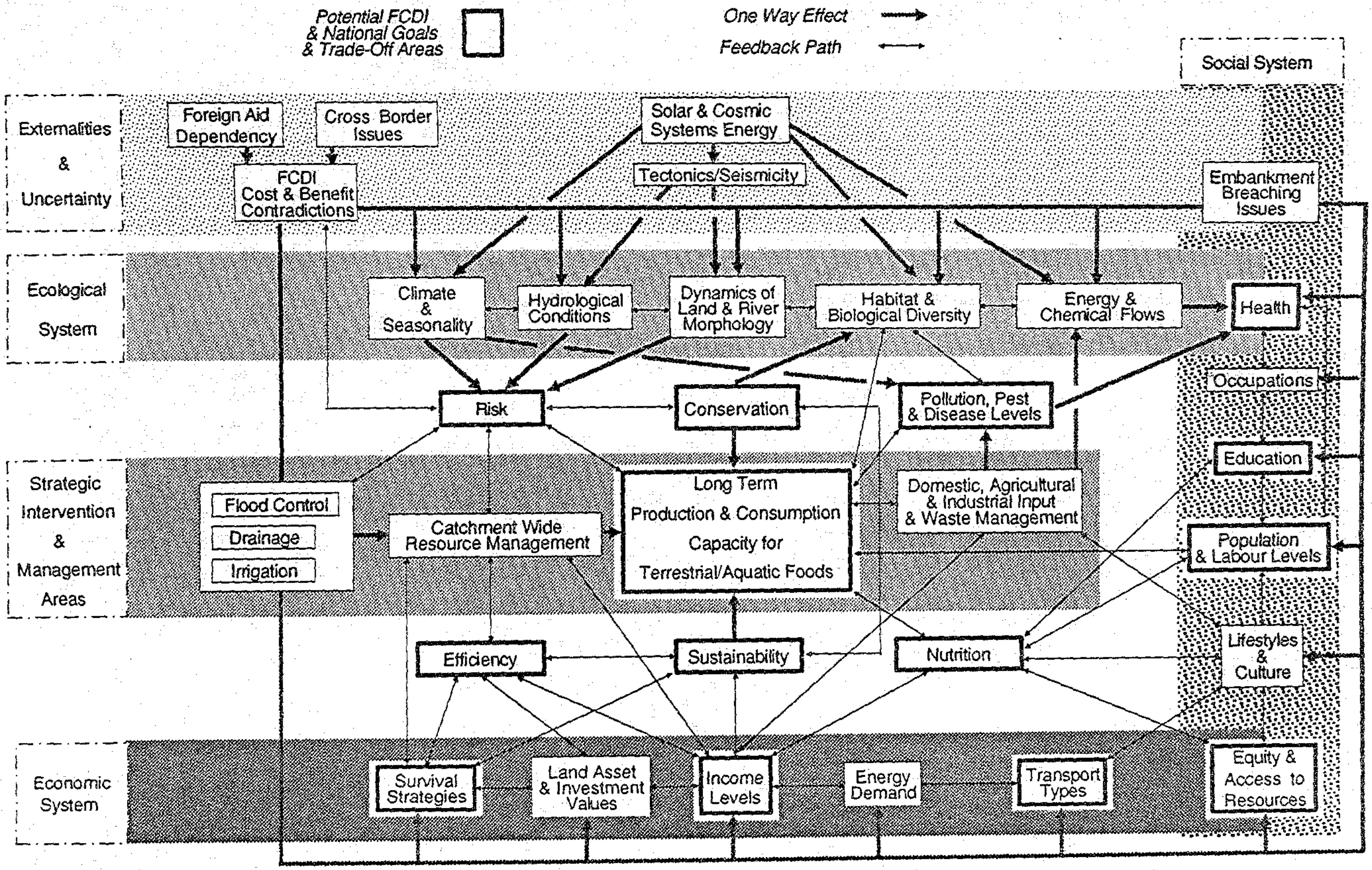
A description of the climatic norms for the region is given in Volume 10. The region's climatic and hydrological regime is dominated by the influence of the Himalayan mountain ranges to the north and the monsoonal systems operating in the Bay of Bengal. The seasonal pattern shows two main seasons, separated by transition seasons. The monsoon (May/June until September) has heavy rain and very high humidity. The dry season (November to February) is sunny and relatively cool, with only occasional scattered showers. The transition in October-November is relatively smooth, with declining temperature, humidity and storm frequency. The start of the dry season transition period is also smooth, but the pre-monsoon period in April and May has somewhat unstable atmospheric conditions. This period is very hot and is characterized by thunderstorms and squalls and coincides with the peak cyclone season in the Bay of Bengal. The tracks of cyclone while reaching inland to the North West Region do not cause damage, but the area may be affected by associated storms.

Average annual rainfall is a around 1900mm; significantly below the national average of 2320mm. The highest rainfall is in the far north (3000mm). Annual rainfall shows considerable variability; 1962 to 1990 averages ranged from 1350 - 2600mm. The extremes have been measured at 554mm at Bagdogra and 5633mm at Bhitargarh. There is a small trend of increasing rainfall since 1962, but this is not believed significant when compared to similar to variations earlier this century. Storm rainfalls can be very heavy in all parts. Daily falls of 200mm have been recorded, with 10-day totals of 700mm being not uncommon; the most extreme record being over 1100mm at Kaunia in 1987. Correlation between wet years regionally and over the upper catchments is believed to be slightly significant thus severe rainfall conditions are quite likely to coincide with, and be exacerbated by, severe floods on the main rivers.

The sub-tropical location produces temperature variations that are pronounced. Diurnal variation is a low 5°C during the monsoon, but around 15°C in February. Maximum temperatures range from around 35°C in April/May to about 25°C in January, while minima peak at about 26°C in August and drop to 10-11°C in January. Seasonal patterns show relatively little variation with location. Peak temperatures are closely connected with the passage of the monsoon. Daily maxima occur just before the arrival of the monsoon, while the highest night-time minimum occurs at the peak of the monsoon season.

Figure 2.1

Simplified System Analysis of FCDI Interventions, Linkages and Trade-Offs



Humidity levels are consistently very high during monsoon, and only drop significantly for a short period at the end of the dry season. Sunshine levels are low during the monsoon, but from November to May are consistently high. Wind speeds are at a maximum in the early part of the monsoon, but drop substantially by the beginning of the dry season.

Evapotranspiration reaches a maximum in April when temperature, sunshine and wind are all at or close to their maxima for the year, while humidity is a little below its peak. Evapotranspiration drops substantially thereafter as the humidity reaches very high levels and the other significant parameters all also become less favourable for evapotranspiration. Evapotranspiration is exceeded by average rainfall from May to October, while for the remaining months it is substantially higher than rainfall.

The general conditions of the air quality are good. Rural pollution sources are few (mainly brick fields) while the urban centres are developing into foci of industrial pollution but, as yet, on a minor scale. The output from industrial and urban areas is growing and the pace of rural mechanisation has increased rapidly in the last decade. This is particularly associated with the introduction of tubewell engines and the conversion of country boats to motorised power using the shallow tubewell engines. The growth in demand for kiln bricks has also lead to a rise in the use of fossil and timber fuels. There is very little data available on which to make any assessment of its significance. Global aerial pollution is far more significant and it's influence on global climate that the region will have to adapt to. It is impossible to assess the significance of these possible changes. However, the ionic status of the region's waters is determined primarily by rainfall chemistry. Research studies would be the best mechanisms through which to assess the likely future changes to the quality of soils, water, crops and health.

2.2.2 Landscape Structure and Formation

The region physically comprises floodplain, piedmont plains and the higher ground of the Barind Tract. Settlement has always been more active in the floodplain areas while the Barind has a drought prone tendency, even though annual average rainfall is relatively high.

The landscape of the NWR varies in altitude from the northern border piedmont areas (94 masl) and the higher ground of the Barind Tract (55 masl) to the banks of the Ganges (9 masl). The local variations in height in the floodplain themselves are between 1-4 metres. The depth and seasonality of flooding from the various sources of river, embankment breaches and rain are the primary influences which determine the types of ecology, settlement patterns and land use found in any particular area. The nature of the topography, hydrology and morphology is complex and dynamic. This produces the similar complexity in the ecology, settlement and land use patterns. These create considerable problems for planning, particularly at the pre-feasibility level when broad generalisations necessarily have to be made. Scaling problems are the most significant problem, particularly related to local topographic variations.

The Bengal basin cover West Bengal, Tripura and Assam. It comprises a flat surface created by the geologically recently formed delta and alluvial plains of the Ganges, the Brahmaputra and Meghna rivers, with a total area of 60,000 km^2. The basin is essentially a Cretaceous-Eocene depositional centre within major delta building episodes during the recent Oligocene age.

The unconsolidated sediments comprise coastal, deltaic, paludal, alluvial, and alluvial fan deposits of Holocene age. The older alluvium consist of Madhupur, Barind and Lalmai residual deposits of Holocene-Pleistocene age. In general, the deposits range from coarse sand and gravel in the alluvial fan areas to silty clay and clay in the mangrove swamps in Sundarban. Different rivers carry different

kinds of sediments depending upon their source materials. The Brahmaputra river sand is coarse to fine grained and contains mostly quartz, feldspar, mica and a little amount of heavy minerals. The Teesta alluviums are rich in weatherable minerals, especially mica.

The primary physiographic units characteristic in the region are shown in the floodplain units of the Teesta, Brahmaputra and Ganges rivers. Considerable variation is seen in the older floodplain deposits of the higher Barind Tract. The alluvial fans and floodplains comprise a variety of landscapes created as the rivers have variously formed and abandoned successive channels across the area.

Piedmont plains occur throughout most of Dinajpur district and part of Rangpur district at the foot of the Himalayas, and also adjacent to the northern and eastern hills. The Himalayan plain is composed mainly of sand and minor pebbles and cobbles. The drainage pattern is braided with broad, smooth, but irregular-shaped ridges crossed by numerous branching and reconnecting, broad and shallow channels. The piedmont plains at the foot of the northern and eastern hills are from a few meters to several kilometres wide. The deposits are coarsely textured near the hills and streams but become more sandy with increasing distance from the origin.

Meander floodplain include the greater parts of the Teesta, Brahmaputra, Ganges. The landscape is curved ridges, saucer-shaped basins, and abandoned channels. Generally, the sandy or silty sediments occur in the ridges and the finer materials occur in the basins.

The surface deposits are predominantly stratified silts and sands occupying a low and generally smooth, but locally irregular, relief of ridges, depressions and partly infilled channels. An important feature is the instability of the alluvial formations, both in outline and in relief. Shifting river channels erode large areas of river banks and islands (chars) during the monsoon season and deposit large areas of alluvium as new land within the channels or on top of older deposits.

2.2.3 Geological Processes

The NWR lies within an active seismic zone and mostly classified as medium risk. The most northern area around Kurigram is a high risk area. The design standards for major engineering structures should take these risks into account during the feasibility stage. The design of embankments is a particular problem due to the risks of liquefaction or breaches. Contingency plans for all areas protected by embankments are needed.

Bangladesh forms the major part of the Bengal basin. This is considered part of the Himalayan Foredeep which is a subsiding region stretching across the Indian subcontinent. The rivers that originate from the Himalayas, entering the subsiding foredeep, are diverted along it either to the southwest into the Indus system, or to the east to the Ganges-Brahmaputra river system.

Seismic activity through tectonic sources can come from two sources. First, through the subduction and subsidence of the Bengal Basin. Rates of subsidence here are locally variable and range between 1.5-21 mm per year due to a combination of physical consolidation of alluvial sediments under their own weight. This, in turn, can trigger minor earthquakes with low energy releases. Current analysis suggests a general uplifting of the Barind and the possible subsidence of the Lower Atrai in the Chalan Beel. These factors are partially countered by erosion from the high ground and by level rises from sedimentation in the lower lying ground. Tectonic movements are generally sufficiently slow not to affect planning. However, sudden seismic-induced changes to the landscape, drainage and sedimentation are far more significant.

Second, there are major tectonic movements. Bangladesh is located on the northern edge of the Indian Plate. The Bengal Basin forms a rifted, passive, marginal basin that is gradually closing due to plate destruction in the subduction zone beneath the Indo-Burma ranges in western Myanmar. The wide subduction has contributed to the development of the Himalayan mountain belt. Relatively high displacement is caused by the Indian Plate underthrusting the largely stable Asian Plate. This is a potential source of catastrophic energy release through earthquakes. The epicentres of the major historical earthquakes concentrate in the Shillong Plateau, in the Assam valley and in the Arakan Yoma and Indo-Burmese ranges. Analysis of historic data records is given in Volume 7.

The probability and intensity of seismic events declines moving across the country from north-east to south-west. The NWR lies mostly in the area of medium risk of seismic vulnerability, but the whole of the northern reaches lie in the area of highest risk.

Large events on record close to the region include the Shillong earthquake of 1897 estimated at 8.7 on the Richter scale which caused widespread damage and liquefaction over a large area. The largest known event with its epicentre in Bangladesh was probably in 1885 which has been associated with the crossing of the Atrai and Hinge Fault which reached 7 on the Richter scale. Studies by Rajshahi University indicate that there is a 96% probability of a high magnitude event occurring in Bangladesh every 25 years. The general return period of a earthquake of magnitude 7 was 63 years and of magnitude 6 was 10 years.

Investigations on liquefaction of delta deposits have confirmed that events exceeding only 5 on the Richter scale and with sufficient duration can induce liquefaction on embankment foundation materials where relative density of materials is less than 85%. The risks of liquefaction are therefore real hazards that cannot be ignored in the planning, assessment and contingency arrangements of FCD schemes. The risks vary according to distance of the epicentre, project location, soil type, engineering design criteria and the construction method and quality of work.

The statistical analysis of ground acceleration and return periods indicates that events of high risk are extremely unlikely to affect the economic rational and criteria for engineering design. Therefore, to date no counter-measures for structure and embankments have been deemed necessary for basic engineering design. However, given the general features of energy build up in tectonic processes associated with tectonic movement, the actual occurrence of an event above 5 on the Richter scale in the medium-term future can be regarded as extremely likely. These events are thus directly relevant to the immediate medium time scale of planning.

Any confinement of the regional drainage pattern will concentrate long-term deposition and lead to rising bed levels. The time scale for these changes are less than 100 years and need to be given more prominence in future planning. There are conditions when sudden influxes of large amounts of sediment can occur associated with landslides, seismic activity, or excessively high rainfall in the upper catchment. Such an event occurred in the 1950 Assam earthquake when large quantities of sediment were brought into the Brahmaputra, raising the bed levels and exacerbating flooding in the NWR for subsequent years until the load had passed through to the estuary.

The catastrophic earthquakes of 1762 and 1782, together with the extreme high rainfall in 1787 are believed to have been responsible for the shifting of a number of river and drainage courses in the region. The most notable was the westward movement of the Brahmaputra and the re-alignment of the Teesta from its southwards drainage into the Atrai to its current east-south-east drainage into the Brahmaputra. A series of seismic events since have continued to alter the drainage and landscape features including drainage paths, gradients, landslides, faulting, uplift and subsidence. Coincident with these changes have been the westward shift of the Ganges. These created the current levee and

floodplain morphology of the Ganges and Brahmaputra and the significant area of beel wetlands, referred to collectively as Chalan Beel. The more recent development of polder schemes and groundwater development in the Lower Atrai, together with sedimentation from the Ganges along its northern floodplain, has significantly diminished the ecological significance of these wetlands.

The 1897 Great Assam Earthquake destroyed many masonry buildings in Rajshahi, Natore and Naogoan. Earth fissures up to 3 m wide and one kilometre long occurred and the railway over the Atrai and Baral was damaged. Changes in elevation and land subsidence effected the hydrology, particularly in the Rangpur and Gaibandha areas (see Volume 7). Bed levels were raised and channels constricted by collapse of the banks. The changes in elevation created many new swamps and beels and some agricultural areas were covered with deposits of sand. The type of risks associated with seismic damage depends on the nature of the soils and geological material. These will have to be taken into account during feasibility planning.

2.3 Land Resources

2.3.1 Soils

Analysis of the basic soils characteristics has not been included at this pre-feasibility stage. They will become important during feasibility study because of a number of potential adverse impacts identified and associated with localised problems.

The physiographic units of the region include:

Teesta Floodplain: This comprises the floodplains of the Atrai, Little Jamuna, Karatoya, Dharla and Dhudkumar. The soils are mostly loams with small areas of sands and clays getting heavier moving southward. Most of the lowlands are in this sub-unit.

Karatoya-Bangali Floodplain: This occupies a strip along the Brahmaputra-Jamuna river, in Gaibandha, Bogra and Sirajganj districts. Two thirds is highland or medium highland and the rest lowland. It was subject to regular flooding and silt deposits from the building of the BRE. Medium-textured loam soils predominate and a quarter of the area exhibit surface clays.

Lower Atrai Basin: This occupy both banks of the Atrai river on the borders of Naogaon and Rajshahi districts. Only about 10% is highland or medium highland. The soils are mostly acidic basin clays. They crack deeply when dry and become sticky and plastic when wet.

Lower Punarbhaba Floodplain: This small narrow strip of land is at the extreme west of Naogaon district. It is a low-lying, flood-prone area differs from the adjacent land as the soils are derived from non-calcareous Teesta and Brahmaputra alluvium and not from the calcareous Gangetic deposits. Most of the soils are cracking acid clays. Some 70% is "low" or "very low" land.

Active Brahmaputra Floodplain: This extends along the western bank floodplains of the Brahmaputra in Kurigram, Gaibandha and Bogra districts. Some 60% of the area is medium highland or medium lowland. An outstanding feature is the extent of "char" lands. They are sandy and very variable in the stability.

The Gangetic Floodplains: This comprises three sub-units of the Active, the High and the Low Gangetic Floodplain forming part of Nawabganj, Rajshahi, Natore and Pabna districts. Less than a quarter are lowlands. Soils are mostly of medium or medium-heavy texture and typically calcareous.

There are minor differences in the soils, notably, that the Gangetic plains are rich in lime while the others are not. No salinity problem from soil or groundwater exist. Soil conditions are suitable everywhere to grow all the crops commonly cultivated in the country. However, many concerns have been expressed inside and outside of FAP and the issue is addressed.

On-going historical trends in land use and farming systems have changed the basic conditions of soil structure, chemistry and organic matter content. The main loss of organic matter has already occurred with the removal of the original forest, woodland, grassland and wetland flora. The longer term spread of cultivation, the more recent continuous mono-cropping, the loss of dry season following and the increased of fertiliser are directly implicated in this and, thus, cannot be ignored in the context of future agricultural planning.

Soil fertility, if measured by the amount of biologically fixed nitrogen (i.e. the blue-green algae), has likely decreased due to interference in the wetland conditions brought about by FCD projects. Other nutrients such as phosphate, potash, sulphur and the micronutrients, become more readily available as water relations improve under aerobic surface water and aerated soil conditions; their overall amounts depend on the geological origin, soil-water-biological inter-actions and chemical composition of soil-forming materials. These processes are not sufficiently researched or understood to be able to conclude the degree or adverse impacts which FCD may imply for flooded or irrigated rice. From the perspective of dryland crops there are clear advantages to the changed soil-water relations which enable better use to be made of the chemical fertilisers that are applied.

Proper water management as part of an FCD scheme could help maintain the continued flushing of water bodies receiving potential pollution run-off from higher ground. It could also support the seasonal aquatic status and enhance the provision of "free" nutrients from biological activity in wetlands, fallows and paddy systems.

The major soil problems affecting planning concern the complex of processes by which soil fertility and productivity can be maintained under more intensive future farming systems associated with FCDI schemes. Deficiencies in macro-nutrients (primarily nitrogen), micro-nutrients (particularly zinc and sulphur) and organic matter have all been noted in different areas. Problems of toxicity under groundwater irrigation also occur in a number of areas and include iron, boron, molybdenum and bromide. Local soil physical and management characteristics lead to pans and impeded drainage. These issues are not only important for reasons of sustaining crop yields and low input costs; there are also nutritional and health implications as discussed below.

In situ soil is far from inert, and through its interactions with water, humus, and a remarkable range of biological activity, is a dynamic, living medium of which harvested crops are just one level. The daily and seasonal cycles of activity by which life is sustained are still poorly researched (see Catling et al, IRRI 1989), and even less appreciated in the commercial direction which most farming has now taken. Farming systems which are sustainable and cost-effective in the long-term are only likely to be established when the on-farm management system and its support services turn to nurturing the ecological and bio-chemical realities created by the interactions and life forms of the soil.

In the lower Atrai basin there are isolated areas of peat deposits, or soils high in organic matter. These are often associated with old marshes and more are believed to mainly occur at depths beyond the cultivation and crop rooting zone. Any deposits close to the surface could lead to problems

associated with acid soils or to subsidence if they were not properly managed. These areas would be of concern if they were used as sources of material for constructing embankments as these soils are quite unsuitable as a construction material. Where they have been used in existing schemes, settlement, subsidence and erosion of organic matter have led to breaches. Similarly, very sandy soils are also unsuitable as an embankment material, due to the rapid passage of water through them. Only detailed site surveys, proper site supervision and contractual controls can address these problems in the detailed design phase.

The issues discussed here are problems not solely related to FCD. Nevertheless, the operational criteria of water management, once FCD strategies are decided on, will determine how, when and where the role of water can assist the evolution of sustainable farming systems. In practise, many other issues will determine how on-farm and off-farm agricultural policy develops. Market pricing, subsidies, commercial pressures, tenure arrangements are a few that will be involved. Future planning will need to ensure that the changing conditions are properly monitored, that policy and planning criteria recognise the problems involved and reflects these concerns in the TOR for the next phase of studies.

2.4 Water Resources

2.4.1 River and Flooding Systems

The region is bounded by the River Padma to the South, the Brahmaputra/Jamuna to the East, the Indian border hills to the North and the less hilly border to the West. The main river system is shown in Figure 2.2.

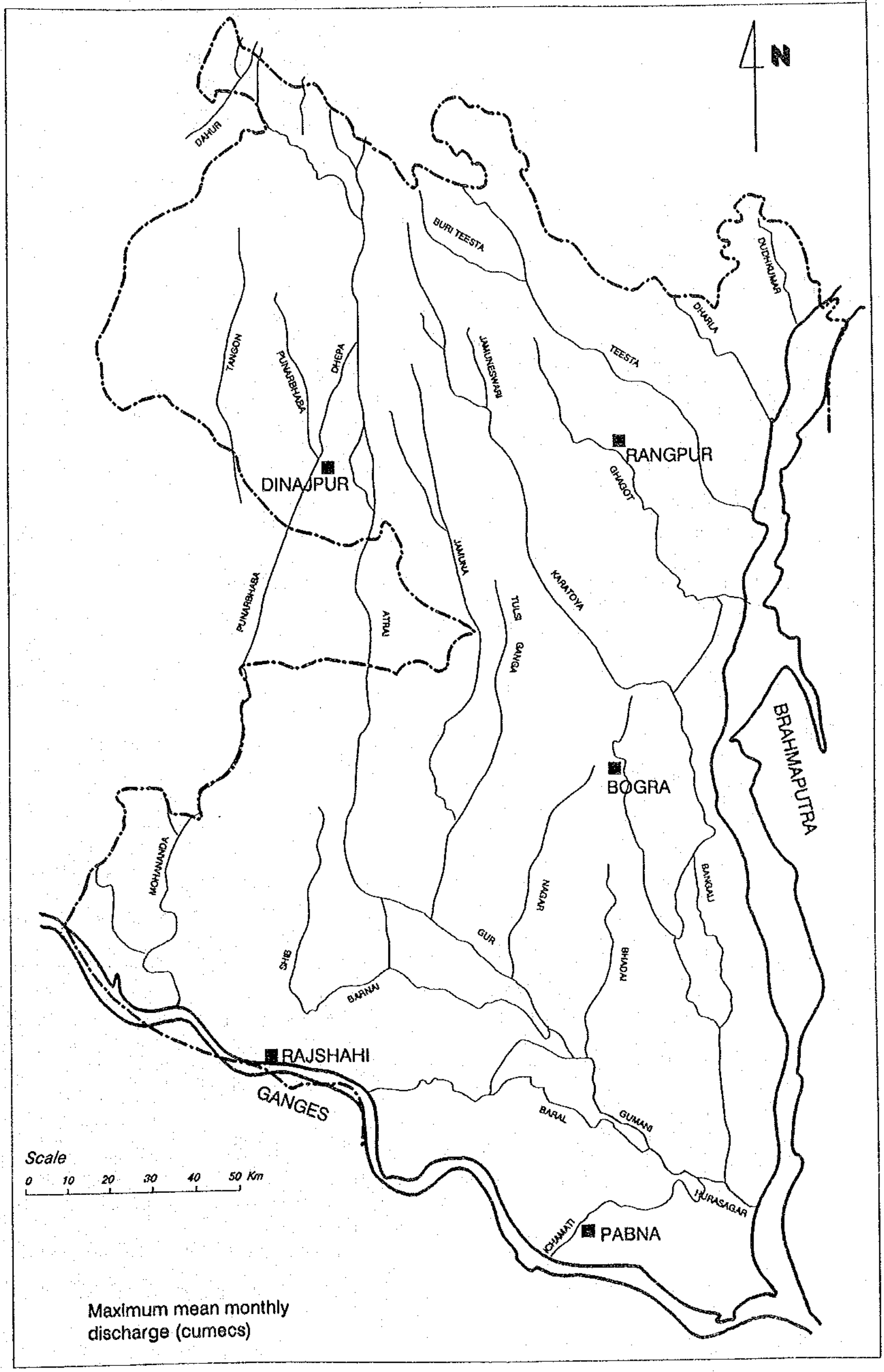
The Teesta, Dharla and Dudhkumar rivers originate in the Himalayas and Himalayan Piedmont Plains. Though they are large rivers they are relatively steep on entry from India into Bangladesh, and their floods can be flashy. On a number of occasions the Teesta has changed its course in the vicinity of its outwash fan, generally in an easterly direction, so that the watercourses internally draining most of the North West Region are in fact former Teesta channels. In the past, the Teesta has occupied the channels now followed by the Mohananda, Purnabhaba, Atrai, Little Jamuna, Karatoya and Ghagot. The floodplain and delta formation process is dynamic, unstable and evolving. This power of these processes places considerable limits on sustainable development based on fixed structures. Even now Teesta flood waters feed into the Atrai and Karatoya systems at times of very high levels.

The rivers in the north east corner have relatively steep gradients of 1 in 2000 or more, but in nearly all the remainder of the area river courses have very flat gradients of 1 in 5000 or less. The rivers are consequently heavily meandering and have limited capacity for passing flood discharges. The lower system is exacerbated by overland flow.

The flood network can be characterised as a highly complex riverine floodplain system, rather than a river catchment. The flood regime falls into three categories: fluvial, interaction and backwater. In the fluvial zone, the water levels respond to the local flow rate and are not influenced by tail water conditions at the outfall of the river system. In the backwater zone the water level is nearly independent of the discharge in the river and is governed by the tail water level at the outfall. The interaction zone lies between the fluvial and backwater zones and the relative importance of the river flow and tail water level changes progressively along this zone.

Figure 2.2

THE RIVER SYSTEM



Of fundamental importance to the flooding problems is that flood levels in the Ganges and the Jamuna are often equal to or higher than internal river levels for long periods, which means that drainage is only possible for short periods at the beginning and end of the flood season. The result is backwater ponding in the lower Atrai/Hurasagar/Bangali against the backwater effects from the Jamuna, even in dry years. The effect of constructing polders can only lead to serious confinement and a consequent increase in flood levels outside the polders. Thus, the effects of any engineering works can only be small in the backwater zone.

In addition, there is the local rainfall run-off system, some parts of which drain into isolated pools, although the number and extent of these varies depending upon the degree and timing of river flooding and the intensity, timing and location of rainfall. Flooding caused by storm run-off in the upper catchments are localised in nature mainly affecting the northern areas.

Flooding and drainage problems must be separated into their primary causes. The primary flood problems in the region are due to breaches in the embankments of the major rivers (the BRE, the TRE and less so the Ganges, Dharla and Dudhkumar). Flood damage is only partially related to the severity of the flood event because accidental or intentional breaches occur with "normal" as well as extreme floods. The confining effect of the polders in the Lower Atrai also mean that the primary problem of damage here is also due to public cutting to save property and protect livelihoods.

The flooding and drainage pattern is significantly affected by the existence of man made structures, particularly the railway and road networks which are on embankments of varying heights incorporating hydraulic structures of differing types (bridges, culverts etc). In addition there is a relatively long history of construction of flood embankments in the area and these are kept in varying degrees of repair and are at times deliberately breached to solve drainage problems. These structures and the virtual total landscaping by terracing of fields throughout the region create a water and land management system pre-existing in its own right, irrespective of any later or new FCD projects.

2.4.2 Morphology of existing rivers

The timescale of morphological change is difficult to predict. Bangladesh comprises a developing deltaic formation where three of the major rivers of the world deposit their sediment load. Flows in these rivers depend on climatic conditions and, to some extent, on man-made influences such as land use practices and water demand. Most rivers are changing their dimensions and courses and the rate of change is determined by the extent to which individual rivers differ from their equilibrium dimensions and slopes.

Projects developed under FAP may affect river morphology by introducing works which effectively move individual rivers further away from their natural or equilibrium condition. They will induce morphological responses and the rivers will "react". by aggradation, degradation, changes in size or changes in plan shape. The rate at which rivers will initially react and the time before full readjustment depends on many factors. An indication can be given of the time which could elapse before re-adjustment is achieved and what the nature of that re-adjustment is likely to be. Full re-adjustment is attained asymptotically and will possibly by overtaken by future works and hydrological events. Hence these data should be taken as guidance only. The time of re-adjustment has been categorised as follows :

- Less than 20 years (Rapid)
- 20 to 50 years (Modest)
- Greater than 50 years (Slow)

In general the rivers show a tendency to become deeper and narrower. Differences between the regime slope and the observed slope of many of the rivers in the NWR indicate that changes in channel planform may occur. In many areas these natural changes in river morphology explain current flooding and drainage problems. The following assessment was made:

Lower Atrai: between 20 and 50 years.

Middle Bangali: still adjusting to the change in the flow and sediment regime resulting from the breaches in the BRE - likely to be less than 20 years.

River Teesta: analysis indicates a general movement South-West: if it continues the frequency of breaching will increase and will threaten erosion to TRE - likely to be 20 to 50 years.

Ghagot river: likely to be less than 20 years.

If the spills from the Teesta or the Brahmaputra are prevented then there will be a reduction in both the flow and sediment input to the rivers within the region. The change in both flow and sediment transport is likely to lead to significant changes in the morphology of the rivers affected.

If partial or complete FCD is carried out on the internal rivers then this will have a two-fold impact. The FCD will remove flood storage from the system and hence impact on discharges and secondly, by restricting flow widths, it will change the sediment transporting capacity of the river sections.

If desilting were used to reduce flood levels then the way that the excavated sediment is disposed of must be carefully considered and closely defined and controlled. While desilting may give an immediate increase in conveyance it cannot be regarded as a permanent solution. If bed levels have risen in the past then the desilted bed levels will continue to rise at the same, or in some cases at an enhanced rate. Desilting will only provide temporary relief before the channel returns to its original form.

Attempts to reduce the length of a stable river by carrying out cut-offs are normally unsuccessful as new meander bends usually develop and the river gradually reverts to its former sinuosity. This can be prevented by carrying out bank protection works to prevent further changes in plan form at the same time as carrying out the cut-offs. An exception is when a river is not stable and is evolving in time. If the sinuosity of the river is reducing naturally then artificially induced meander cut-offs may accelerate the process and help to stabilise the river. Cut-offs are not relevant only to the river morphology but may also impact on the environment of the area by disrupting important habitats.

The immediate impact of a cut-off is usually to reduce water levels for a distance upstream. In channels with erodible beds erosion and sedimentation are likely to take place. Erosion usually occurs upstream of the cutoff and deposition downstream. This deposition will have the effect of raising water at the lower end of the cut-off and immediately downstream.

Groundwater

The aquifer system in the NWR comprises Quaternary to Recent sediments. The surface geology incudes Holocene Piedmont deposits in the north west, Holocene Interstream Deposits, and the Madhupur Clays of the Barind in the central and south west parts. The aquifer system has three main divisions:

- an semi-confining upper layer of silts and clays of variable thickness, but not exceeding 10m except where it is locally in excess of 50m in the south of Dinajpur district. A gradual thickening of the layer occurs towards the south of the region were maximum thickness ranges from 10 to 20m.

- a composite aquifer of very fine to fine sands which overlies the main aquifer. Its thickness varies from only a few metres in the northwest to over 30m in the Atrai basin. The composite aquifer is a major source of supply for village water supply wells and for hand tubewells.

- a main aquifer of medium to course sands which has excellent water transmitting properties. The exploited thickness of the aquifer ranges from less than 10m in parts of Bogra district to over 60m in the northwest. Aquifer transmissivity is generally high to very high with values in a general range of 2000-4000 m^2/d. Values in excess of 4000 m^2/d are common along the Jamuna River.

Recharge to the aquifer is predominantly derived from deep percolation of rain and flood water. Lateral contribution from rivers comprise only a small percentage (0.04%, MPO, 1987) of total potential recharge. Actual recharge is generally much less than potential recharge due to 'aquifer full' conditions during the monsoon season when water tables reach the ground surface. After this recharge is surface drainage.

The aquifer system has the capability to support large scale groundwater abstraction for irrigation. The rapid development of tubewell irrigation, particularly in the 1980's, clearly highlights this potential.

Development of Minor Irrigation

Tubewell irrigation in Bangladesh started in the mid 1960s with the introduction of 785 deep tubewells in Thakurgaon District. During the 1970s tubewell development was mainly controlled by BADC. The use of shallow tubewells become widespread in the 1980s and a rapid expansion occurred when controls on STW development were lifted in 1986. The development of minor irrigation in the NW region is shown in Table 2.1 The information was derived from a variety of sources, including the MPO and AST/CIDA.

Table 2.1 Development of Minor Irrigation in NW Region

Mode	Number of Minor Irrigation Units					
	1985	1986	1987	1988	1989	1991
DTW	7038		6958		8561	7360
STW	79227	76368	83616	94211	115871	136652
LLP		4671	4879	4754	5178	4877

The data indicate that the increase relates mainly to a 79% increase in STWs since 1986. In some thanas a marked decline in DTWs has occurred between 1989 and 1991. The reasons for this decline are not clear. The growth in STWs is not evenly spread having mainly occurred in Bogra District (83%), parts of Natore District (101%) and Sirajganj District (138%). STWs declined in Nawabganj District and parts of Rajshahi District where aquifer conditions are clearly unfavourable for STW development. Both DTW and LLP numbers have remained approximately constant over the past 5 years.

The 1989 dry season extended well into May and irrigation requirements were high. The decline in groundwater levels required the conversion of many of STWs into deep set STW (DSSTW), particularly in parts of Naogaon, Pabna and Rajshahi Districts. For all 70 thanas an average of 11.5% of STW were deep set in 1989. The 1991 data shows a significant reduction in the number of DSSTW (only 3% of total).

LLP irrigation is generally of minor importance. The average surface water irrigation for the 70 thanas studied was only 3% of NCA, while this was 30.8% for groundwater irrigation. In two thanas it exceeds 10% of NCA in Gomastapur in Nawabganj (11.8%) and Manda in Naogaon (12.6%).

STW and DSSTW irrigation represents 74% of the total irrigated area with DSSTW providing 2.9% of the area served by suction mode units. In 1989 this was about 11.5%. Command areas for DTW range from 4.9 to 35.9 ha while STW range from 1.5 to 6.0 ha.

Surface and groundwater resources are discussed in Volume 10. The drainage morphology is influenced by geological processes discussed above and by the topography of the high ground of the Barind Tract and the steeper slopes of the Himalayan piedmont. There is no tidal or salinity influence which currently affects the region.

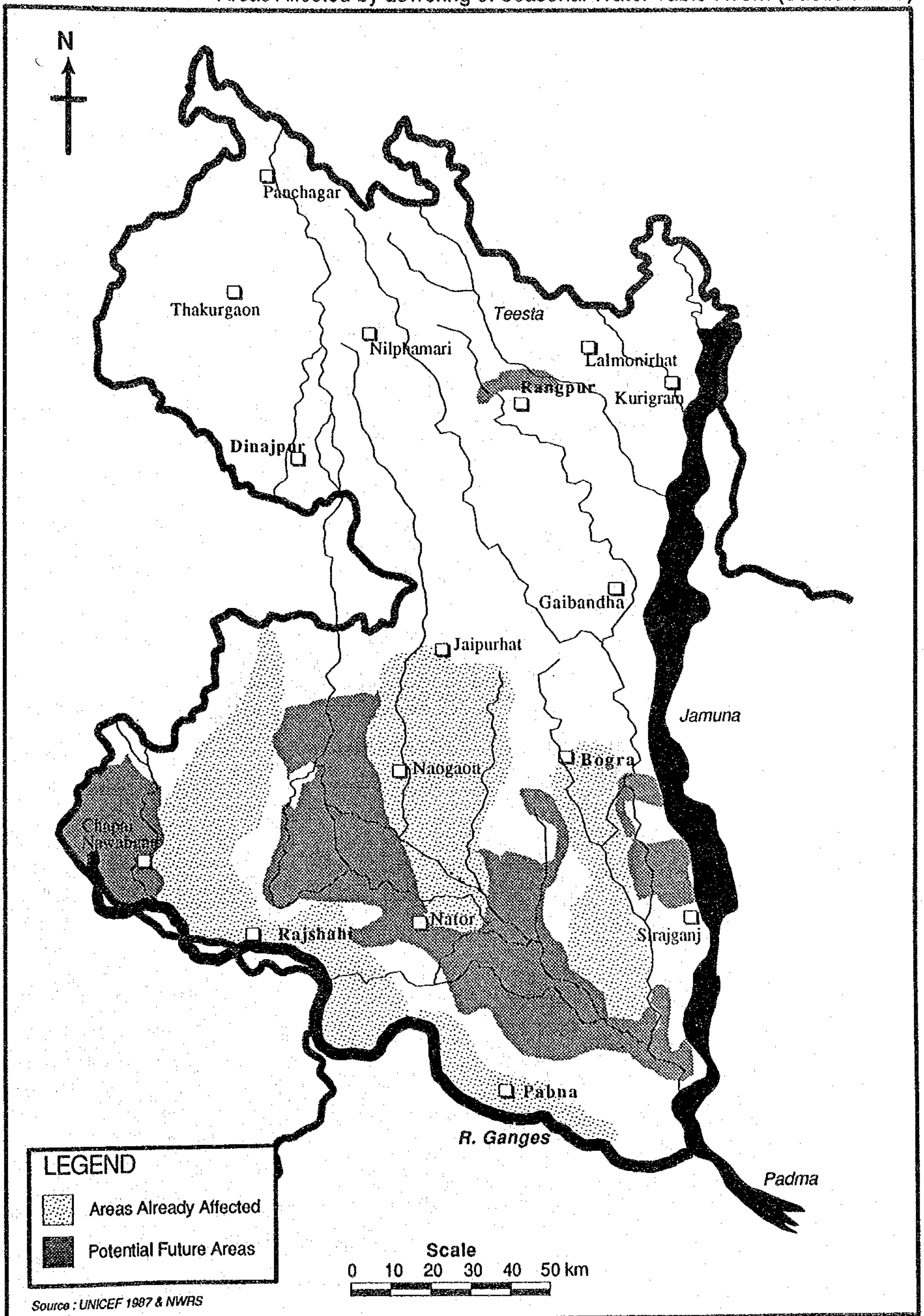
Domestic water supplies are taken from a number of sources and, even when tube wells have been installed, surveys have found that families continue to use a variety of other surface supplies, either for drinking water supplies, but more commonly for other uses, such as bathing and washing.

There are a number of impacts of major drains and FCD which might affect homestead water supplies and would require a mitigation planning in the feasibility stage. There are important linkages between the farming and homesteading systems on high ground and the degree and seasonality of soil moisture available on the receding flood. The seasonal depth to the water table and the type of technology used to extract homestead water is also significant in assessing FCDI impacts. There are also important local (and possibly wider linkages) which maintain the recharge and water depths in the lower lying wetlands which can be affected by FCD and I. The details of these linkages cannot be differentiated between schemes at this pre-feasibility stage and will require more detailed analysis during the feasibility surveys. Figure 2.3 indicates the areas where seasonal lowering of dry season water tables beyond the suction lift of domestic pumps has been noted and associated with both FCD and groundwater irrigation.

The implications for planning are that non-agricultural water supplies, sources and extraction technologies must be given careful consideration in FCDI planning designs and specific mitigation programmes included to deal with the problems.

Figure 2.3

Areas Affected by Lowering of Seasonal Water Table 7.75m (Suction Limit)



Source : UNICEF 1987 & NWRS