GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

FEASIBILITY STUDY
ON
GREATER DHAKA PROTECTION PROJECT
(STUDY IN DHAKA METROPOLITAN AREA)
OF
BANGLADESH FLOOD ACTION PLAN NO.8A

FAP 8A

MAIN REPORT

JUNE [illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

THE PEOPLE'S REPUBLIC OF BANGLADESH
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PREFACE

In response to a request from the Government of the People's Republic of Bangladesh, the Government of Japan decided to conduct a study on Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan No. 8A and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bangladesh a study team headed by Mr. Hajime Tanaka of Pacific Consultants International 4 times between October 1990 and June 1992.

The team held discussions with officials concerned of the Government of Bangladesh and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the People's Republic of Bangladesh for their close cooperation extended to the team.

June 1992

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

FEASIBILITY STUDY
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June, 1992

Mr. Kensuke YANAGIYA
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

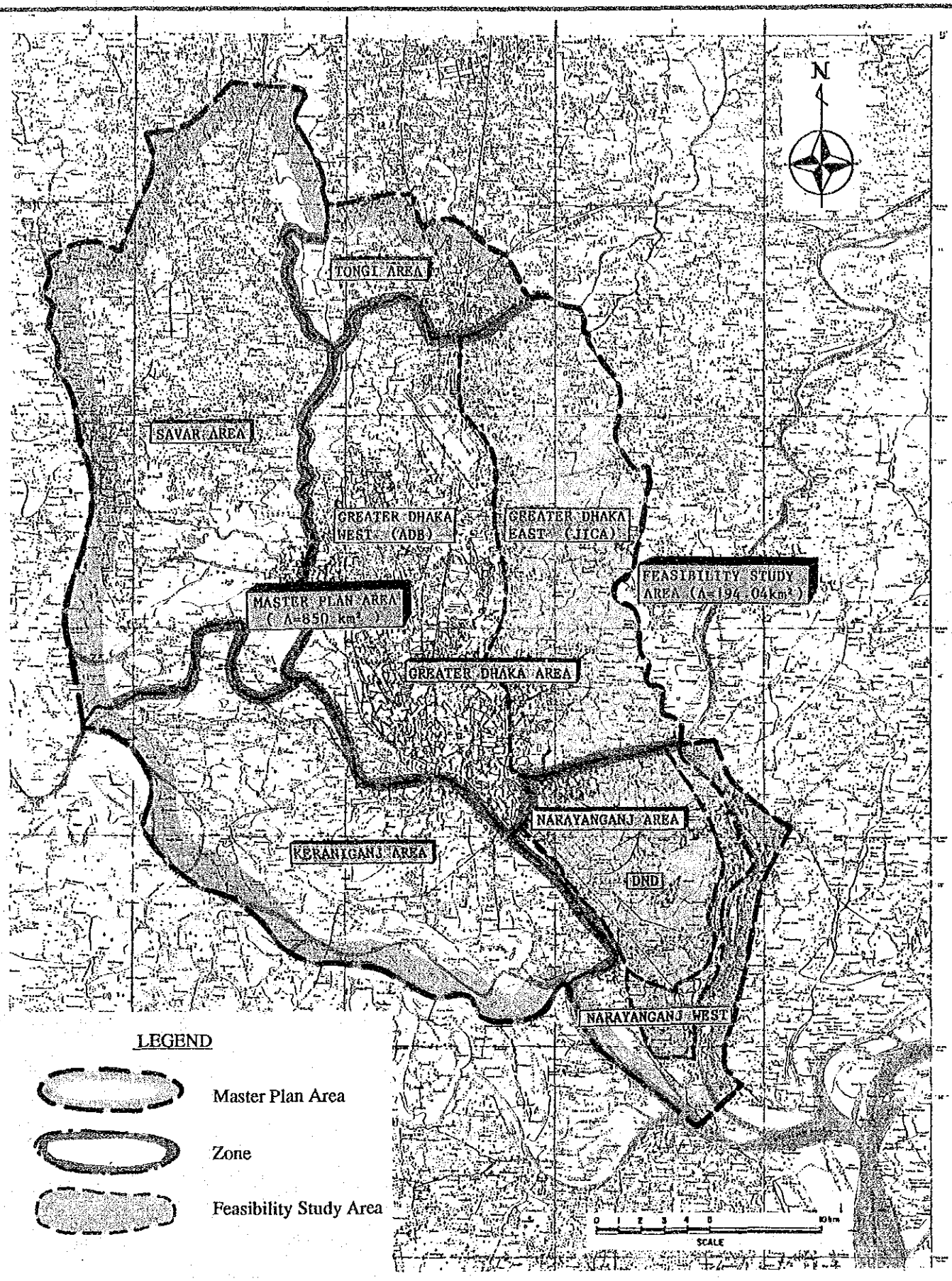
We are pleased to submit the final report entitled the "Feasibility Study on Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan No.8A". This report has been prepared by the Study Team in accordance with the contract signed on September 1991 and May 1992 between the Japan International Cooperation Agency and Pacific Consultants International.

In the study, the Study Team has carried out a Feasibility Study on the priority areas identified by the Master Plan which was conducted from October 1990 to August 1991.

All members of the Study Team wish to express appreciation to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Bangladesh for their assistance. The team also like to thank officials and individuals of the Government of the People's Republic of Bangladesh.

Yours Faithfully,

Hajime TANAKA
Team Leader



LOCATION MAP

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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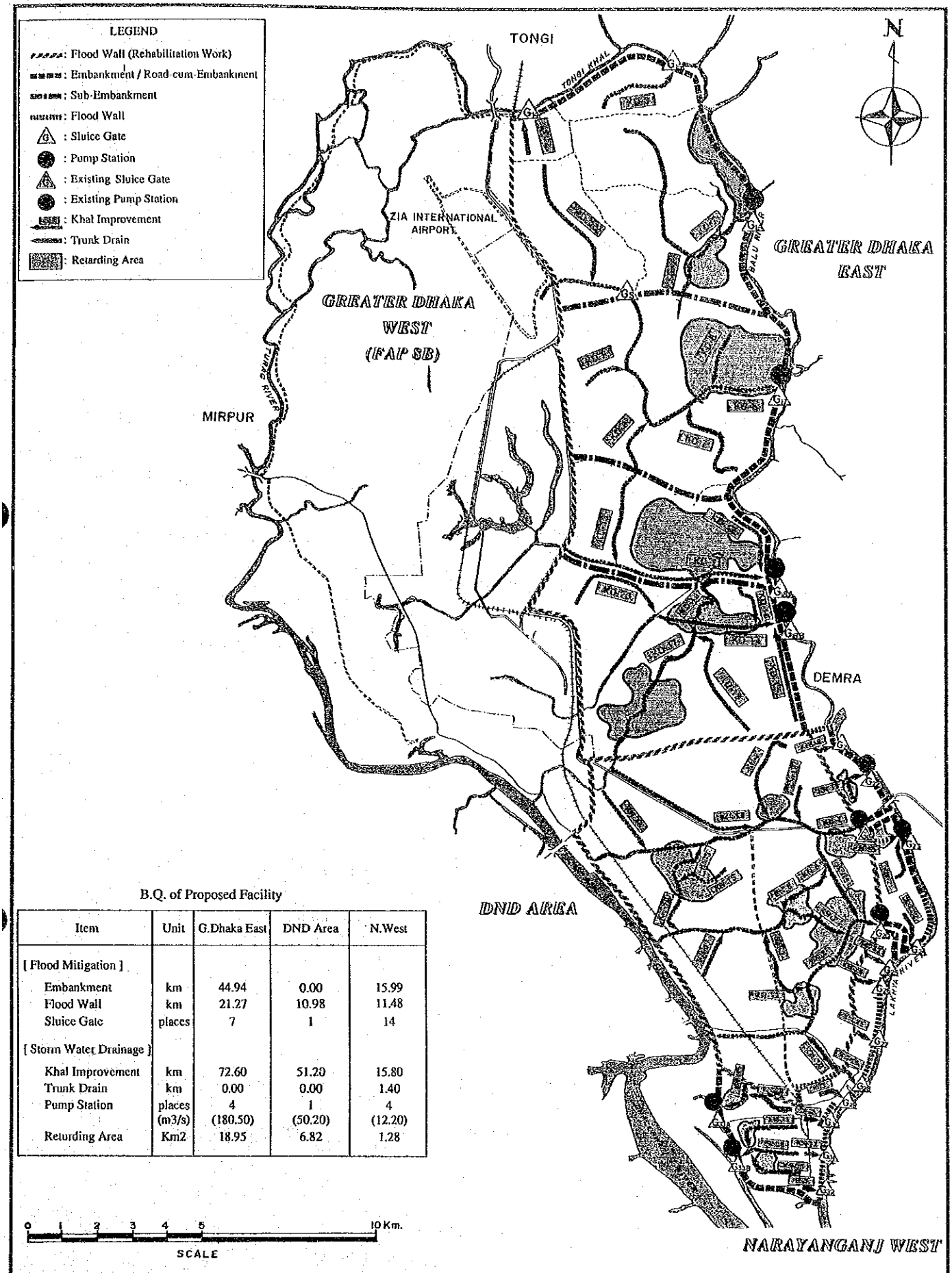

B.Q. of Proposed Facility

Item	Unit	G.Dhaka East	DND Area	N.West
[Flood Mitigation]				
Embankment	km	44.94	0.00	15.99
Flood Wall	km	21.27	10.98	11.48
Sluice Gate	places	7	1	14
[Storm Water Drainage]				
Khal Improvement	km	72.60	51.20	15.80
Trunk Drain	km	0.00	0.00	1.40
Pump Station	places	4	1	4
	(m3/s)	(180.50)	(50.20)	(12.20)
Returding Area	Km2	18.95	6.82	1.28

PROPOSED FLOOD MITIGATION AND DRAINAGE IMPROVEMENT PLAN

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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Table of Contents

CHAPTER 3 HYDROLOGY

CHAPTER 4 LAND USE AND URBAN PLANNING

CHAPTER 5 FLOOD DAMAGE ANALYSIS

List of Tables

(Chapter 11)

List of Figures

(Chapter 6)

ABBREVIATIONS

ADB	Asian Development Bank
AIT	Asian Institute of Technology
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CAAB	Civil Aviation Authority of Bangladesh
CARE	Cooperative for American Relief Everywhere
DCC	Dhaka City Corporation
DEPC	Department of Environment and Pollution Control
DIT	Dhaka Improvement Trust (now RAJUK)
DIFPP	Dhaka Integrated Flood Protection Project
DMAIUDP	Dhaka Metropolitan Area Integrated Urban Development Plan
DMC	Dhaka Municipal Corporation
DND Triangle	Dhaka - Narayanganj - Demra Triangle
DPHE	Department of Public Health Engineering
DOE	Department of Environment
DWASA	Dhaka Water and Sewerage Authority
ERD	External Resources Division Ministry of Finance
FAP	Flood Action Plan
FPCO	Flood Plan Coordination Organization
GDPP	Greater Dhaka Protection Project
GDFCD Project	Greater Dhaka Flood Control and Drainage Project
GOB	Government of Bangladesh
IBRD	International Bank for Reconstruction and Development (world Bank)
IDA	International Development Association (of the world Bank)

IPH	Institute of Public Health
JICA	Japan International Cooperation Agency
MEF	Ministry of Environment and Forest
MIWDFC	Ministry of Irrigation, Water Development and Flood Control
MLGRDC	Ministry of Local Government, Rural Develop and Cooperatives
MOI	Ministry of Information
MOW	Ministry of work
MPO	Master Plan Organization
PC	Planning Commission
PDB	Power Development Board
PHD	Public Health Department
PWD	Public Works Department
RHD	Roads and Highways Department
RAJUK	Rajdhani Unnayan Katripakkha (Capital Development Authority)
RRI	River Research Institute of the Ministry of Irrigation, Water Development and Flood Control
SOB	Survey of Bangladesh
SWMC	Surface Water Modelling Center
SPARRSO	Space Research and Remote Sensing
UNCHS	United Nations Center for Human Settlements
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Education Fund
USAID	US Agency for International Development
WAPDA	Water and Power Development Authority
WASA	Water and Sewerage Authority
WHO	World Health Organization
WMO	World Meteorological Organization

CHAPTER 1
INTRODUCTION

Chapter 1 : Introduction

1.1 Background

In 1987 and 1988, Bangladesh experienced two of the most severe floods on record. Soon after the floods, various studies were conducted by different agencies, countries and the Government of Bangladesh. The World Bank coordinated the studies and framed a Flood Action Plan (FAP) with 26 components as the initial stage in the development of a long-term for flood control, drainage and river management in Bangladesh. The activities are divided between 11 main components and 15 supporting studies or pilot projects.

The FAP was propose in the London Conference held in December 1989 and agreed for implementation by the attendant agencies and countries concerned. As a follow up to the London Conference, the Government of Japan and the Asian Development Bank (ADB) agreed, at the Dhaka Conference held on January 1990, to undertake the Study on Dhaka Town Protection (FAP N. 8) consisting of a long term comprehensive master plan and feasibility studies.

In response to the request of the Government of People's Republic of Bangladesh (GOB), the Government of Japan decided to conduct the study on Greater Dhaka Protection Project (Study in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan No. 8A (FAP 8A) within the general framework of technical cooperation between Japan and Bangladesh. The ADB decided to finance " Dhaka City Integrated Flood Protection Project" (FAP 8A).

The Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programs, was assigned to undertake the study, in close cooperation with the Flood Plan Coordination Organization (FPCO) and other concerned authorities of GOB.

The JICA study team commenced the study in October 1990, and held a discussion on the study program with the GOB study team. The study is composed of three (3) phases, and the respective period and objectives of each phase are as follows :

Phase 1 : Preliminary Review (from October 1990 to December 1990)

The objectives are :

- to prepare a general study program based on the Scope of work, and
- to review the existing conditions and prepare detailed study plans.

The study plan was discussed with FPCO and the GOB study term and shown in the Inception Report (October, 1990). And after reviewing the existing conditions and the relevant previous studies, structural measures for the forecast urban areas by the target year of 2010 and non-structural measures for the other remaining rural areas were proposed and also, according to the concept, a detailed study plan of the Master Plan study (Phase II) on comprehensive flood mitigation and storm water drainage improvement measures for Dhaka Metropolitan area was prepared and compiled in the Preliminary Review Report (December, 1990).

Phase II : A Master Plan Study (from January 1991 to August 1991)

The objectives are :

- to carry out a master plan study on comprehensive flood mitigation and storm water drainage improvement measures for Dhaka Metropolitan area.

- to identified priority areas for a feasibility study.

A master plan study on comprehensive flood mitigation and storm water drainage improvement measures for Greater Dhaka, Narayanganj, Keraniganj, Tongi and Savar was conducted. For elimination of flooding and drainage problems from the areas, optimum measures were studied. The priority areas for a feasibility study were identified. The study results were presented in the Master Plan Report (November, 1991).

The identified priority areas are :

- Greater Dhaka West,
- Greater Dhaka East ,
- Narayanganj DND and
- Narayanganj West,

The priority area of Greater Dhaka West was taken by FAP 8B, ADB. The feasibility study of FAP-8B "Dhaka Integrated Protection Project" is already completed and taken up by GOB and ADB for implementation of the Project. It has been decided that the feasibility study of all the remaining areas be conducted under this FAP 8A study. The basic concept of storm water drainage improvement of the FAP 8A's master plan has already been incorporated in the F/S of FAP 8B.

Phase III : A Feasibility Study (from September 1991 to May 1992)

The objective is :

- to conduct a feasibility study on flood mitigation and storm water drainage improvement measures for the priority areas identified during the phase II.

During this phase, the proposed flood mitigation and storm water drainage improvement measures were studied and reported in the Interim Report (January, 1992). This Draft Final Report was prepared after the completion of entire field studies.

1.2 Study Objectives

The objectives of the study is to carry out a feasibility study on flood mitigation and storm water drainage improvements for the identified priority areas of Greater Dhaka East, Narayanganj DND and Narayanganj West.

1.3 Study Area

The study area will cover the forecast urban areas (A = 194.04 km^2) of Greater Dhaka East, Narayanganj DND and West in the target year of 2010 (Fig. 1.1).

1.4 Methodology

In order to carry out the objectives, the study consists of the followings :

- Supplementary data collection, field surveys soil investigations, and ecological surveys,
- Detailed studies for flood mitigation and storm water drainage improvement measures,
- Preliminary designs of proposed facilities,
- Study for environmental impacts,

- Preparation of B/Q and cost estimate,
- Assessment of environmental and social impacts,
- Preparation of an optimum implementation program,
- Evaluation of economic efficiencies, and
- Assessment of the project.

The study has been carried out in collaboration with FPCO, the GOB study team and the other related FAP studies.

1.5 Report Layout

This report presents all results of the engineering studies conducted during the period from September 1991 to March 1992. The comments raised on the Interim Report (January 1991) are duly incorporated. The report consists of the followings :

(1) Summary Report
(2) Main Report
(3) Supporting Reports

A. Urban Planning and Land Use
B. Flood and Flood Damage
C. Living Environment and Ecology
D. Meteo - Hydrology
E. Flood Mitigation and Storm water Drainage Improvement Plan.
F. Preliminary Design of Proposed Facilities
G. Operation and Maintenance
H. Cost Estimate
I. Project Evaluation
J. Supplementary Survey and Water Level Gauge Installation
K. Scope of Work and Minutes of Meeting.

1.6 Acknowledgments

The study has been carried out by the study team which was composed of the consultants retained by JICA and local sub-consultants in close cooperation with FPCO and the GOB study team.

The panel of experts of GOB and the Advisory committee of JICA acted as advisors to the study. A list of participants is shown in Appendix 1.

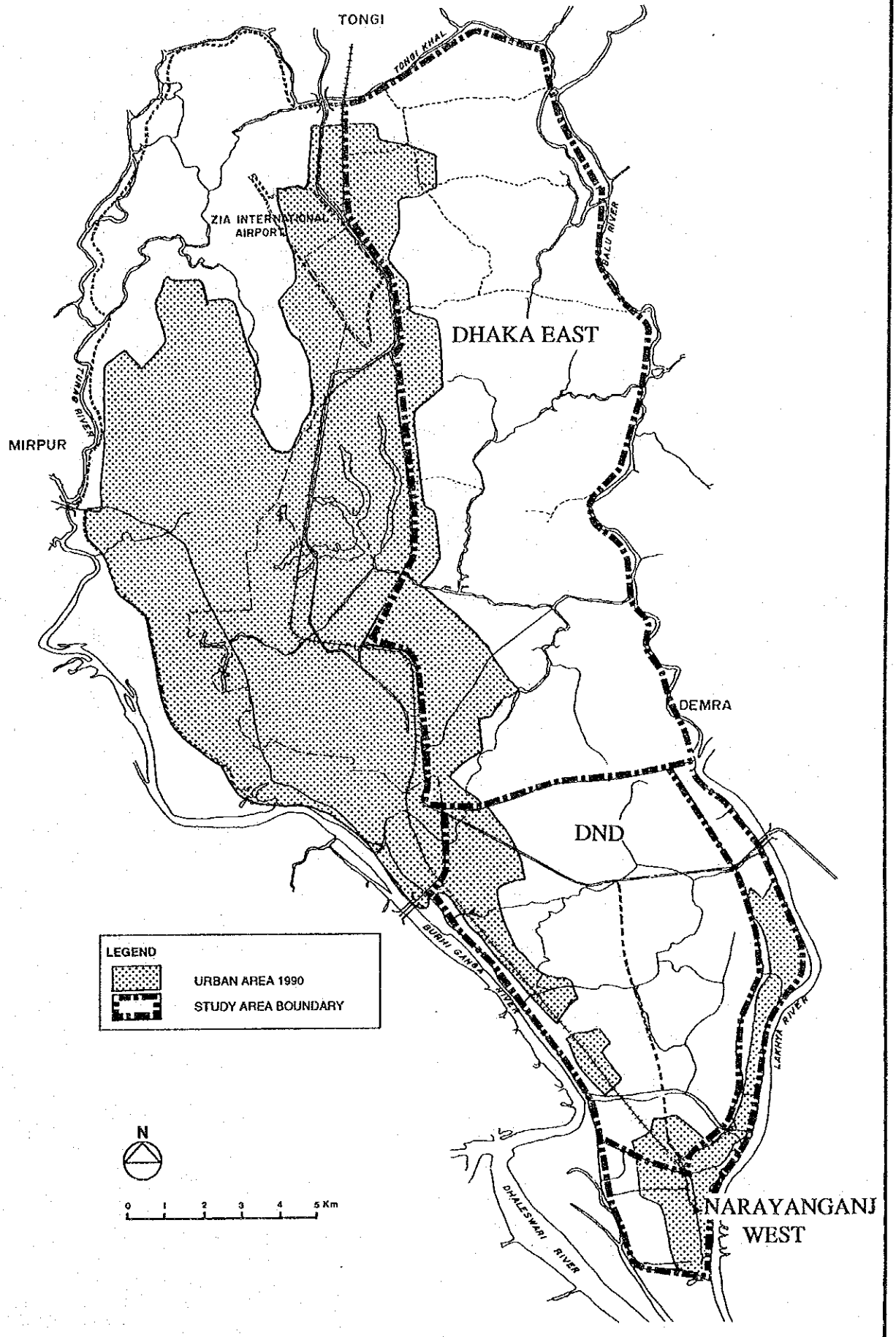

FIG. 1.1 LOCATION OF FEASIBILITY STUDY AREA

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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CHAPTER 2
STUDY AREA

Chapter 2 : Study Area

2.1 General

The feasibility study areas of Great Dhaka East, DND and Narayanganj West, constitute a continuous zone along the eastern side of the town area, though each area is at a different stage of urban development and has different characteristics.

The Greater Dhaka East (118.6 km^2) is by far the largest area but least developed among the feasibility study areas. This is mostly because, under current conditions, large parts of the central and southern areas are flooded for most of the year. Nevertheless, considerable peripheral development has taken place during the last decade.

The DND is the second largest area (56.8 km^2) bounded by road-cum-embankments and floodwalls. As the area was developed for irrigation, it is drained and generally flood free. Because of its proximity to the city and also being relatively flood free, the DND has developed quite rapidly during the last decade.

The Narayanganj West (18.6 km^2) is much smaller but much more intensively developed. The town is on relatively high land and developed independently from Dhaka. However, as Dhaka grew, the area between the two towns has become almost continuously built-up. The development of DND will see Narayanganj further becoming a part of Dhaka.

Due to the population and land use forecast by the Master Plan study, the population in 1990 and the target year of 2010 is estimated at 1.6 million and 4.4 million respectively. Accordingly the urban areas are likely to expand from 58 km^2 (30 % of the total area) in 1990 to 145 km^2 (75% of the total area) by 2010 (Table 2.1).

The existing built up areas are located mostly at the higher land above 5.0 m (GTS), however the forecast urban development areas, under current conditions, are still mostly flood prone and low-lying. The flood and storm water drainage problems would become severe constraints to future urban development. Optimum flood mitigation and storm water drainage improvement measures will be indispensable.

The climate of Dhaka area is classified as tropical monsoon type with three (3) annual seasons i.e. monsoon, post-monsoon and pre-monsoon. The monsoon is the rainy season, normally from May to October. In Dhaka area, 90% of the annual rainfall

(approx. 2000 mm) occurs during the monsoon. The post-monsoon is the dry season from November to December. The pre-monsoon is the transitional season between the rainy season and the dry season. A little rainfall occurs during the pre-monsoon. The climatic conditions are shown in Table 2.2.

In the beginning of the monsoon and the post-monsoon, cyclones with strong wind hit Bangladesh and sometimes cause a destructive storm surge on the eastern coastal area. But Dhaka is usually outside the affected area.

The master plan study area is surrounded by the Tongi Khal, the Balu River, the Lakhya River, the Dhaleswari River and the Buriganga River. The floods are caused by these rivers, which are affected by the big flood discharge through the Ganges and the Brahmaputra - Jamuna River on the high backwater stage of the Meghna River. There are two types of floods, external and internal floods, in the study area. External floods are caused by flooding of the surrounding rivers, while internal floods are caused by storm water flooding in the built-up area due to insufficient and poorly maintained drainage facilities.

Major floods of the study area were recorded in 1954, 1955, 1958, 1970, 1979, 1980, 1987 and 1988, since the water level observation was initiated at Mill Barak in Dhaka in 1945. In 1987 and 1988, the study area experienced severe floods. The 1987 flood was one of the medium size floods and assessed at a 10-year return period, while the 1988 flood was the largest one on record and assessed at a 70-year return period. During the 1988 floods, also a large part of the build-up area, which is usually flood free, was submerged.

2.2 Greater Dhaka East

2.2.1 Physical Features

The area covers approx. 118.6 km^2. It is bounded on the north by the Tongi Khal, to the east by the Balu River, to the south by the Demra Road, and to the west by the Rampura-Biswa Road and the Dhaka-Mymensingh Road (Fig. 2.1).

The area except 8.45 km^2 of the northern part is drained east to the Balu River through the Begunbari Khal, the Jamair Khal and the Boalia Khal.

There is a relative high land area above 5.0 m (GTS) along the western border, the portion being to the north in Uttara East and in the south from Khilgaon to Jatrabari. The higher land is usually flood-free. However the most other areas, under current conditions, are low-lying and under water for over half year, of which perhaps half is under 2.0 m (GTS) (Fig. 2.2).

2.2.2 Existing Land Use and Proposed Development

The built-up area is still 23 km^2 (19 %). The other remaining area is mostly low-lying and under water for over half year, but cultivated for the rest of the year. A considerable peripheral development has taken place during the last decade by means of land fill, especially in the southern part close to the city centre (Fig. 2.3).

The construction of the Rampura road has provided a platform for further peripheral development to the east. Fig. 2.4 shows the areas currently under development. In addition, there are other areas where RAJUK intends to implement its own development and where development is intended in accordance with a RAJUK zonal plan. There are also commitments for large scale planned private developments. Elsewhere, unapproved developments are known to be proceeding. A continuation of such peripheral growth may be expected even without the flood protection afforded by embankment. But as public perception regarding flood protection becomes established, an acceleration may be anticipated. Such development, and its associated landfill, may affect the drainage pattern and prejudice the flood protection plan.

During the next decade, in the absence of any public transport system to allow for northern expansion, non-availability of large service areas will persist. Under such conditions, Greater Dhaka East, though low-lying, is one of the major areas where urban growth will become dominant.

In order to minimize encroachment upon the low land, it is important then to delineate all areas needed for flood mitigation and drainage improvement measures and other major infrastructures at the earliest, so that such reservation may be safeguarded until construction take place.

In the feasibility study, the area is planned to be divided into four compartments. The countermeasures could be implemented in phases, compartment by compartment, with progressing urbanization. However an optimum overall development plan for the whole area will be indispensable.

2.2.3 Population

The 1981 census and the 1991 JICA study provide the basis for estimation of the existing and future population of this area.

The population for 1990 and 2010 are estimated at 638,000 and 2,201,000 respectively, assuming that the present rate of growth will continue for all areas. However there may be some discrepancy since a variety of factors such as the execution of flood protection embankment, delivery of urban land etc., will affect the projection both for the whole area as well the individual zones.

It is remarkable that among the four compartments, the southern compartment- 2 would have a big pressure of urban development and a large area will likely be developed during the coming decade.

The population distribution among compartments is summarized below :

	1990	2000	2010
Northern Compartment	126,000	282,000	772,000
Central Compartment	61,000	140,000	259,000
Southern Compartment - 1	24,000	52,000	212,000
Southern Compartment - 2	427,000	677,000	958,000
Total :	638,000	1,151,000	2,201,000

2.2.4 Infrastructure

The present service level of public utilities are still very low. The existing service networks are shown in Fig. 2.5. The present framework of services is restricted to the areas already developed. It shows that infrastructure provision may influence the pattern of growth. Thus unplanned growth may follow the existing roads. The current infrastructure distribution suggests that over the next decade incremental peripheral development will continue. Flood protection measures, which may create a new area of development, will also influence the pattern.

2.2.5 Navigation

There are numerous canals which serve both as drainage channels and as navigation routes. Both passenger and freight services by small and large boats are depending on the waterways throughout the year in the Dhaka East area, between the Balu River and the Rampura-Biswa road area. The absence of all weather land routes allows transportation only by boats through the Begunbari Khal and others, except a short couple of months in the dry season.

Bamboo, sugarcane, building materials, poultry are brought in from the distant east along with passengers. However the existing water transport system will likely loss its significance due to development of road networks gradually with progressing urbanization.

2.2.6 Outline of Flood Mitigation and Drainage Improvement Strategy

The northern and eastern boundaries of the area will be defined by the main flood embankment against a 100 - year frequency flood. The western boundary, on the existing new road, will be raised and flood proofed to form a permanent partition within the compartmentalizing strategy. Similarly, the southern boundary of the zone, the existing flood wall on the Demra Road, will be rehabilitated to form a partition in the compartmentalizing system.

Though three drainage zones were proposed in the Master Plan, four compartments are proposed in the feasibility study instead (Fig. 2.6).

Each compartment will have a drainage system consisting of trunk drains with retarding areas and a pump station., except 8.45 km2 of the Northern comp. which is a gravity drainage zone.

Sub-embankments between the Northern compartment, the central compartment and the Southern compartment are proposed along the existing roads and the other between the southern compartment-1 and 2 is proposed along the south side of the Begunbari Khal.

2.3 Narayanganj

2.3.1 DND

1) Physical Features

The area covers 56.8 km^2, which was developed as an agricultural development area in the mid 1960s (Fig. 2.7).

The area which is protected by the existing embankments, flood walls and drainage pumps (14.52 m^3/s), was marginally safe from the 1988 floods. and after the 1988 floods, the flood walls have been constructed. Most parts of the area is low-lying from 2.0 m to 5.0 m (Fig. 2.8). The entire DND area is crisscrossed by irrigation canals, the pump station pumps water in and out as per the irrigation and drainage requirement.

2) Existing Land Use and Proposed Development

Because of its proximity to the town areas and also being relatively flood-free, the area has been developed quite rapidly during the last decade, particularly in the north-west corner.

The built-up area is 21.7 km^2 (38%) and the agricultural area is 31.7 km^2 (56%). According to the forecast land use for 2010, the build-up area is to expand to 42.7 km^2 (75%) (Fig. 2.9).

Currently RAJUK is preparing a housing development program for the area and a part of it (Panchabati) is already in the land acquisition phase. RAJUK with RHD has started Dhaka-Narayanganj road. Further substantial development is anticipated over the next ten years (Fig. 2.10). The Metropolitan Development Plan to be commissioned in 1992 will make an in-depth study into this area vis-a-vis the rest of urban Dhaka. Their recommendation will directly influence the growth of the area along with safeguarding the flood protection plans.

3) Population

The population for 1990 and 2010 are estimated at 449,000 and 1,314,000 respectively.

The new development areas for the next decade of 1990-2000 are likely accurate and take into consideration the RAJUK's housing development program. However the figure for 2000-2010 is less accurate and could vary depending upon various factors.

4) Infrastructure

The new N-S spine road connecting middle of the Demra road and Narayanganj is now under construction. This road will stimulate the escalation of urban development in DND.

The present provision of services are clearly inadequate for any large scale development. Though electrical connections are quite developed and the proximity to the Siddirganj Power Station renders considerable potential, the water and gas services leaves a lot to desire. With the planned growth of the settlement areas these services, however, will develop rapidly as witnessed with similar trends in other areas of the city (Fig. 2.11)

5) Outline of Flood Mitigation and Drainage Improvement Strategy

Currently the DND area is protected by the existing raised flood wall along the existing road. The existing flood wall and embankment are proposed to be rehabilitated and leveled. The area is planned to be divided into two drainage zones and the existing pump house be used for the northern zone, where as a new pump facility need to be built for the southern zone. Retarding areas are also proposed for each drainage zone (Fig.2.12).

2.3.2 Narayanganj West

1) Physical Features

The area covers 18.6 km^2. It is the most urbanized area among the F/S areas. Narayanganj town area has been developed on the river terrace over 5.0m (GTS) and generally flood-free. A linear part of the Narayanganj West area extends all the way up to the Demra Road and is placed between the DND and the Lakhya river and is dominated by industrial and non-agricultural land use. Only small parts in the south west is low-lying below 3.0 m and remain unbuilt (Fig 2.8).

2) Existing Land Use and Proposed Development

Narayanganj is an important river port and also has an industrial area along the Lakhya River. The area is small but intensively developed.

However, as Dhaka grew, the area between the two towns has become almost continuously built-up. The development of DND area will bring Narayanganj further becoming a part of Dhaka. RAJUK's housing development plan of Panchabati overlaps into the Narayanganj West. The existing built up area is now 13.1 m^2 (70%) and the forecast built up area for 2010 is estimated at 17.2 km^2 (92%) (Figs 2.9 and 2.10).

3) Population

The total population in the Narayanganj West in 1990 is estimated at 470,000. This population is expected to increase to 696,000 by the year 2000. After the century the growth rate will decline from 4.0 % to 2.9% and the 2010 population is expected to be 927,000.

4) Infrastructure

The present service level of public utilities is reasonably high. Electricity, gas, and water lines follow all the existing road, leaving only the south west unserved. From the present level of development, it can be assumed that services will be extended further to urbanized area due to the demand increase (Fig. 2.11).

5) Outline of Flood Mitigation and Drainage Improvement Strategy

The town area is generally flood-free, however, the entire Narayanganj area is planned to be protected by embankment and flood wall against the floods of a 100-year return period. The narrow area along the Lakhya river is planned to be protected by floodwalls due to non-availability of land. The southern part is to be protected by embankments along the eastern rive bank, the southern river bank and the western side. About drainage improvement, the area is divided into five drainage zones. Four zones are drained by gravity and pump to the Lakhya River or the Dhaleswari River, and the other zone is drained by gravity to the Lakhya River (Fig. 2.12).

TABLE 2.1 SUMMARY TABLE OF LAND USE

YEAR 1990

F/S AREA	TOTAL AREA (ha)	DETAILED LAND USE(ha) Res'tial (ha)	Com'cial (ha)	Industry (ha)	Ins'tion (ha)	Agri'ture (ha)	Water (ha)	BUILT-UP AREA (ha)	POP'TION YR 1990 (person)
DHAKA EAST	11,862	2,249	40	1	23	8,814	735	2,313	637,500
		19%	0%	0%	0%	74%	6%	19%	
DND	5,679	1,864	56	196	59	3,173	332	2,174	448,590
		33%	1%	3%	1%	56%	6%	38%	
N'GANJ WEST	1,863	981	86	178	67	464	87	1,312	470,449
		53%	5%	10%	4%	25%	70%		
TOAL	19,404	5,094	182	375	149	12,451	1,154	5,799	1,556,539
		26%	1%	2%	1%	64%	6%	30%	

YEAR 2010

F/S AREA	TOTAL AREA (ha)	DETAILED LAND USE(ha) Res'tial (ha)	Com'cial (ha)	Industry (ha)	Ins'tion (ha)	Agri'ture (ha)	Water (ha)	BUILT-UP AREA (ha)	POP'TION YR 2010 (person)
DHAKA EAST	11,862	5,917	436	39	2,158	1,310	2,002	8,550	2,201,935
		50%	4%	0%	18%	11%	17%	72%	
DND	5,679	2,463	172	482	1,153	532	877	4,270	1,313,749
		43%	3%	8%	20%	9%	15%	75%	
N'GANJ WEST	1,863	827	173	292	427	8	135	1,720	926,820
		44%	9%	16%	23%	0%	7%	92%	
TOAL	19,404	9,207	782	813	3,739	1,850	3,014	14,540	4,442,504
		47%	4%	4%	19%	10%	16%	75%	

Note : The areas of water bodies are on the different basis for the Year 1990 and 2010. The water area in 1990 is based on the land use survey map which shows the land use pattern in dry season (which means minimum), while the area in 2010 is based on the proposed scheme of retarding ponds and major drainage channels (which means maximum including the right of way and reserved area).

TABLE 2.2 CLIMATE CONDITION IN THE STUDY AREA

MONTH	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	oct	Nov	Dec
Temperature, °c												
High (Extreme)	34.2	36.6	40.6	42.3	40.6	38.4	35.2	35.9	35.3	38.8	33.3	31.2
Low (Extreme)	5.6	4.5	10.4	15.6	18.4	20.4	21.7	21.0	22.0	10.4	10.6	6.7
Avg.	18.8	21.5	26.1	28.7	28.9	28.7	28.7	28.7	28.7	27.4	23.6	19.8
Relative Humidity, Percent	70	66	63	71	79	86	87	86	86	81	75	74
Evaporation, millimeters	104	79	81	77	78	83	87	130	118	106	75	105
Days of Rain, per month	1	2	4	8	14	19	22	22	16	9	2	1
Average Rainfall, millimeters	6.5	20.2	52.3	124.0	283.0	398.2	391.4	328.0	264.0	160.0	25.3	7.4
Wind Velocities, Knots (Knot=1,852 km/hr)	2	2	3	5	5	4	4	4	3	2	1	1

Data : 1) Bangladesh Meteorological Department (1953-1985)

2) Evaporation , H.R. Laboratory (Dhaka) No. E-10 (1978-1979)

Source : JICA; Study on Storm Water Drainage System Improvement Project in Dhaka City, 1987

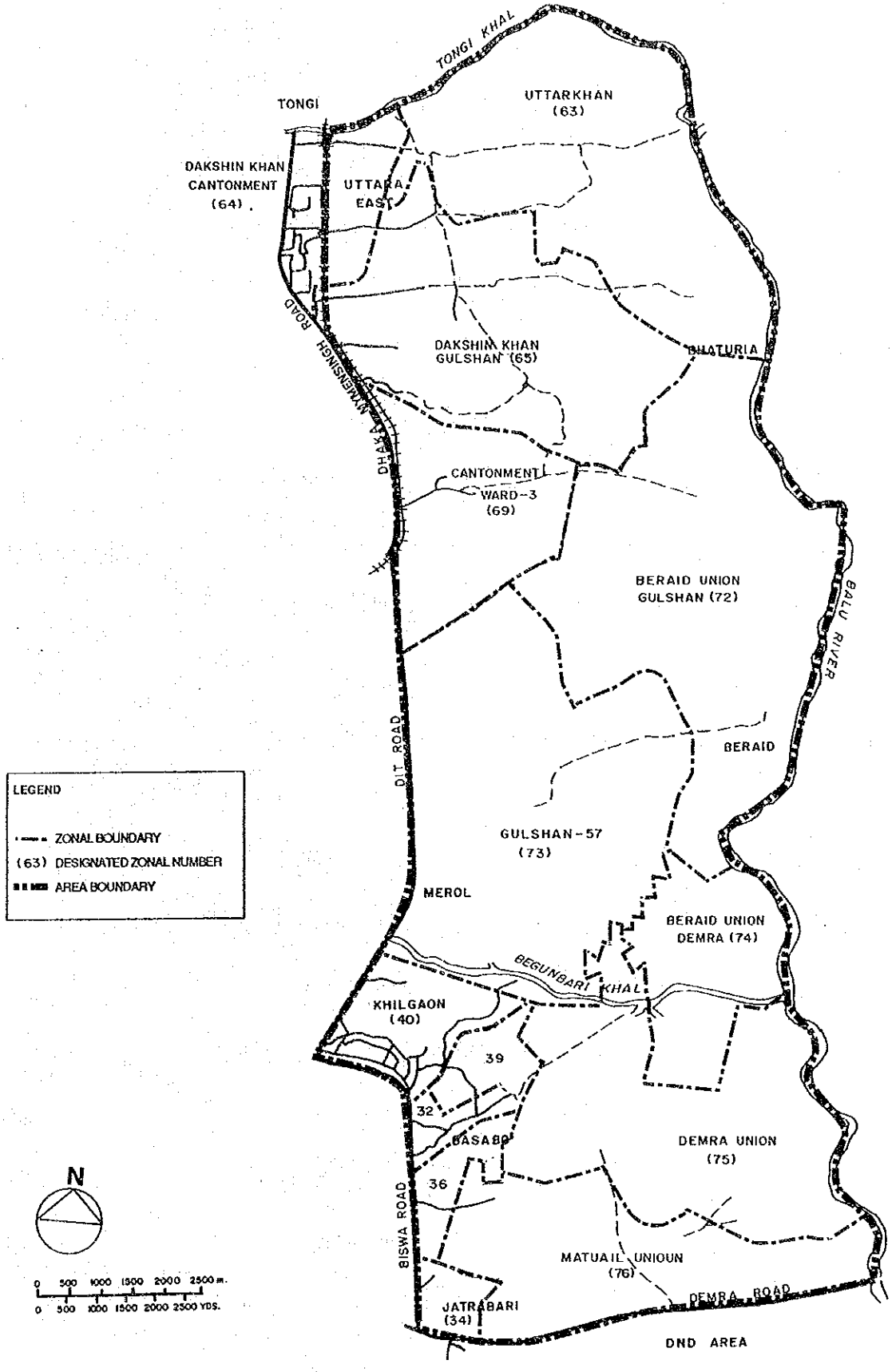

FIG. 2.1 BASE MAP : GREATER DHAKA EAST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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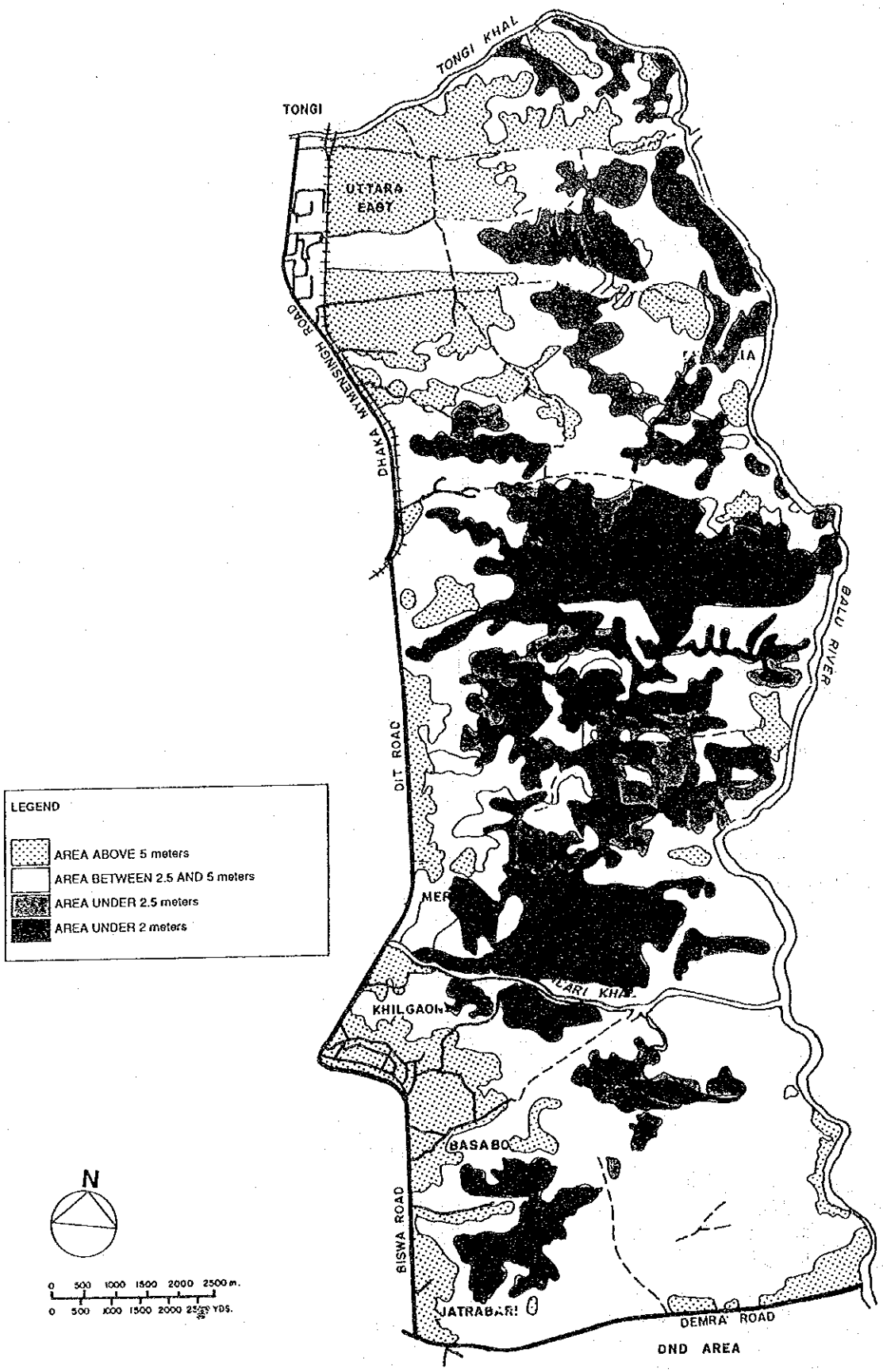

FIG. 2.2 EXISTING LAND HEIGHT : GREATER DHAKA EAST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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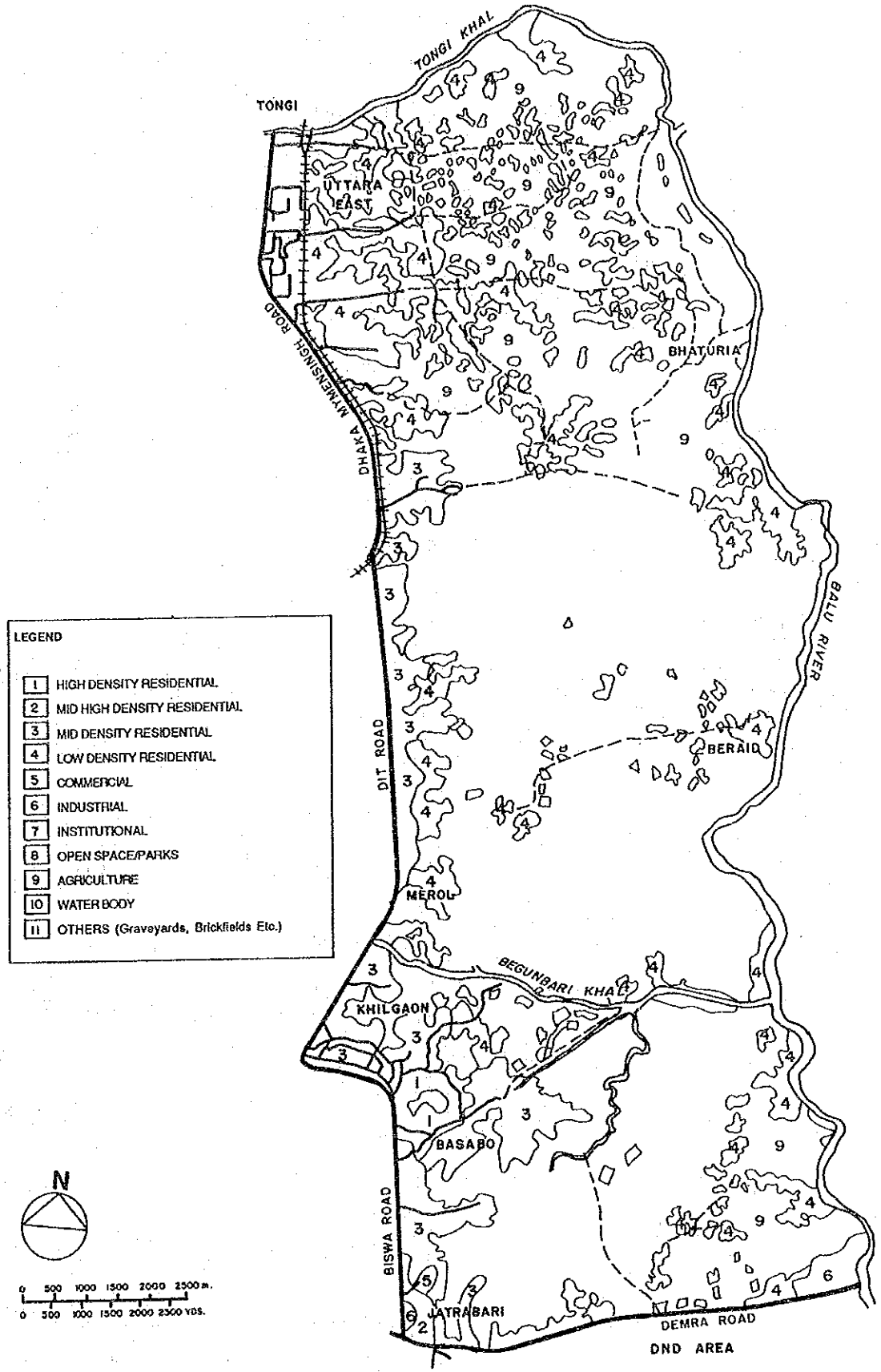

FIG. 2.3 EXISTING LAND USE : GREATER DHAKA EAST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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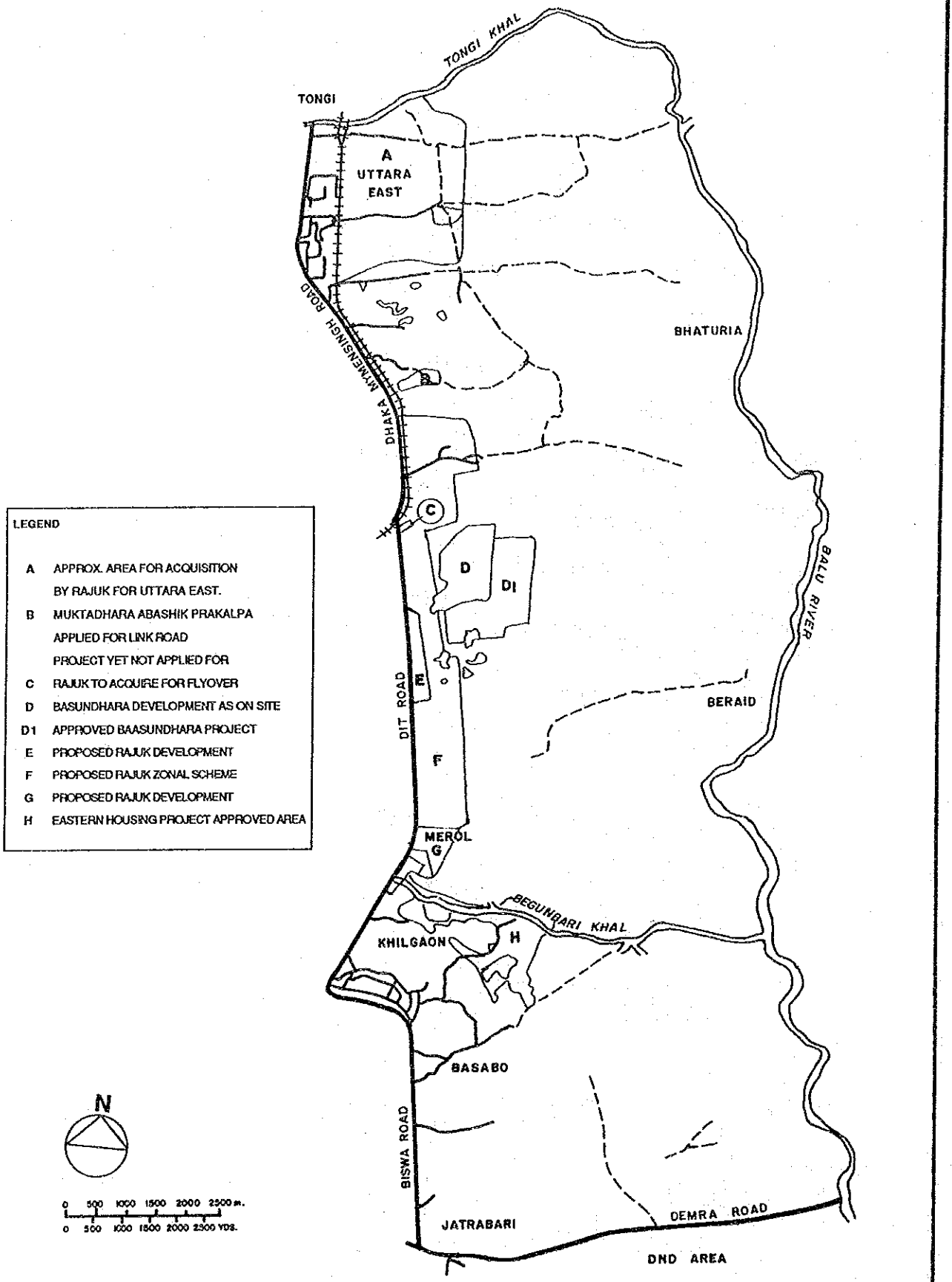

FIG. 2.4 DEVELOPMENT COMMITMENTS : GREATER DHAKA EAST

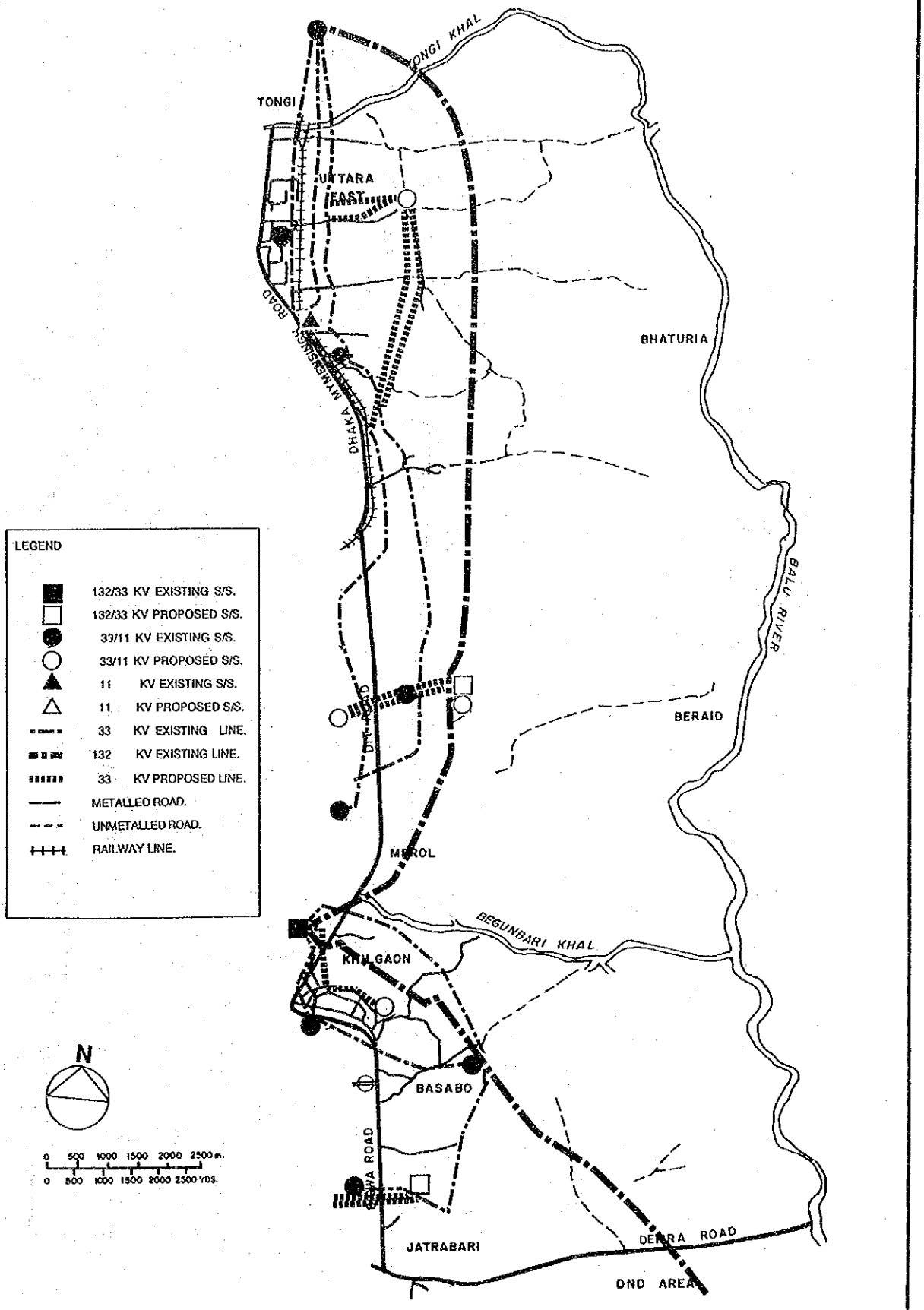

FIG. 2.5 INFRASTRUCTURE : GREATER DHAKA EAST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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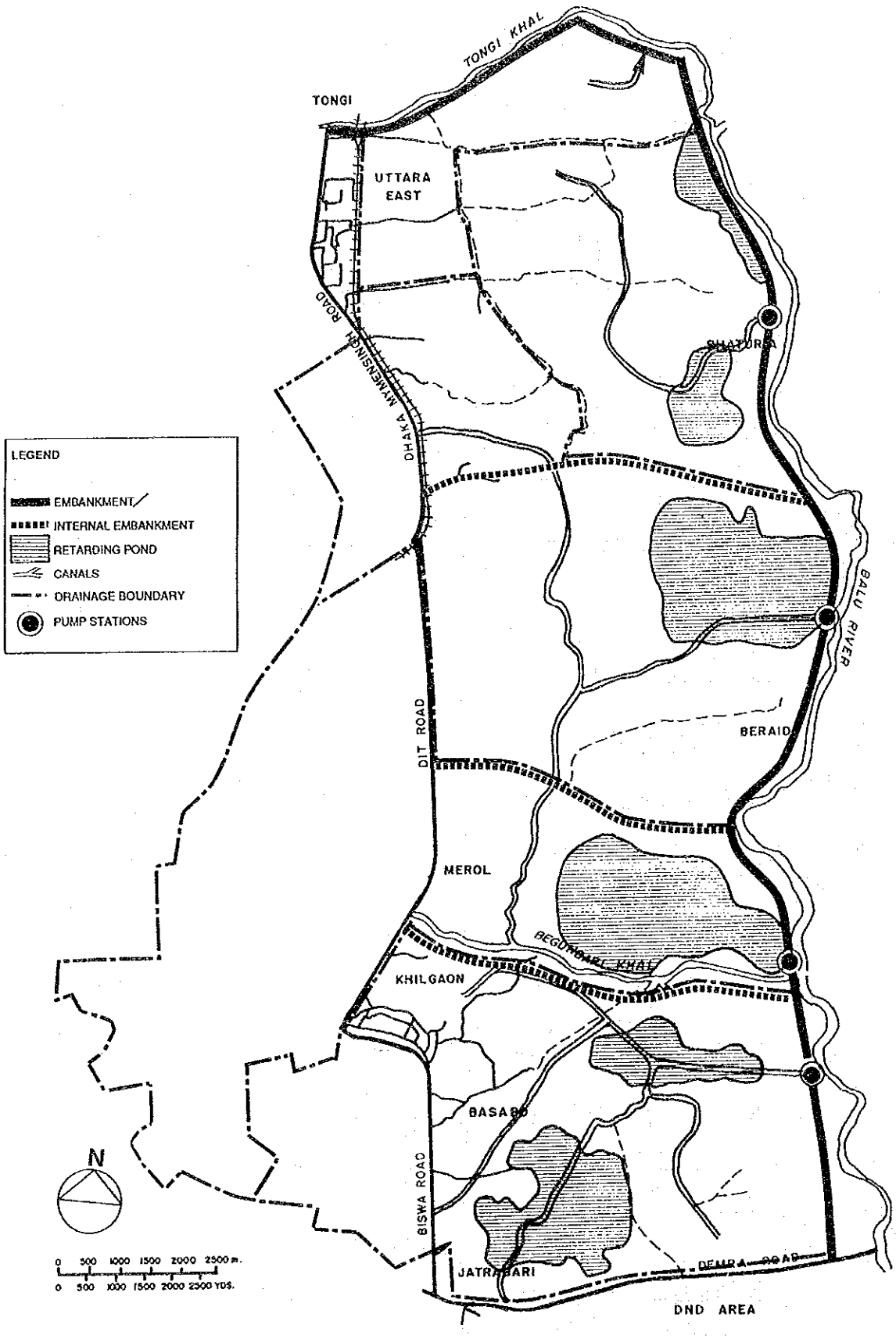

FIG. 2.6 FLOOD PROTECTION PROPOSAL : GREATER DHAKA EAST

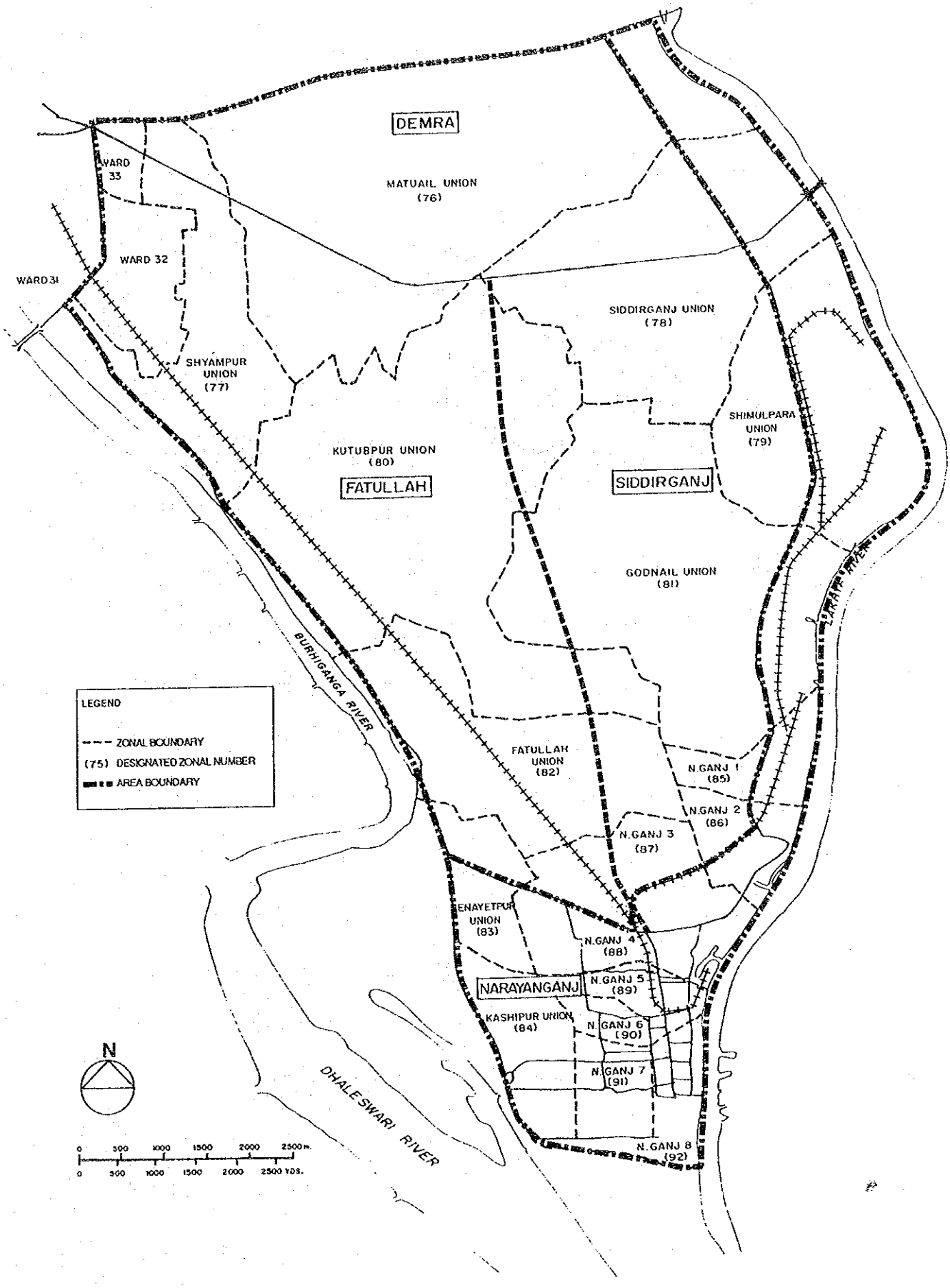

FIG. 2.7 BASE MAP : DND/NARAYANGANJ WEST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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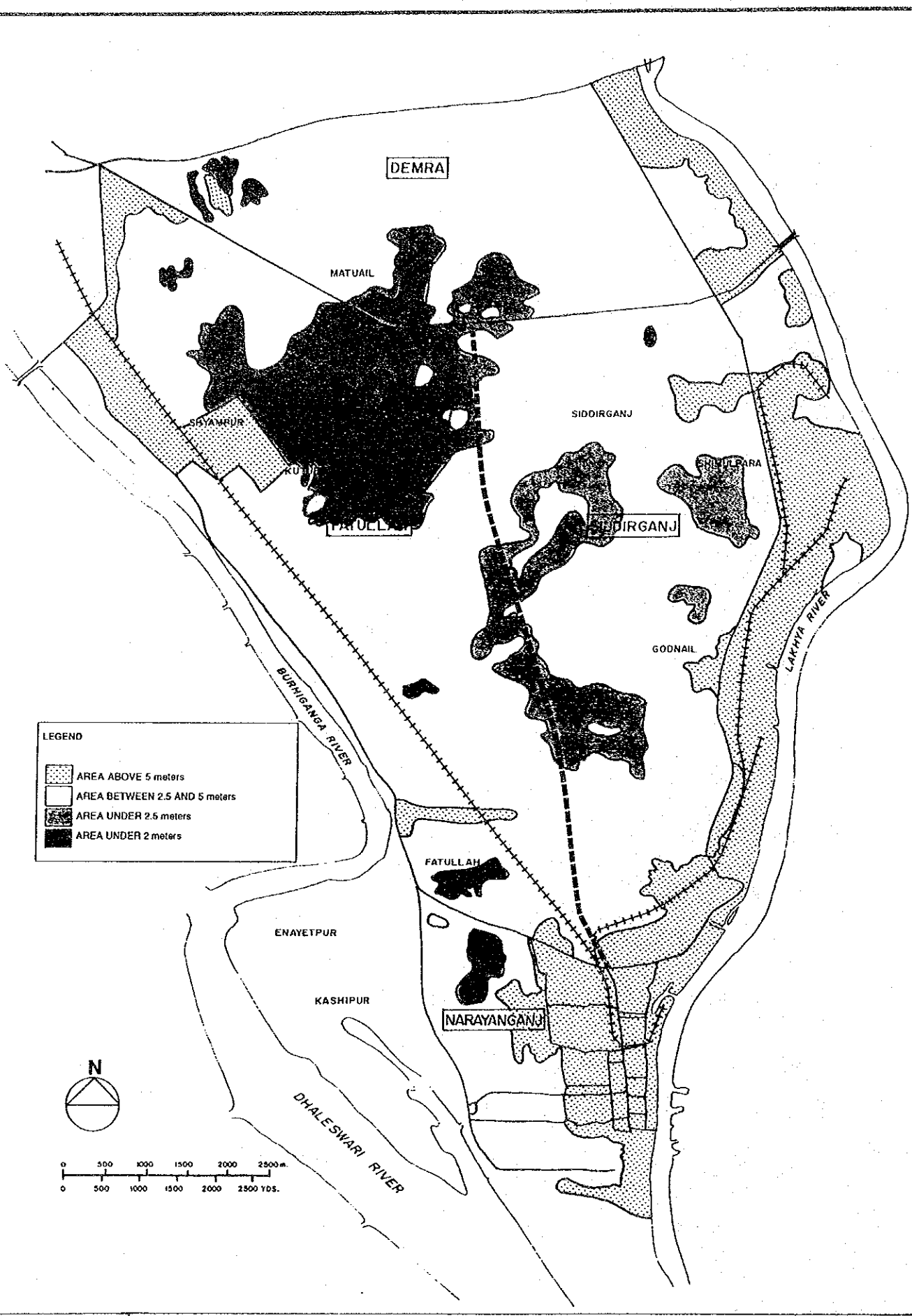

FIG 2.8 EXISTING LAND HEIGHT : DND/NARAYANGANJ WEST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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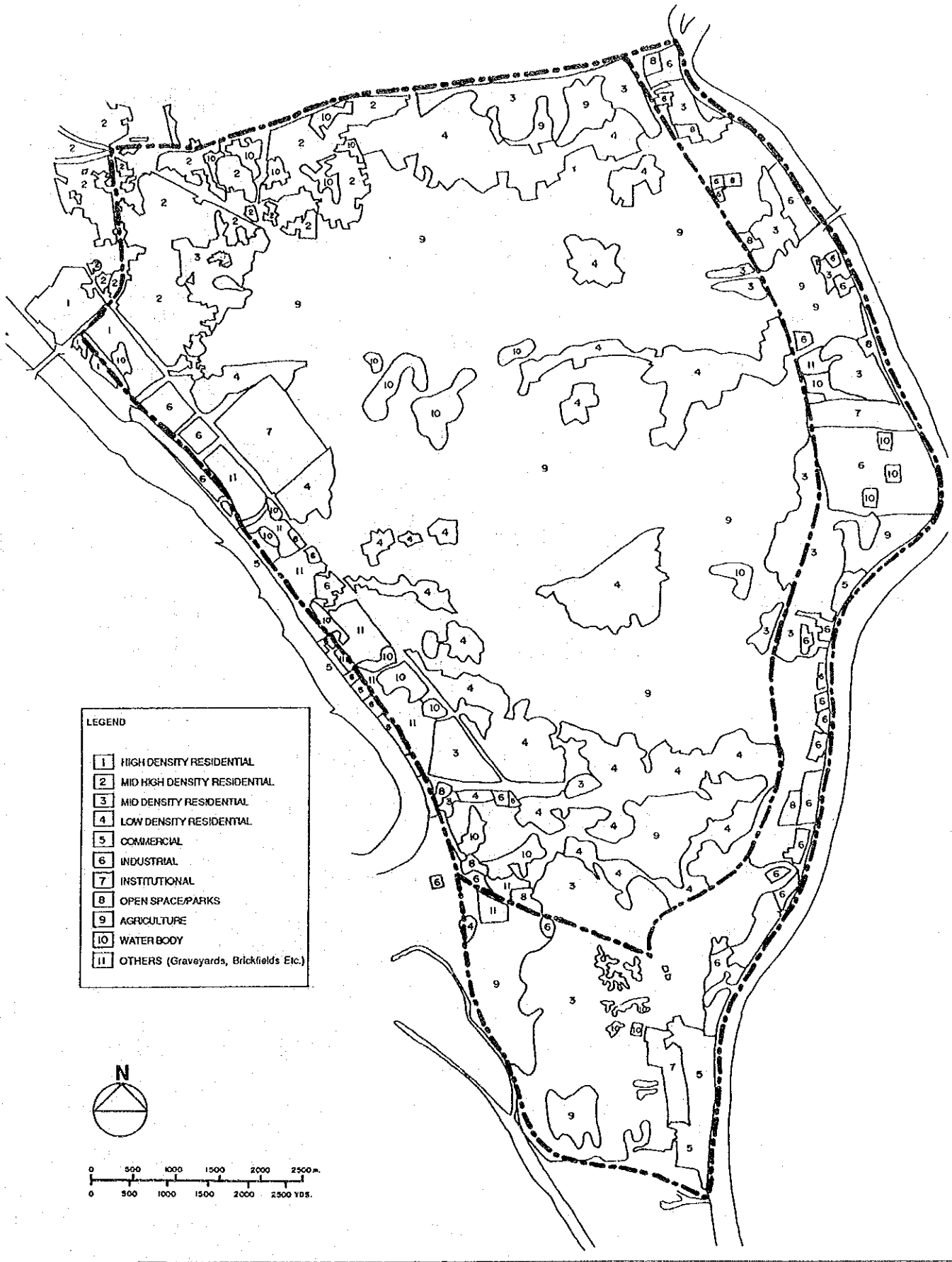

FIG. 2.9 EXISTING LAND USE : DND/NARAYANGANJ WEST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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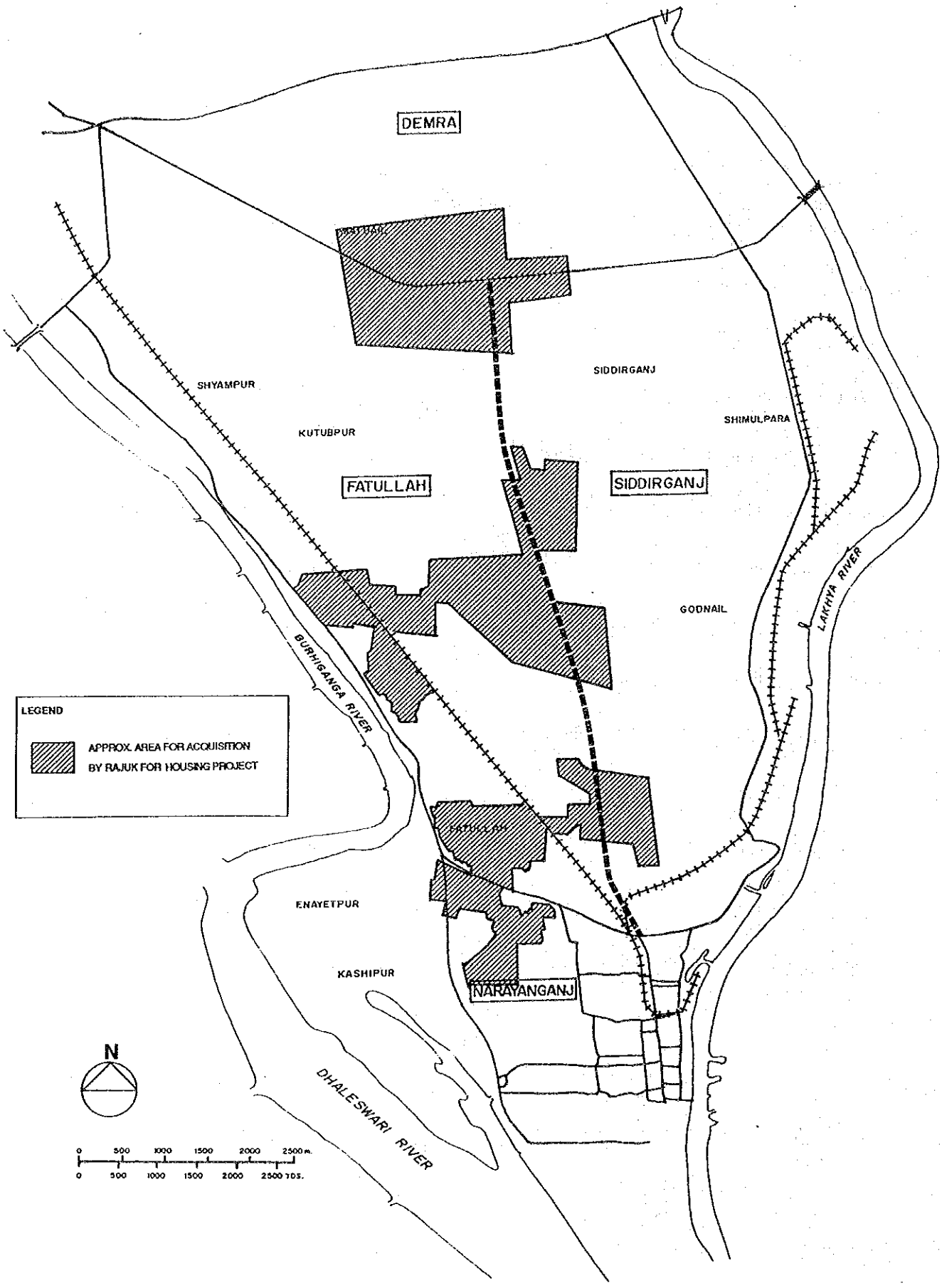

FIG. 2.10 DEVELOPMENT COMMITMENTS : DND/NARAYANGANJ WEST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

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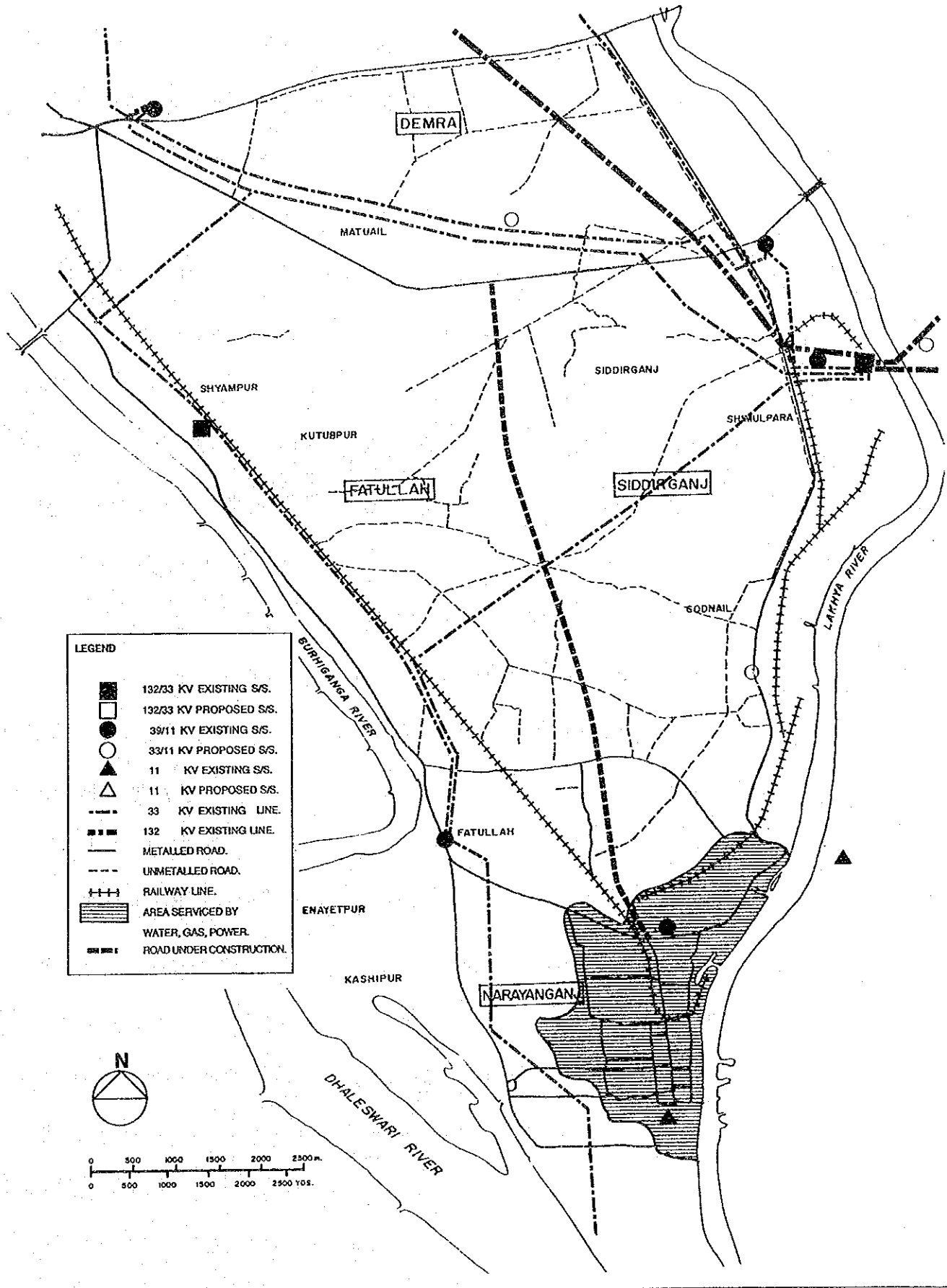

FIG. 2.11 INFRASTRUCTURE : DND/NARAYANGANJ WEST

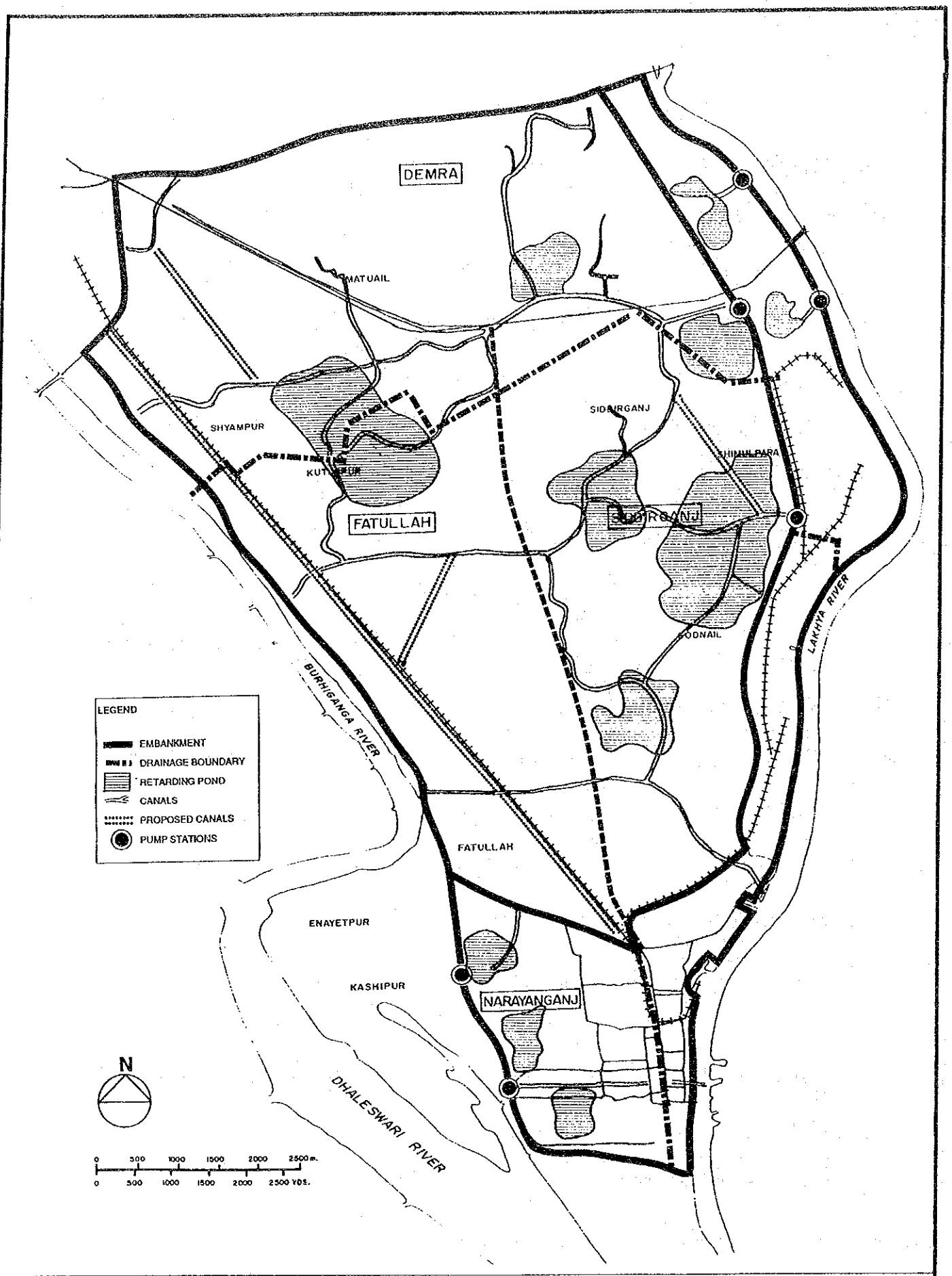

FIG. 2.12 FLOOD PROTECTION PROPOSAL : DND/NARAYANGANJ WEST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROLOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

CHAPTER 3
HYDROLOGY

Chapter 3 : Hydrology

3.1 General

Hydraulic Simulation Models for drainage areas are studied in order to check the effects of proposed retarding ponds and pump stations.

3.2 River and Khal System

3.2.1 River System

The study area is strongly affected by the three international rivers of the Ganges the Brahmaputra-Jamuna River and the Meghna River.

The study area is surrounded by tributaries and distributaries of the Ganges and the Brahmaputra - Jamuna River. The river system is shown in Fig. 3.1.

The feasibility study area is surrounded by the Tongi Khal in the north, the Balu River and the Lakhya River in the east, the Dhaleswari River in the south and the Buriganga River in the west.

The floods are caused by these rivers, which are affected by the big flood discharge through the Ganges and the Brahmaputra-Jamuna River on the high backwater stage of the Meghna River.

3.2.2 Khal System

There are three big khal networks in the study area. They are the Begunbari khal, the Jamair khal and the Boalia Khal in Greater Dhaka East, and a braided khal system in Narayanganj DND. They are shown in Figs 3.2 (1) and (2).

3.3 Features of Storm Rainfall and Flood Water Level

3.3.1 Hydrological Observation Network and Available Data

The hydrological observation network in and around the study area is shown in Fig. 3.1. There are nine (9) active and two (2) closed rainfall gauging stations and fourteen (14) active water level gauging stations.

The period of gauging and available data at each gauging station is shown in Table 3.1. There were only two automatic rain gauges in the study area, but they have not been used since 1984. The others are all measured manually once a day at 9:00 A.M.

There is only one automatic gauging station at Mill Barak. The others are measured manually five times daily at 6:00, 9:00, 12:00, 15:00, 18:00.

Period of gauging and available data at each station is shown in Table 3.2.

There is some inconsistency with the water level data of Narayanganj (St. 180) during the transition period from BWDB to BIWTA, though the annual maximum water level data are the same. Hence, the data of this station is somewhat less reliable in comparison to others.

3.3.2 Features of Storm Rainfall

In the master plan, possible storm rainfall values were calculated. The pump drainage plans including retarding ponds were formulated by using two (2) days consecutive rainfall with a 5-year return period as the typical design hyetograph.

Furthermore, rainfall intensity and duration curves were formulated for various return periods. The drainage channels and culverts were planned by using the curve with a 5-year return period.

Areal reduction curves for converting point rainfall to basin main rainfall were made.

1) Probable Storm Rainfall

Probable storm rainfalls were calculated by Gamble-Chow's method by using the maximum one day, two days, five days and one month rainfall data shown in Tables 3.3 to 3.6 during the Master Plan Study stage.

The correlation among rainfall stations of Dhaka (B.M.D), Joydebpur (BWDB St. 17), Savar (BWDB St. 31) and Narayanganj (B.M.D), which have a long duration of observed data and are considered representative stations of the study area, were studied for two days consecutive rainfalls which are the most dominant rainfalls for causing internal floods of Dhaka area as described in the 1987 JICA study.

However no correlation could be found among them. It shows that using point rainfall data for a specific area seems more reasonable than using basin mean rainfall data.

The frequency analysis was carried out and the results are shown in Table 3.7, which shows that probable rainfalls at the four stations are almost same for one day and two days rainfall of a 2-year and a 5-year return periods. Then the probable rainfall values at Dhaka (B.M.D) for one day and two days rainfall of a 2-year and a 5-year return periods, are also applicable to Savar, Tongi and Narayanganj.

The difference in probable rainfall values at Dhaka (B.M.D) between the 1987 JICA study and this study is shown in the following table :

PROBABLE RAINFALL AT DHAKA (B.M.D)

(Unit : mm)

Duration	Return Period	This Study	1987 JICA Study
1 day	2 Year	137	135
	5 Year	184	192
2 day	2 Year	184	183
	5 Year	239	245

As shown above, probable rainfalls are almost same between the two studies.

Hence, the above values of the 1987 JICA Study are also applicable. Furthermore, the 1987 JICA Study's values of a 5-year return period are more safer than those of this study.

The design hyetograph for planning pump drainage facilities was determined to use the design rainfall of two days consecutive rainfall with a 5-year return period and shown in Fig. 3.3.

In order to get an appropriate rainfall runoff, various kind of calculation models including rational method, storage function method, NAM model etc. are available.

The Rational Method has been used by the study, because this is the most convenient and simplest method among the above rainfall runoff methods, and has been used in the storm water drainage improvement studies not only for Dhaka, but also for many major cities in Asia.

2) Rainfall Intensity and Duration

The rainfall intensity and duration curves up to 120 minutes were made for the storm rainfall with short duration in the 1987 JICA study. However, in the master plan, the curves were modified and extended up to 24 hours (Fig. 3.4).

Drainage channels and culverts were designed by using the above rainfall intensity curve with a 5-year return period. The curve is expressed as follows :

$$i = 9005 / (t + 50) \qquad \text{for } t \leq 2.0 \text{ hr}$$

$$i = 12{,}437 / (t + 115) \qquad \text{for } 2.0 \text{ hr} \leq t \leq 24.0 \text{ hr}$$

where,

i : rainfall intensity (mm / hr)

t : duration (minutes).

3) Areal Reduction of Point Rainfall

In order to convert the design point rainfall at Dhaka (B.M.D) to a design basin mean rainfall of each sub-catchment in the drainage area, areal reduction curves were made in the master plan stage (see Fig. 3.5). These curves are also applied in this study.

3.3.3 Features of Flood Water Level

1) Historical Floods

Major floods recorded in the Dhaka Metropolitan area occurred in 1954, 1955, 1958 1970, 1974, 1980, 1984, 1987 and 1988.

The maximum water levels at Mill Barak (St.42) and Demra (St.7.5) and Savar (St. 69) during the major floods are listed as follows :

ANNUAL MAXIMUM DAILY WATER LEVEL

Flood Year	Demra (St. 7.5)	Mill Barak (St. 42)	Savar (St.69)
1954	---	7.02	8.17
1955	---	7.05	8.26
1958	---	6.41	----
1970	6.24	6.47	7.99
1974	6.58	6.57	7.80
1980	6.23	6.39	----
1984	6.33	6.00	7.58
1987	6.46	6.60	8.30
1988	7.10	7.54	9.68

Note :

1) The above water levels of Mill Barak (St.42) and Demra (St.7.5) are revised based on the results of check survey conducted by the 1987 JICA study

2) 1988 Floods

The 1988 floods were the biggest recorded one. It was caused not just only by the abnormally heavy and intensive rainfall in the upper catchment areas of the Ganges and the Brahmaputra-Jamuna River from the end of August to the beginning of September, but also by the high backwater stage of the Meghna River which coincided with the floods.

The monthly rainfall amount during August and September, 1988 in and around Dhaka area was only 2/3 of annual average (Fig. 3.6).

Figs. 3.7 and 3.8 show the daily rainfall and the maximum water level during August and September, 1988.

The 1988 floods are likely characterized as follows :

(a) The contribution of the rainfall in Dhaka area to the floods was not much.

(b) The sharp hydrographs in the north western part and the gentle ones in the east and south parts confirm the fact that the 1988 floods came mainly from the direction of the Brahmaputra-Jamuna River.

3) Probable Flood Water Level

The available annual maximum water levels are shown in Table 3.8.

Probable flood water levels in and around the study area are revised based on the supplementary water level data from Narayanganj (BWDB St. 180).

In order to estimate water levels of long return periods like 50 years and 100 years, it is necessary to analyze data of long duration including the 1988 floods.

The following gauging stations were selected for the analysis :

1)	Mill Barak (St. 42)	:	37 years data
2)	Savar (St. 69)	:	33 years data
3)	Demra (st. 7.5)	:	35 years data by combining Demra (St. 7.5) and Demra (St. 179) using their correlation.
4)	Narayanganj (St. 180)	:	35 years data

Correlation between the water level data of Mill Barak (St. 42)/ Savar (st. 67)/ Demra (st. 7.5) and other data are checked. They are shown in Figs. 3.9 (1) to (3) and also listed as follows :

CORRELATION OF WATER LEVEL GAUGING STATIONS

Station (X) Station (Y)	Mill Barak (St. 42)	Savar (St. 69)	Demra (St.7.5)
Mirpur (St. 302)	Y = 1.15 x +0.344	-----	----
Tongi (St. 299)	Y = 1.04 x +0.267	-----	----
Hariharpara (St. 43)	Y = 0.848 x +0.543	-----	----
Nayarhat (st. 14.5)	---	Y = 1.105 x -0.432	----
Kalatia (St. 70)	---	Y = 0.867 x +0.367	----
Demra (St. 179)	----		Y = 0.943 x +0.267
Narayanganj (St. 180)	----		Y = 0.848 x +0.561
Pubali (St. 7)	----		Y = 1.066 x -0.130
Rekabi Bazar (St. 71A)	----		Y = 0.834 x +0.549
Kalagachia (St. 71)	----		Y = 0.752 x +0.896

For Mill Barak (St. 42), Savar (St. 69) and Demra (St. 7.5), frequency analysis is conducted by Gumble - Chow's method.
The other probable water levels are calculated by using the correlation above. They are shown in Table 3.9.

The return periods of the 1987 floods and the 1988 floods are estimated as follows :

RETURN PERIOD OF THE 1987 FLOODS AND THE 1988 FLOODS

Station	1987 Floods	1988 Floods
Demra (St. 7.5)	8-Year	50-Year
Mill Barak (St. 42)	10-Year	70-Year
Savar (St. 69)	15-Year	200-Year

3.4 Hydraulic Simulation for Drainage Area

3.4.1 Objective of Hydraulic Simulation

The objective is to check the effects of proposed storm water drainage improvement facilities such as drainage channels, retarding ponds and pump stations by one dimensional unsteady flow model using Mike 11 software.

Case 1-2 : Without retarding ponds and without pump stations under gravity flow condition.
Case 1-2 : Without retarding ponds and without pump stations under gravity flow condition.
Case 2-1 : Without retarding ponds and without pump stations under pump operating condition.
Case 2-2 : Without retarding ponds and without pump stations under pump operating condition.

2) Boundary Conditions :

(1) Rainfall run-off of sub-catchments

Rainfall run-off of sub-catchments are calculated by the Rational formula using the design hyetograph.

(2) Water Level of the Lakhya River

Low water levels of the Lakhya River and the Balu River are 3.0 m (PWD) for gravity flow condition and high water levels for pump operating condition are 5.65~5.75 m (PWD) for the Lakhya River and 6,00~6.50 m (PWD) for the Balu River.

3.4.2 Hydraulic Simulation of Greater Dhaka East

1) Drainage Networks

In the Master Plan, the proposed drainage improvement facilities of drainage channels, pump stations and retarding areas were planned by using the following methods :

(1) Drainage Channel :

- Drainage channels is designed by using the design discharge given by rainfall runoff calculation.
- Rainfall runoff calculation is conducted by the Rational formula using the rainfall intensity curve of a 5-year return period.
- Channel size is determined mainly by conducting uniform flow calculation.

(2) Pump Station :

- Pump capacity is determined by mass curve analysis so as to discharge out the total runoff amount of 2 days consecutive rainfall with a 5-year return period within 2 days.

(3) Retarding Area :

- Retarding pond capacity is determined by mass curve analysis so as to pond the maximum difference between the accumulated amount of rainfall runoff and that of pump discharge during 2 days.

Due to the flat topography and a rather complex network of the drainage system, it is necessary to check the validity of the above design by unsteady flow calculation. Especially the retarding effect can be checked by the hydraulic simulation.

2) Basic Conditions

(1) Cases of Simulation

Cases of simulation for the area are following four cases :

There are three big khals in the Greater Dhaka East. They are the Boalia Khal, the Jamair Khal and the Begunbari Khal. The khal systems of the Jamair Khal and the Begunbari Khal are rather complicated, then the designs of drainage channels, pump stations and retarding areas are checked by one-dimensional flow model of Mike 11 for these khals.

The drainage zones of these khals are determined as follows:

Jamair Khal	:	Sub-drainage zone DC-2
Begunbari Khal	:	Sub-drainage zone DC-3
		Sub-drainage zone DC-4

The drainage networks for hydraulic simulation are shown in Figs.3.10(1) to (3).

(2) Boundary Conditions

Rainfall run-off of the sub-catchments area calculated by the rational formula using the design hyetograph and input in to the network as boundary discharge or lateral inflow.

Water level of the Balu River is LWL for gravity flow condition and HWL for pump operating condition.

	LWL(m)	HWL(m)	Pump capacity(m3/s)
DC - 2	3.00	6.15	54.6
DC - 3	3.00	6.05	53.1
DC - 4	3.00	6.00	47.2

3) Result of Simulation

The results of simulation show that the peak water levels without retarding ponds are higher than the design banks, but with retarding ponds lower than the design banks with a little larger allowance in the channels downstream of the retarding ponds (Fig.3.11).

The simple design method applied for this study can be said appropriate but somewhat conservative.