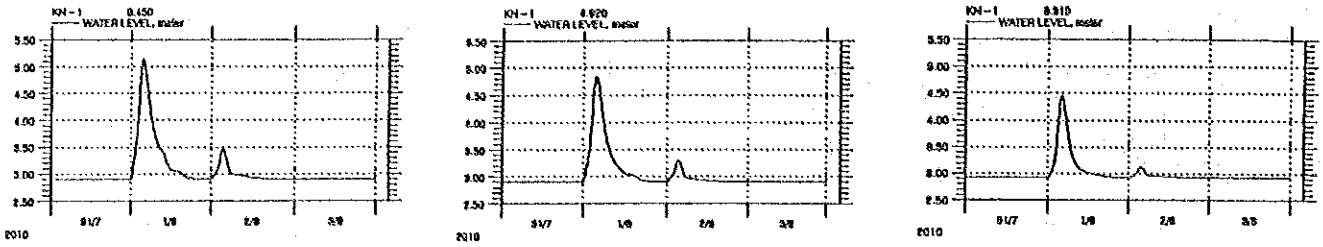
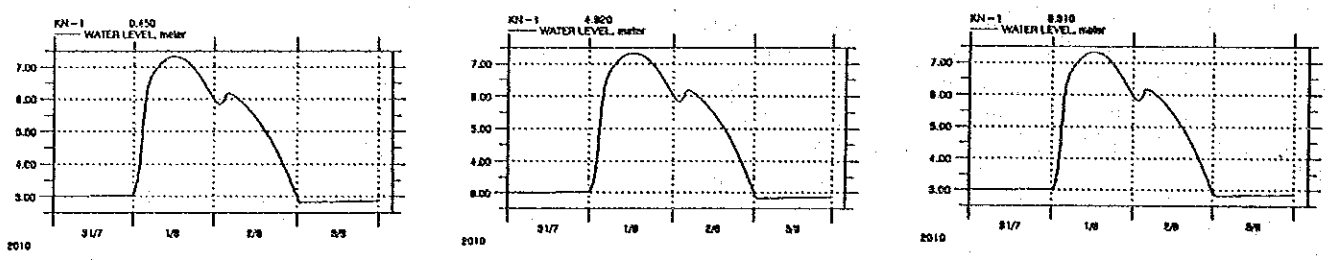
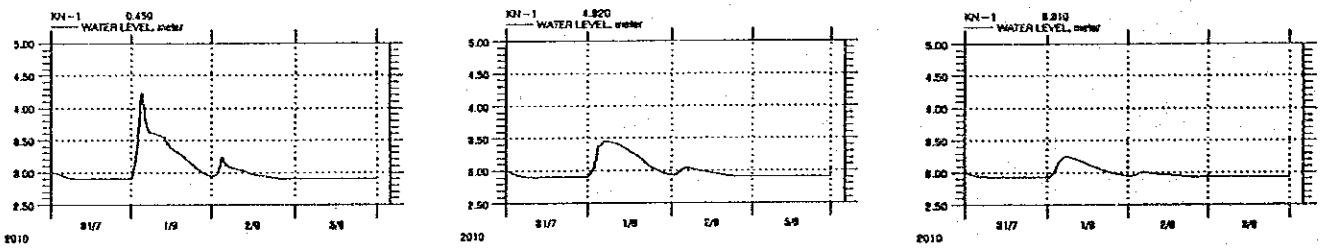
Case 1-1 : Without retarding pond and without pump station



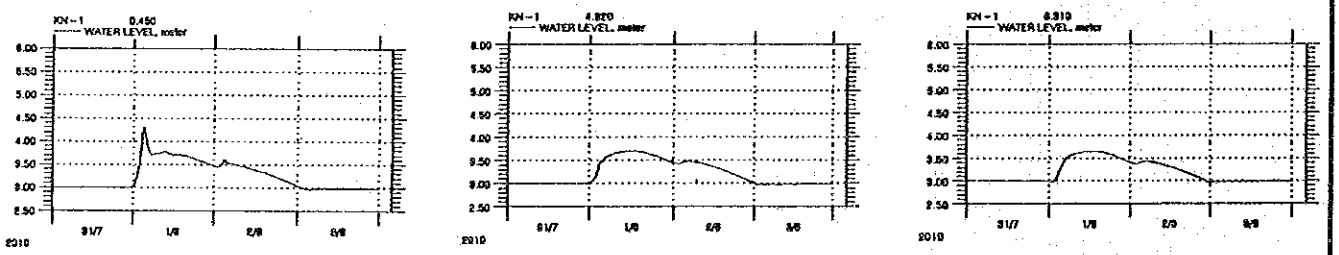
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



Case 2-2 : With retarding pond and with pump station

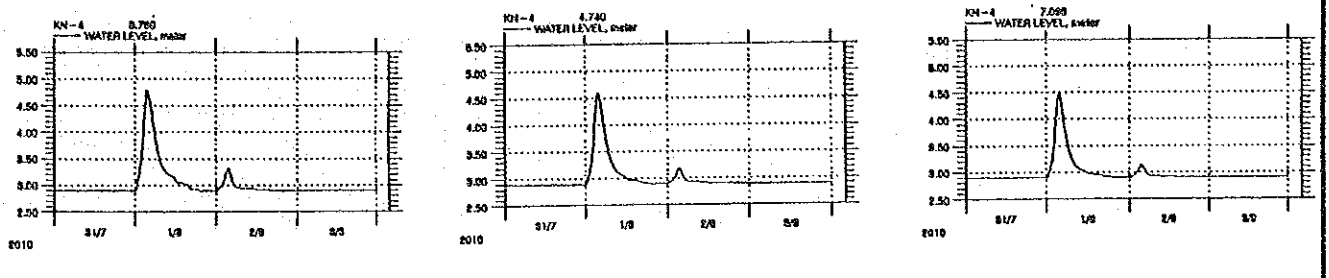


LEGEND :

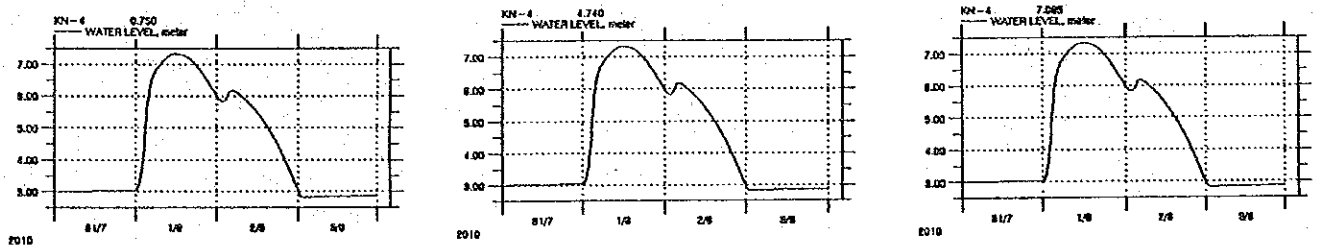
Channel Name	Chainage(km)
KN-1	4.920

FIG. D.15(1) SIMULATED WATER LEVEL HYDROGRAPH OF NARAYANGANJ DND(1)

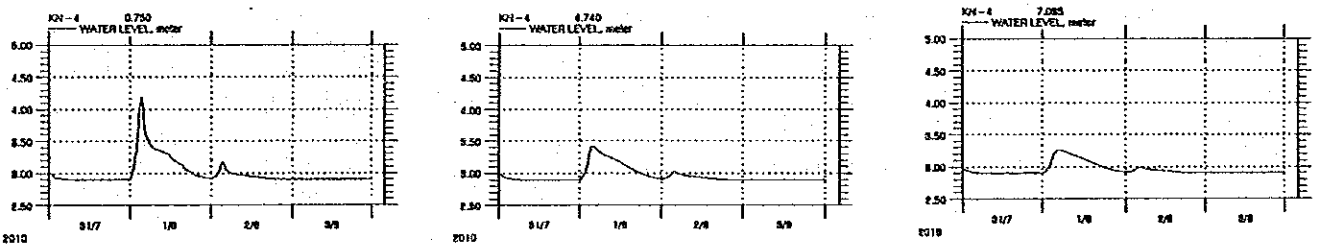
Case 1-1 : Without retarding pond and without pump station



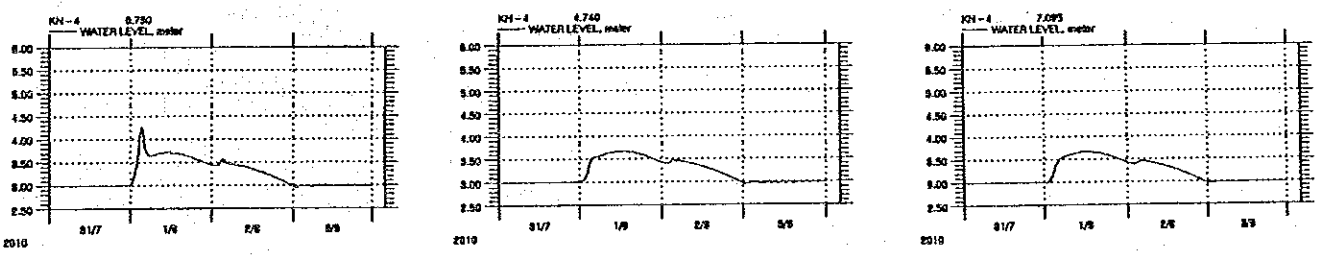
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



Case 2-2 : With retarding pond and with pump station



LEGEND :

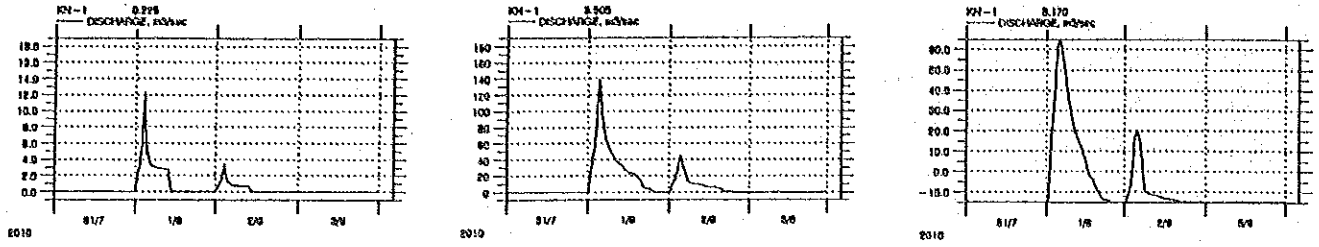
Channel Name	Chainage(km)
KN-4	4.740

FIG. D.15(2) SIMULATED WATER LEVEL HYDROGRAPH OF NARAYANGANJ DND(2)

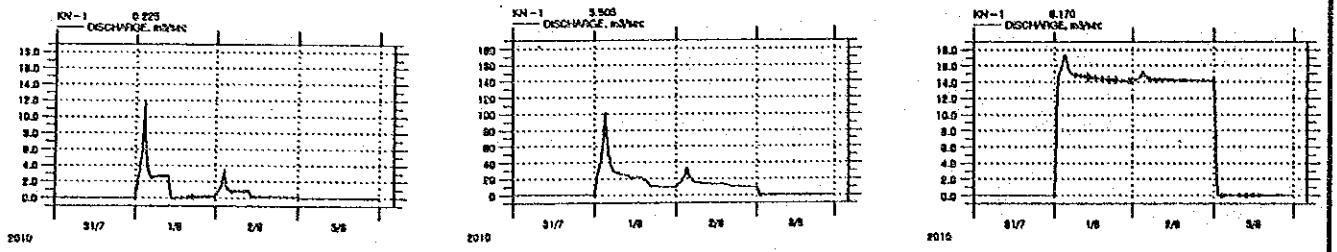
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

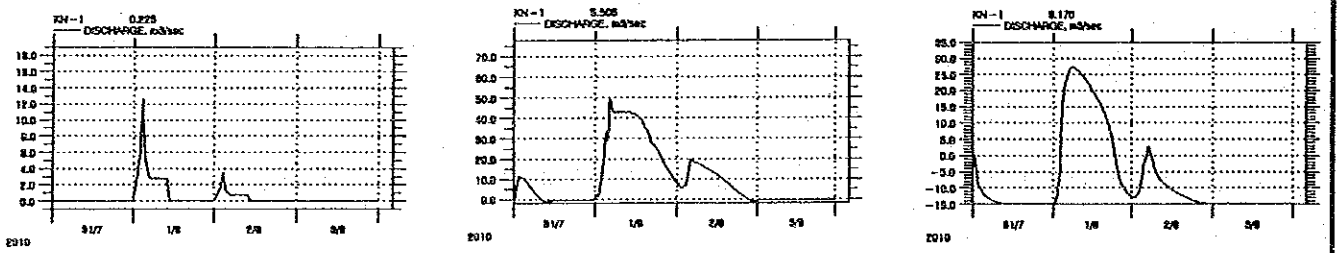
Case 1-1 : Without retarding pond and without pump station



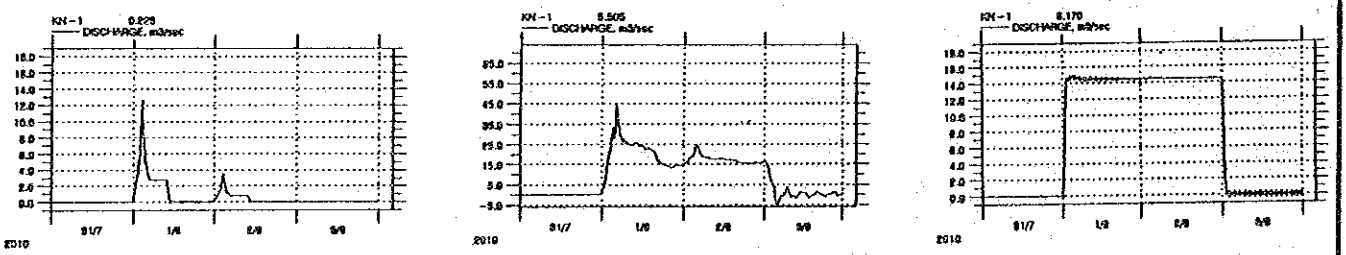
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



Case 2-2 : With retarding pond and with pump station



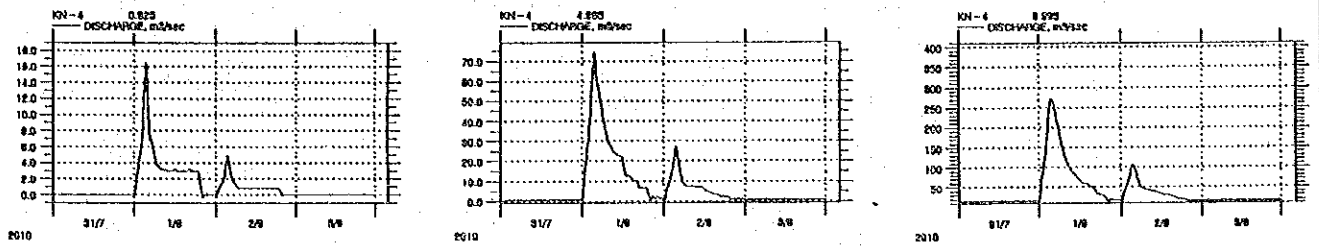
LEGEND :

Channel Name	Chainage(km)
KN-1	5.505

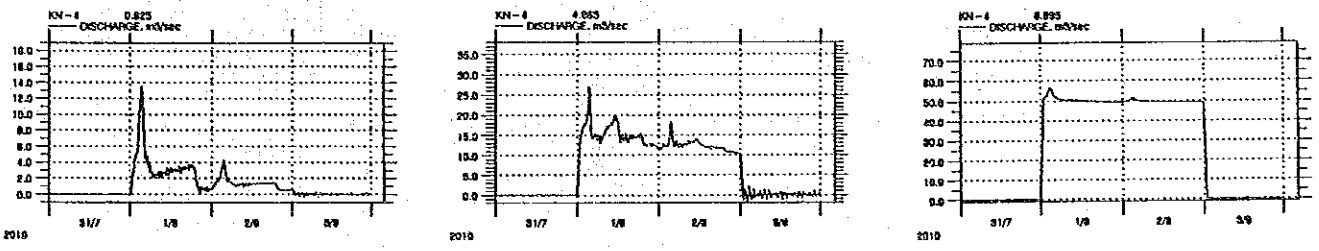
FIG. D.16(1) SIMULATED DISCHARGE HYDROGRAPH OF NARAYANGANJ DND(1)

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

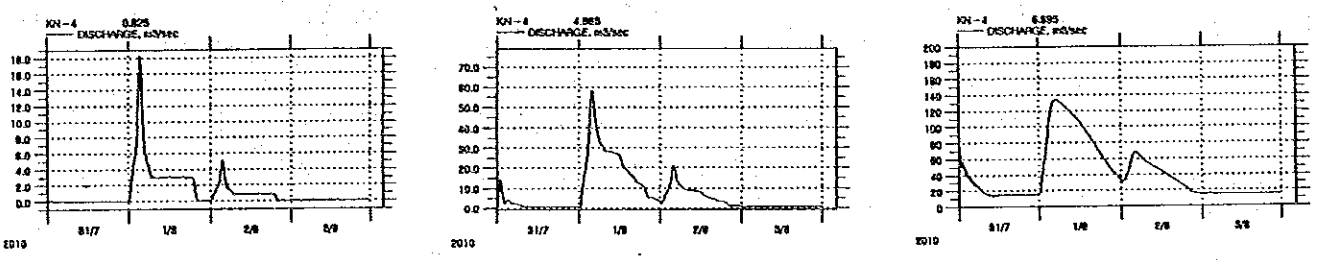
Case 1-1 : Without retarding pond and without pump station



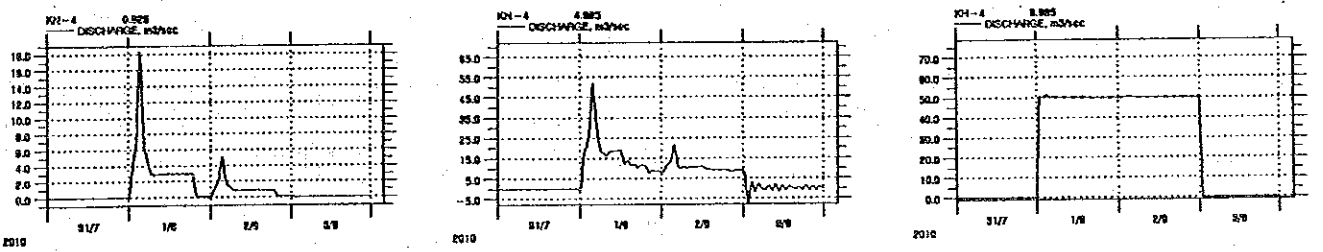
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



Case 2-2 : With retarding pond and with pump station



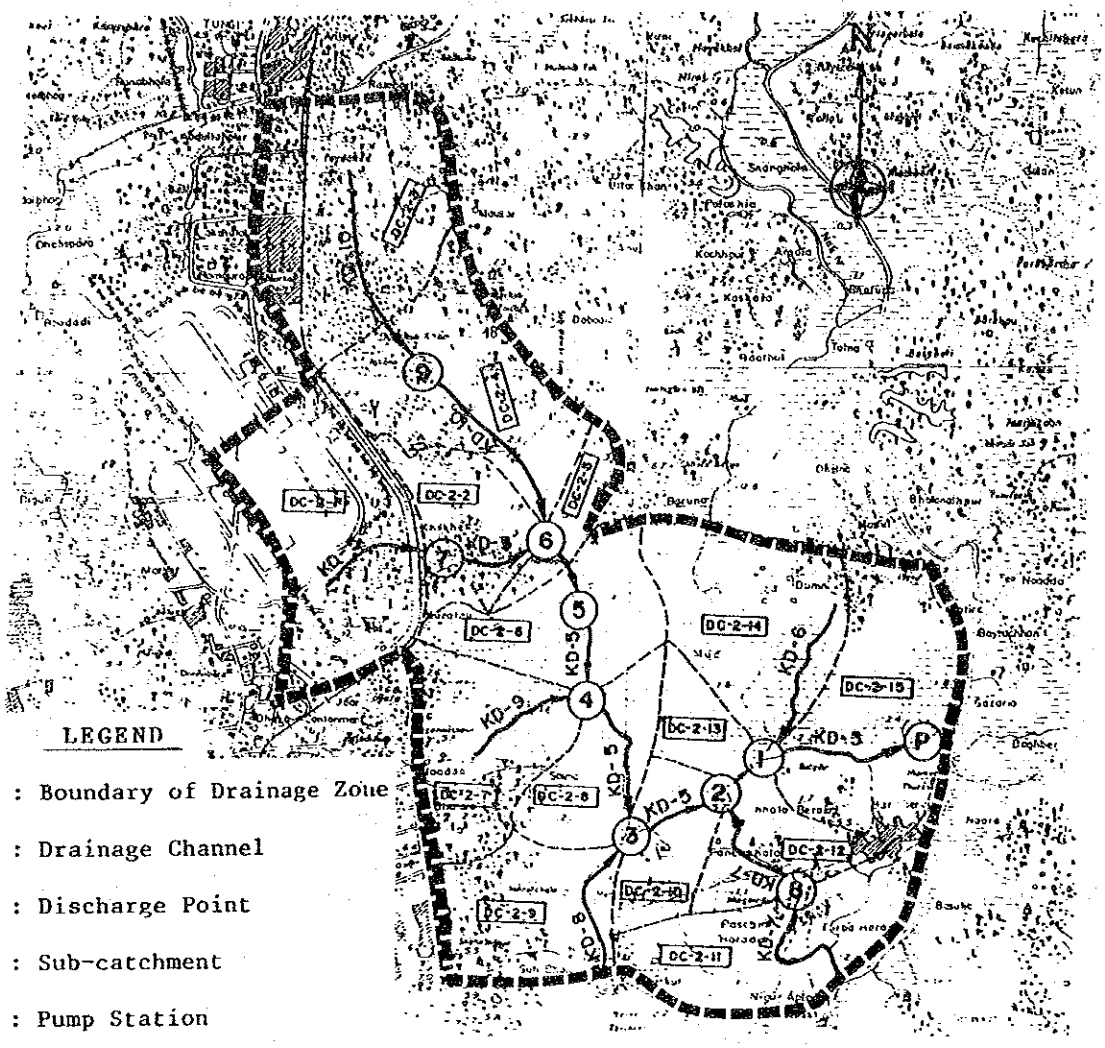
LEGEND :

Channel Name	Chainage(km)
KN-4	4.965

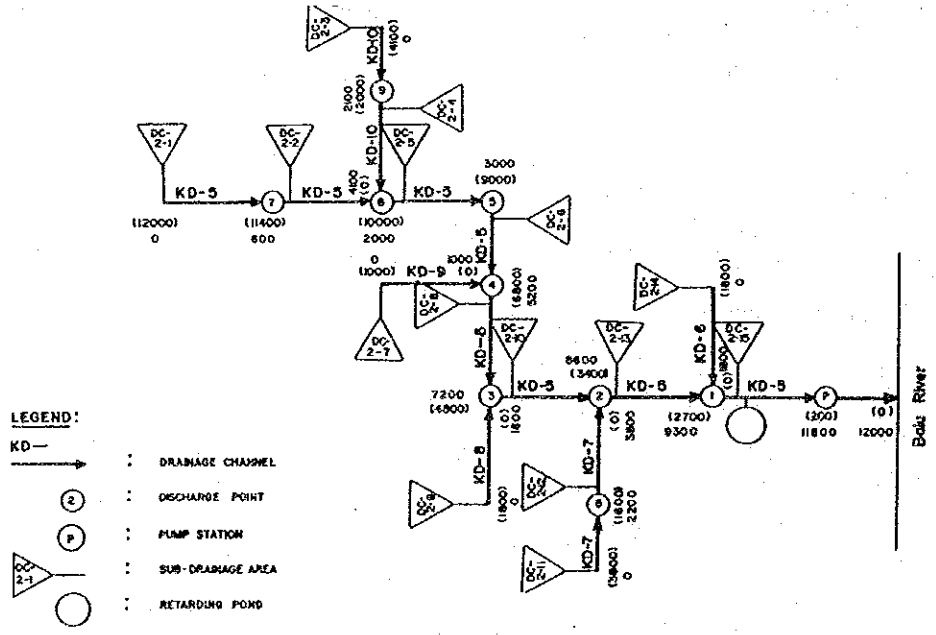
FIG. D.16(2) SIMULATED DISCHARGE HYDROGRAPH OF NARAYANGANJ DND(2)

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

JICA



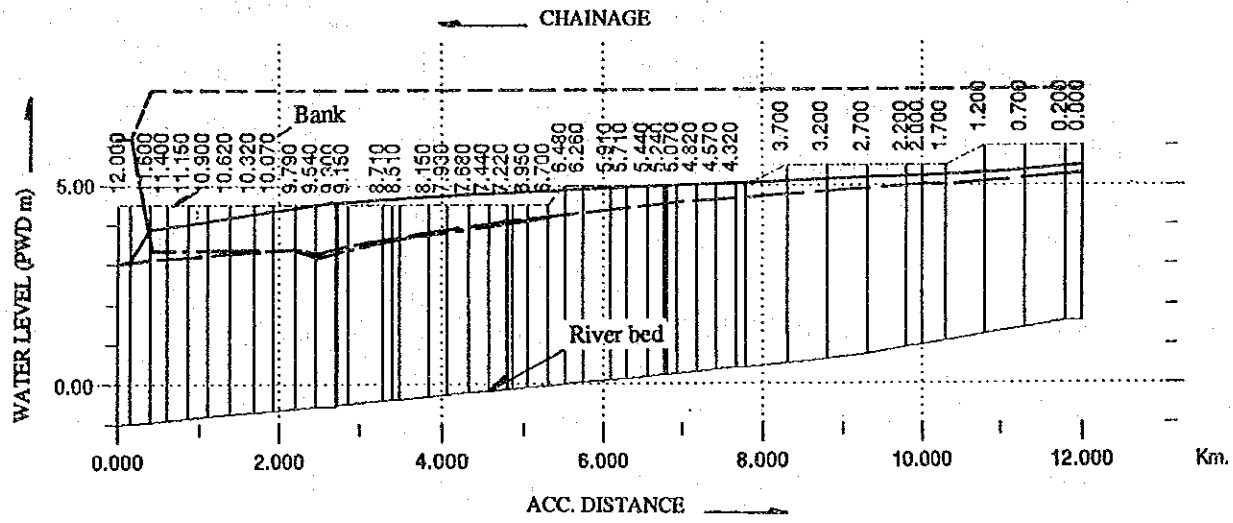
DRAINAGE CHANNELS AND SUB-CATCHMENTS



PROPOSED SIMULATION MODEL

FIG. D.17 DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-2

DRAINAGE CHANNEL : KD-5



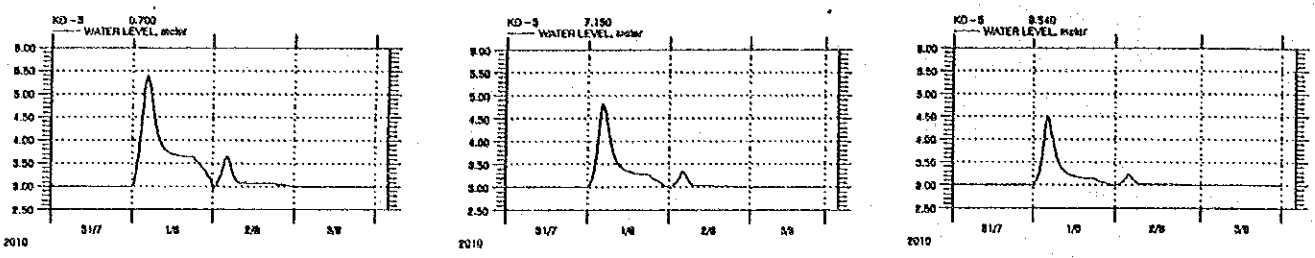
LEGEND :

Water Level

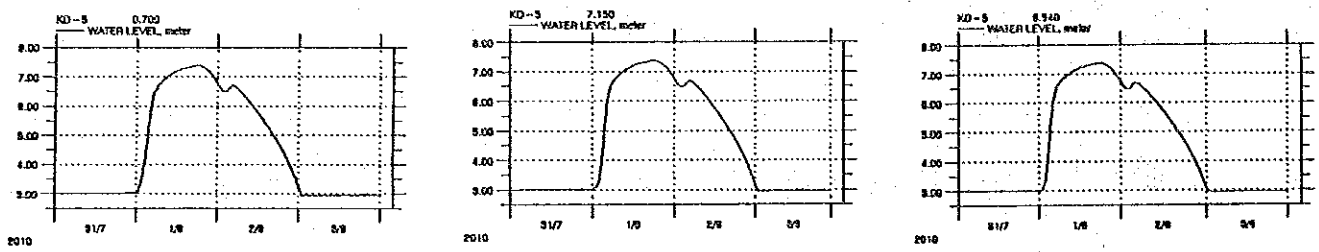
- Case 1-1 : Without retarding pond and without pump station
- Case 1-2 : Without retarding pond and with pump station
- Case 2-1 : With retarding pond and without pump station
- Case 2-2 : With retarding pond and with pump station

FIG. D.18 PROFILE OF SIMULATED PEAK WATER LEVEL HYDRAOGRAPH OF SUB-DRAIANGE ZONE DC-2

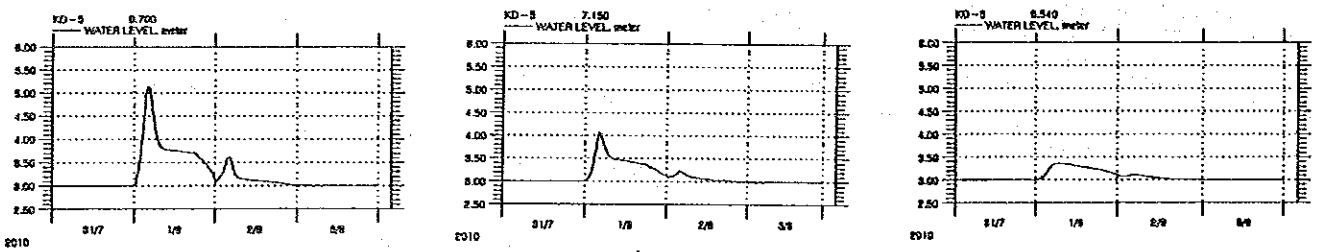
Case 1-1 : Without retarding pond and without pump station



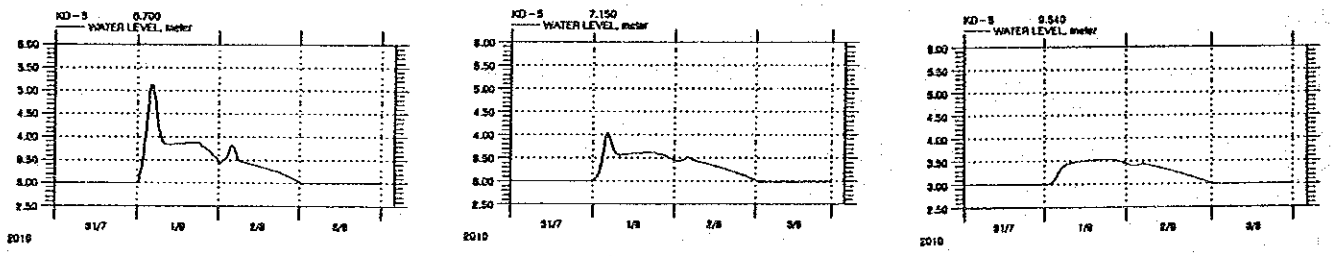
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



Case 2-2 : With retarding pond and with pump station



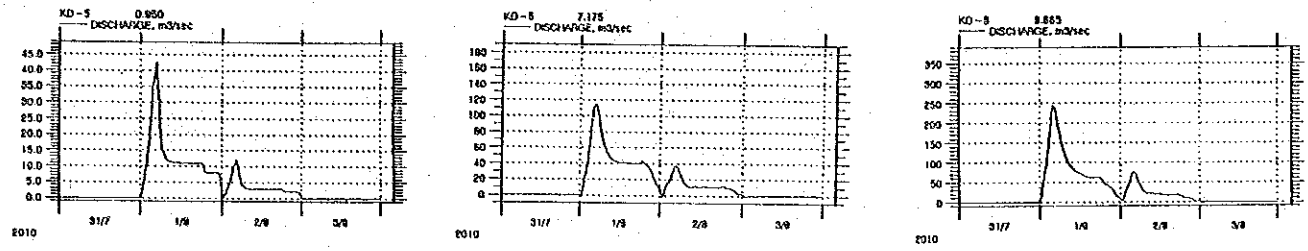
LEGEND :

Channel Name	Chainage(km)
KN-5	7.150

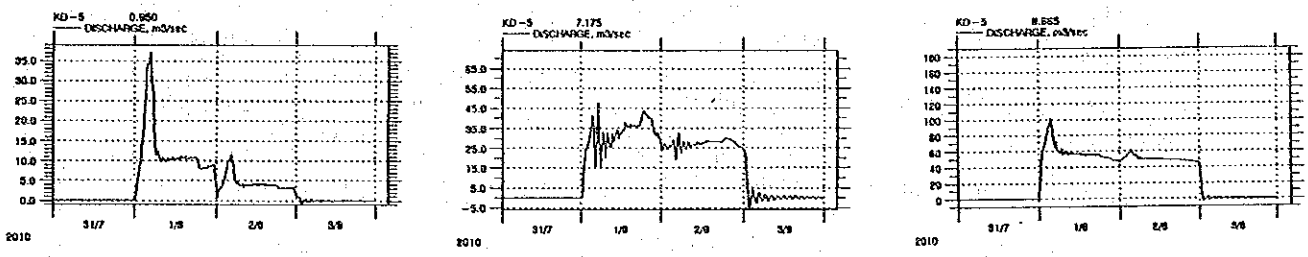
FIG. D.19 SIMULATED WATER LEVEL HYDRAOGRAPH OF SUB-DRAIANGE ZONE DC-2

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

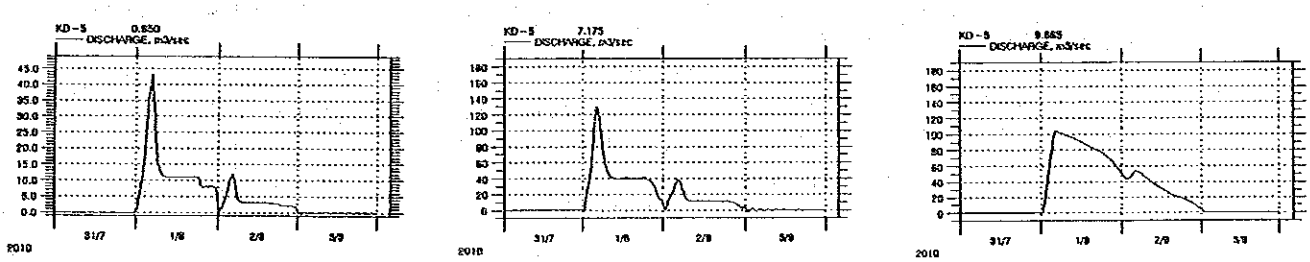
Case 1-1 : Without retarding pond and without pump station



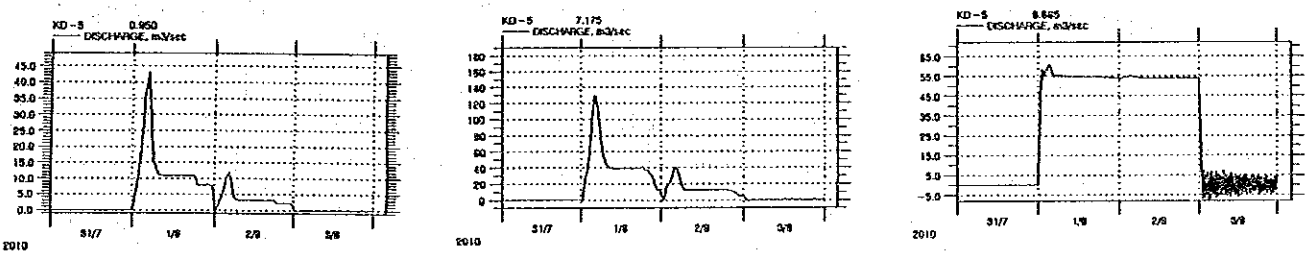
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



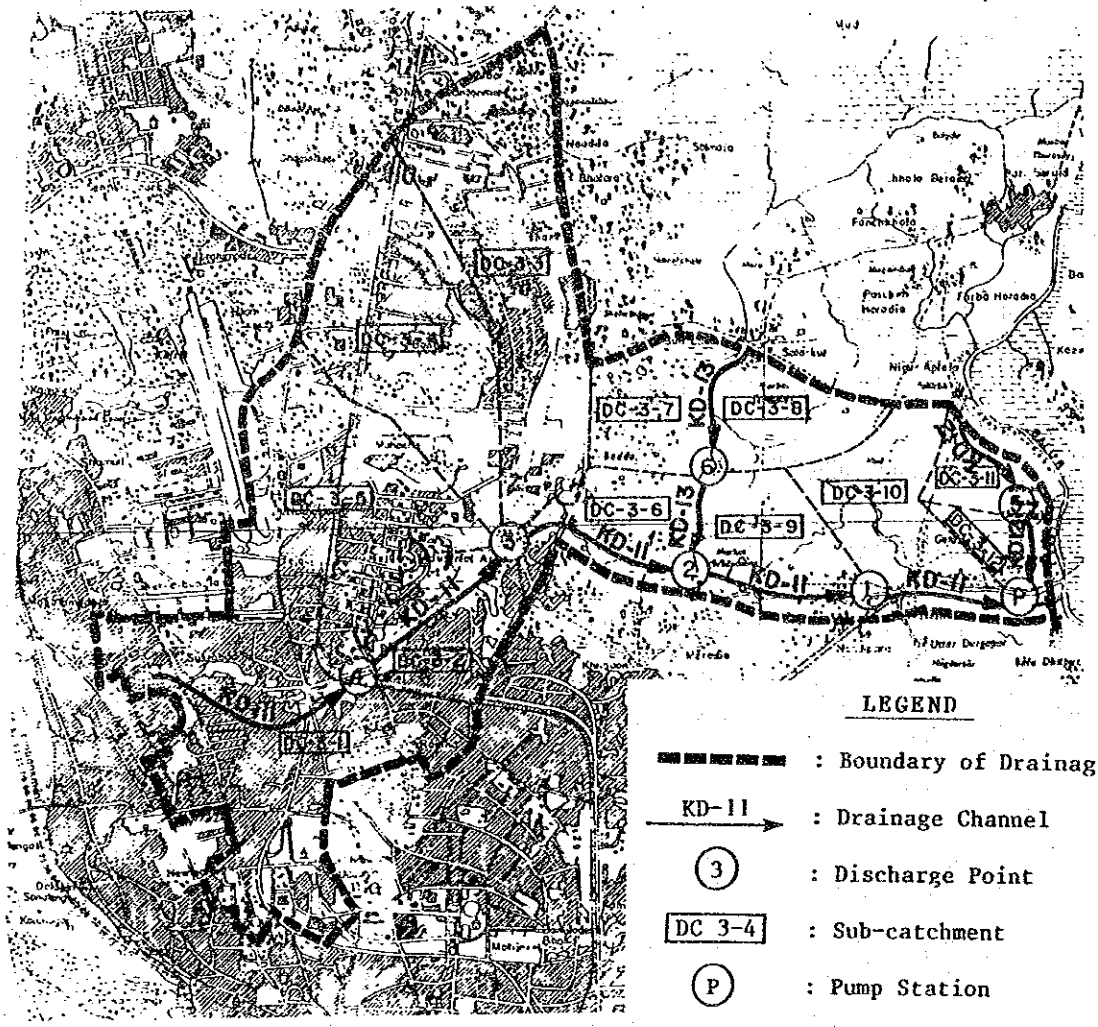
Case 2-2 : With retarding pond and with pump station



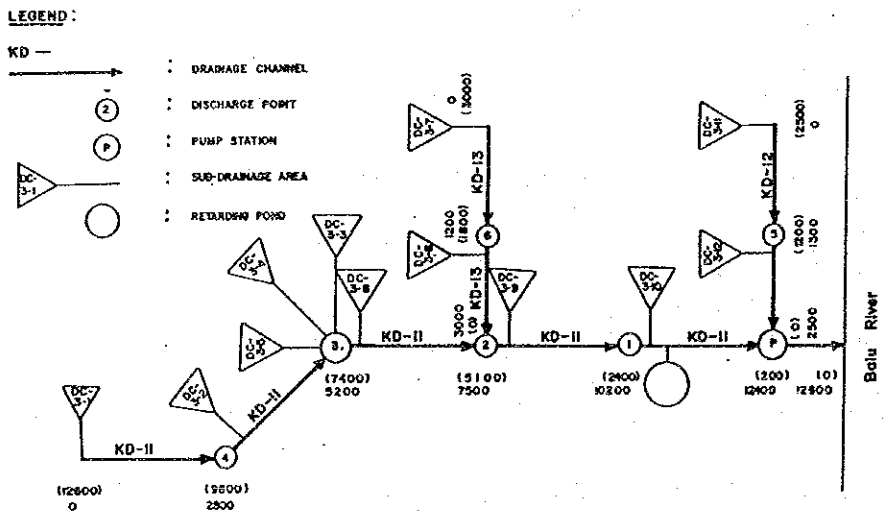
LEGEND :

Channel Name	Chainage(km)
KN-5	7.175

FIG. D.20 SIMULATED DISCHARGE HYDRAOGRAPH OF SUB-DRAIANGE ZONE DC-2



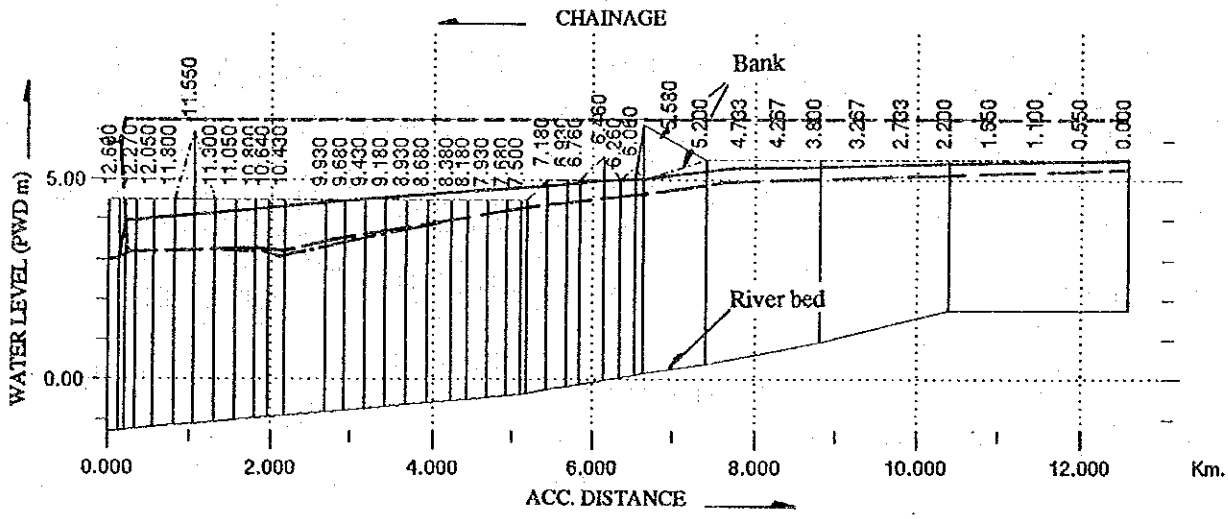
DRAINAGE CHANNELS AND SUB-CATCHMENTS



PROPOSED SIMULATION MODEL

FIG. D.21 DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-3

DRAINAGE CHANNEL : KD-11



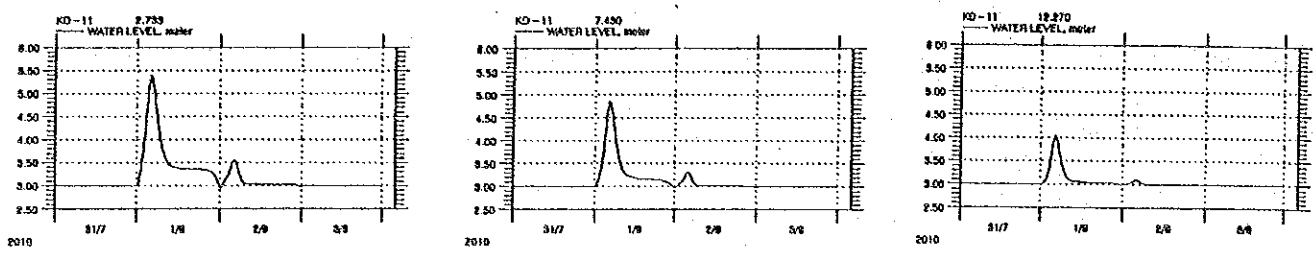
LEGEND :

Water Level

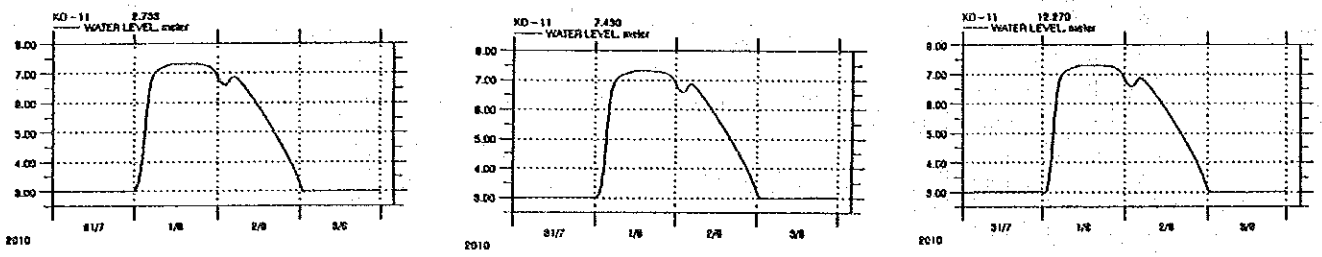
- Case 1-1 : Without retarding pond and without pump station
- Case 1-2 : Without retarding pond and with pump station
- Case 2-1 : With retarding pond and without pump station
- Case 2-2 : With retarding pond and with pump station

FIG. D.22 PROFILE OF SIMULATED PEAK WATER LEVEL HYDRAOGRAPH OF SUB-DRAIANGE ZONE DC-3

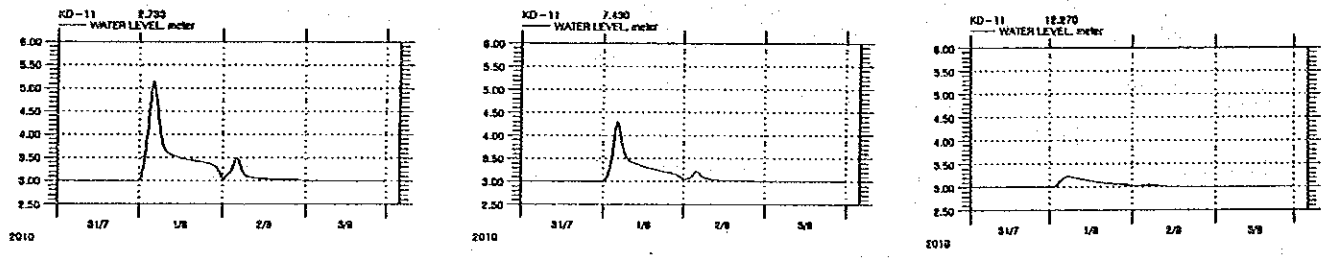
Case 1-1 : Without retarding pond and without pump station



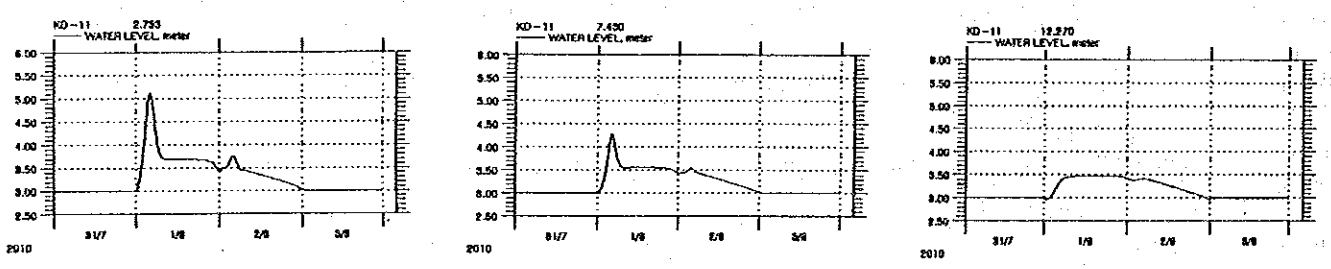
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



Case 2-2 : With retarding pond and with pump station



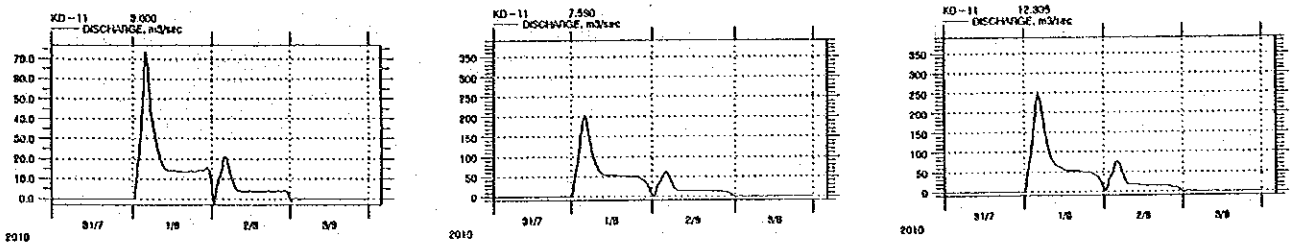
LEGEND :

Channel Name	Chainage(km)
KN-11	7.430

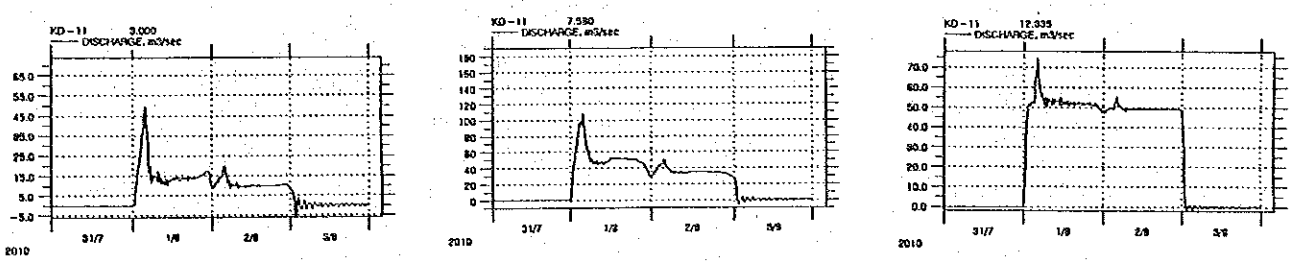
FIG. D.23 SIMULATED WATER LEVEL HYDRAOGRAPH OF SUB-DRAIANGE ZONE DC-3

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

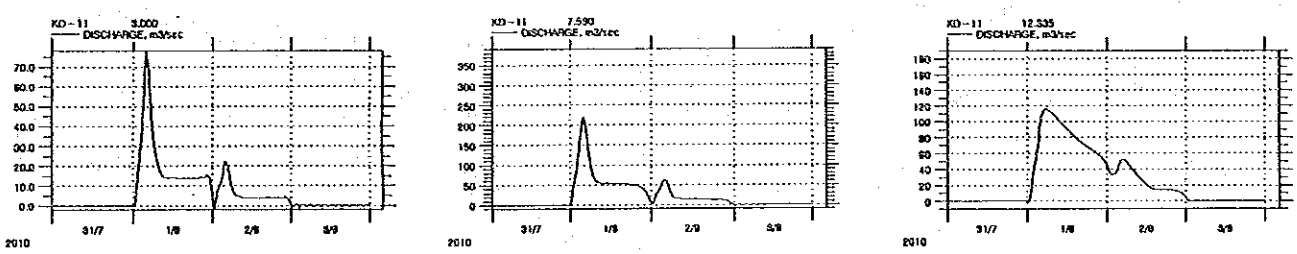
Case 1-1 : Without retarding pond and without pump station



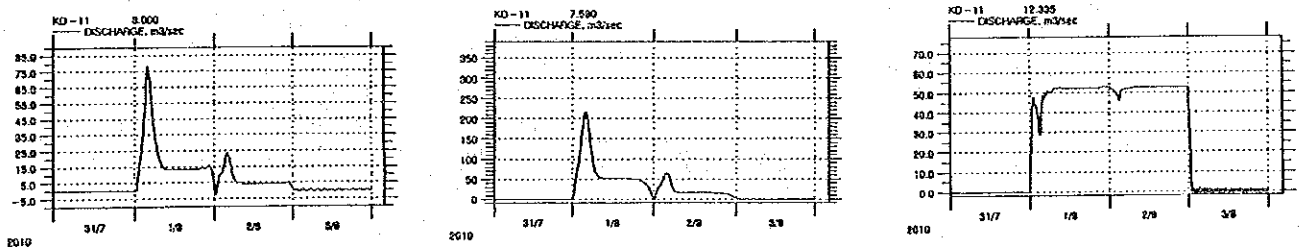
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



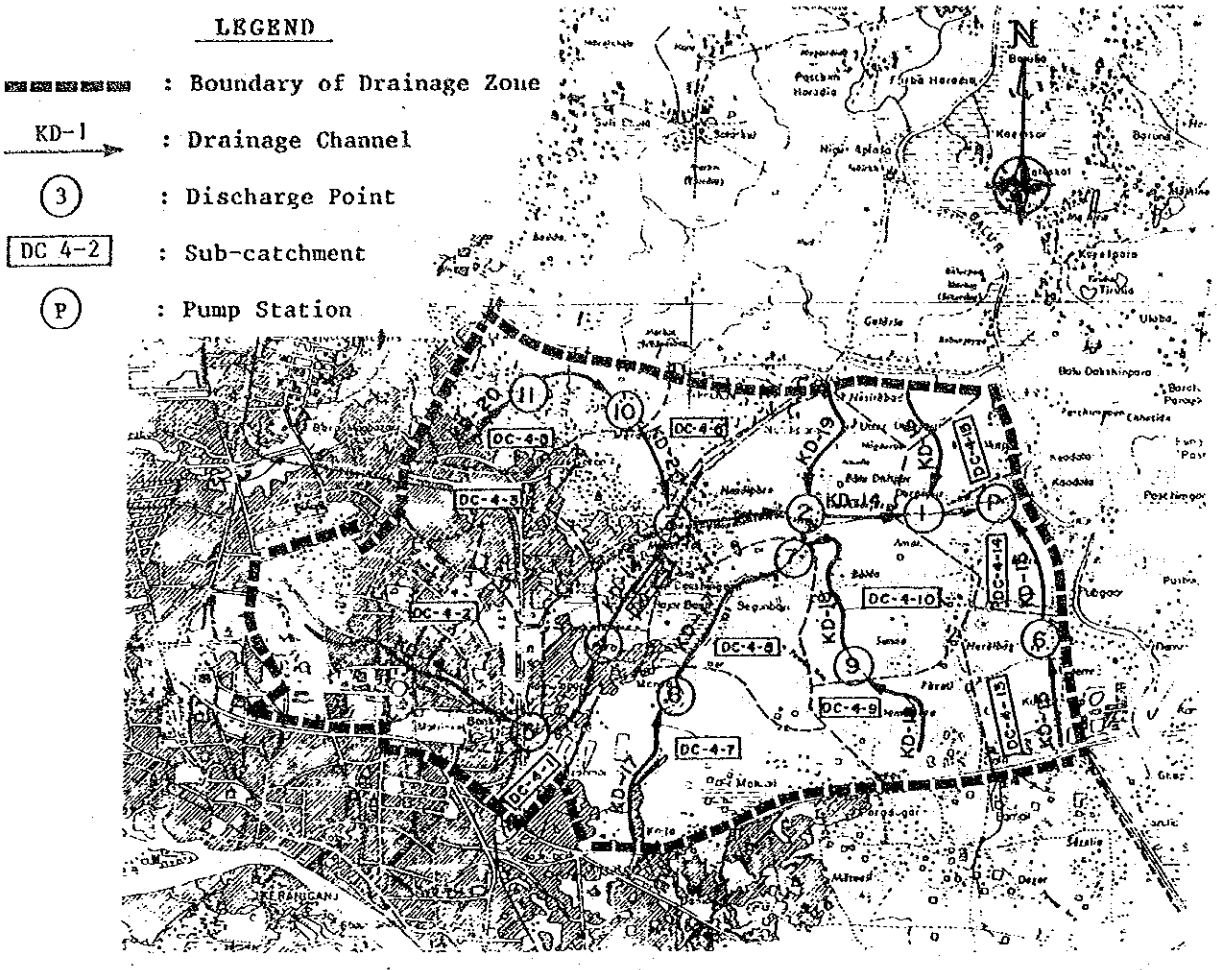
Case 2-2 : With retarding pond and with pump station



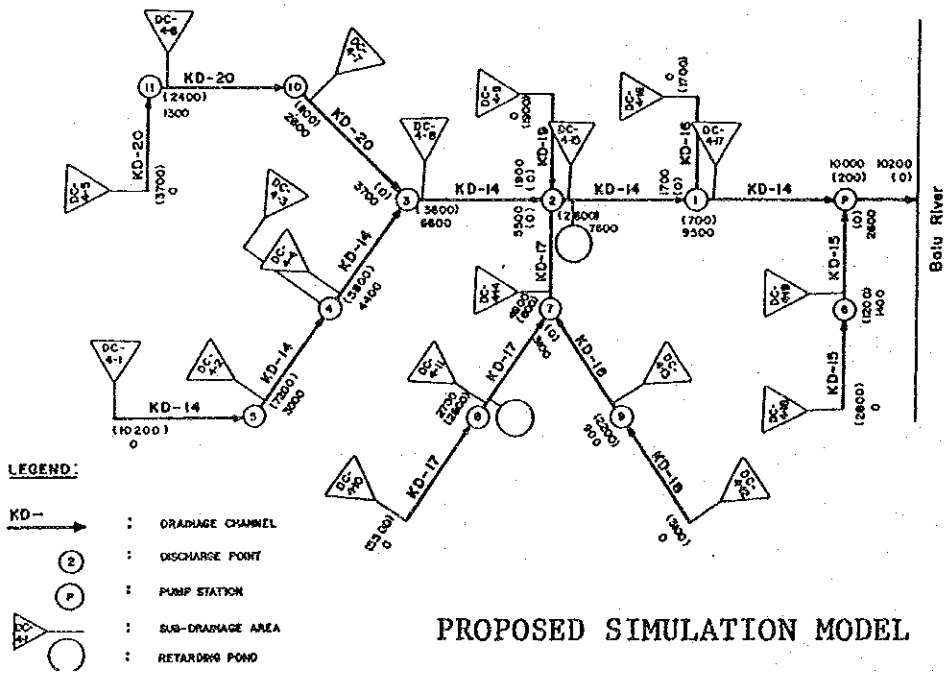
LEGEND :

Channel Name	Chainage(km)
KN-11	7.590

FIG. D.24 SIMULATED DISCHARGE HYDRAOGRAPH OF SUB-DRAIANGE ZONE DC-3

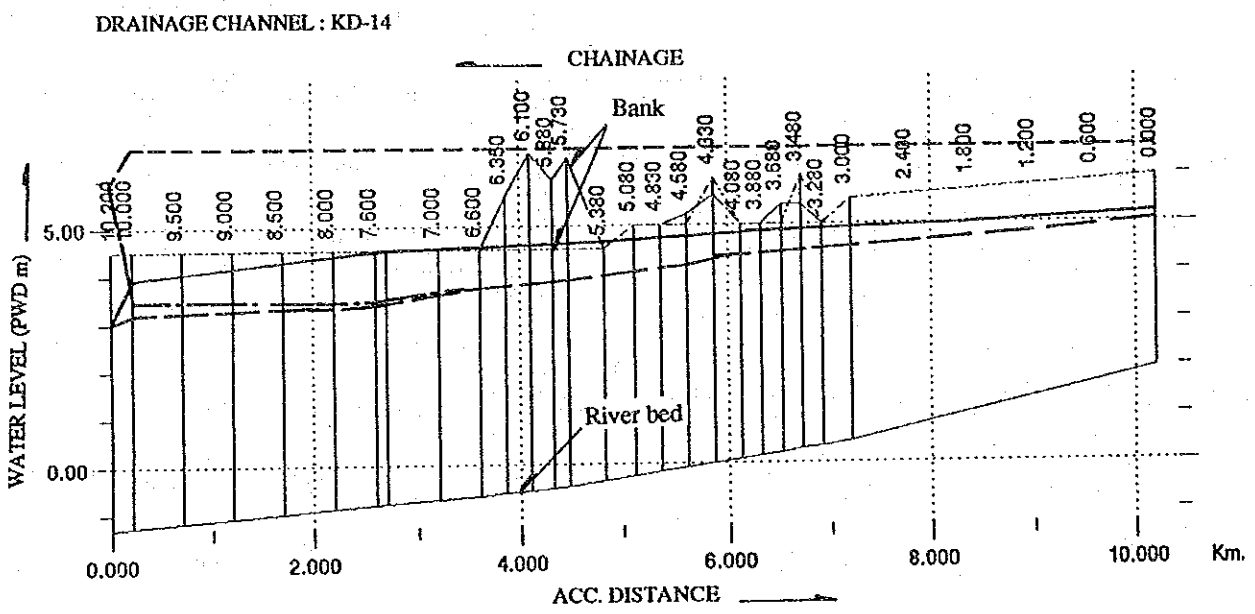


DRAINAGE CHANNELS AND SUB-CATCHMENTS



PROPOSED SIMULATION MODEL

FIG. D.25 DRAINAGE CHANNELS AND SUB-CATCHMENTS, AND PROPOSED SIMULATION MODEL OF SUB-DRAINAGE ZONE DC-3



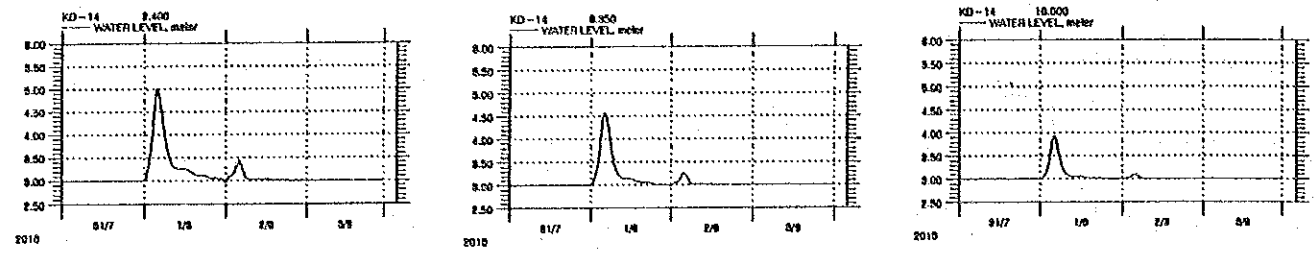
LEGEND :

Water Level

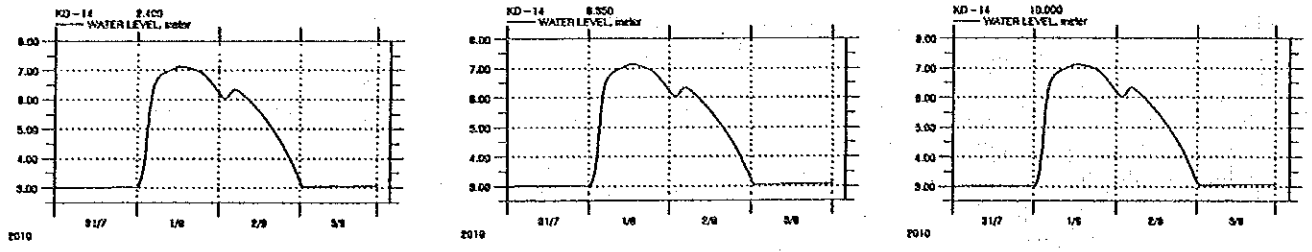
- Case 1-1 : Without retarding pond and without pump station
- Case 1-2 : Without retarding pond and with pump station
- Case 2-1 : With retarding pond and without pump station
- Case 2-2 : With retarding pond and with pump station

FIG. D.26 PROFILE OF SIMULATED PEAK WATER LEVEL OF SUB-DRAINAGE ZONE DC-4

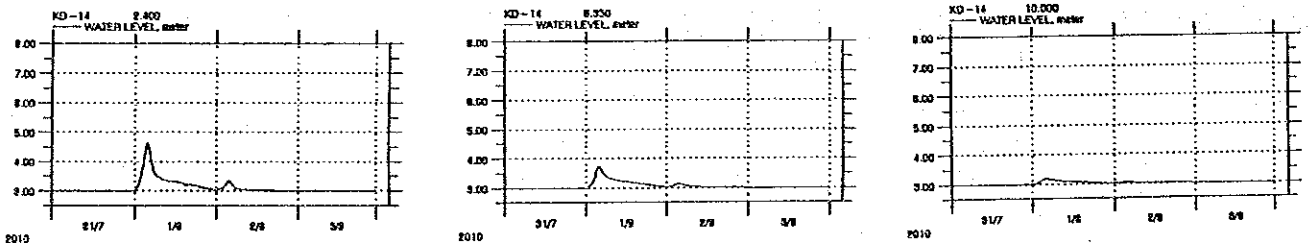
Case 1-1 : Without retarding pond and without pump station



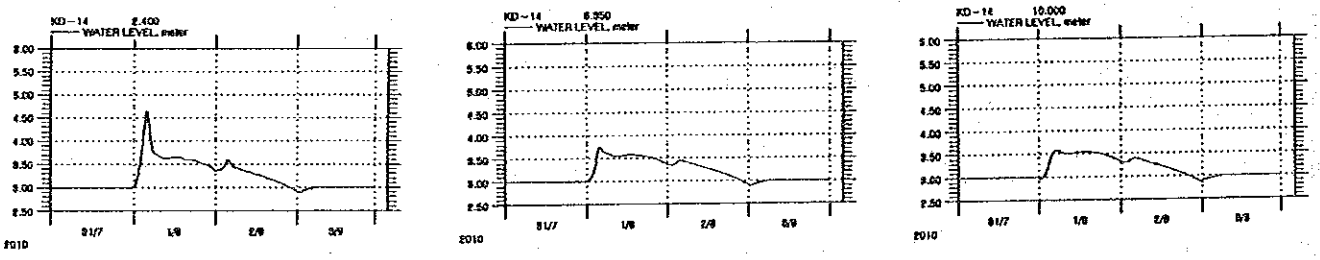
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



Case 2-2 : With retarding pond and with pump station



LEGEND :

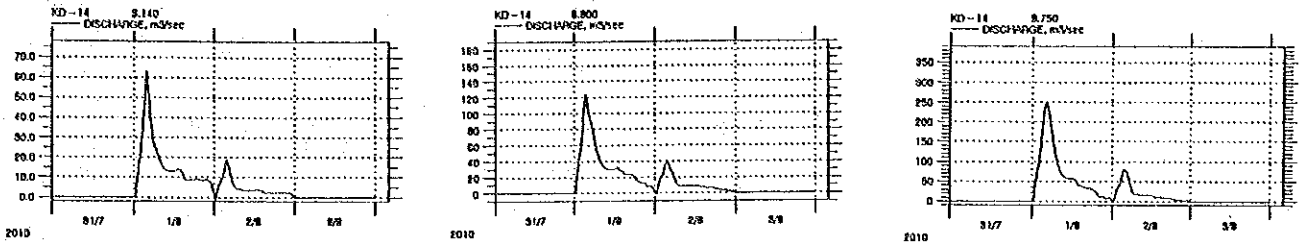
Channel Name	Chainage(km)
KN-14	6.350

FIG. D.27 SIMULATED WATER LEVEL HYDRAOGRAPH OF SUB-DRAIANGE ZONE DC-4

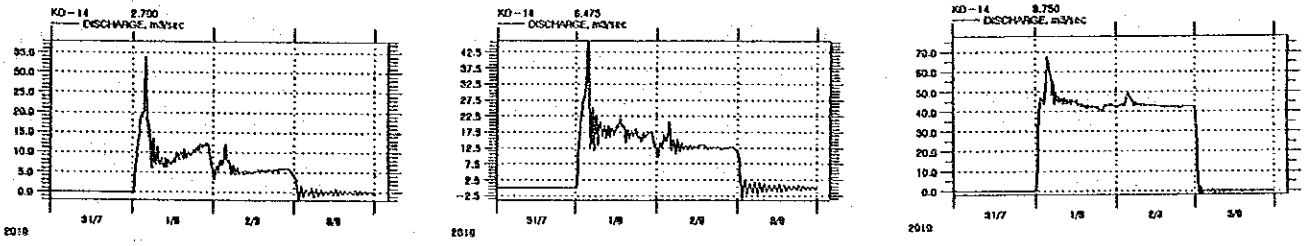
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

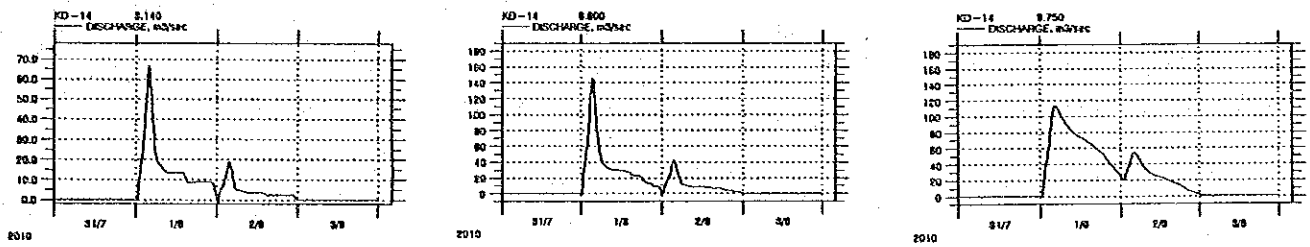
Case 1-1 : Without retarding pond and without pump station



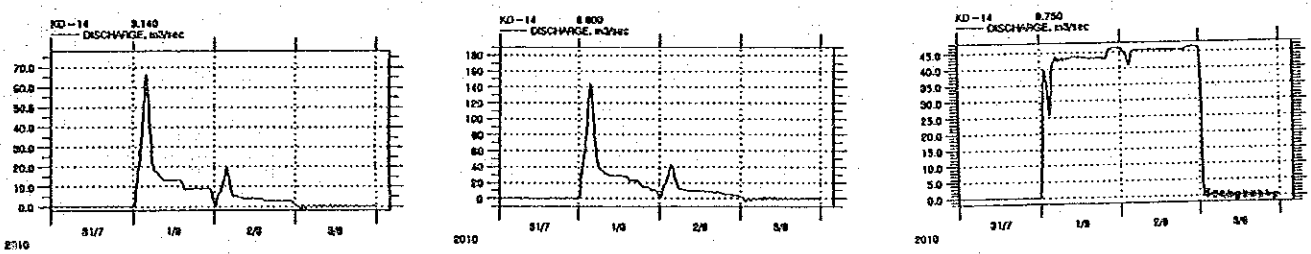
Case 1-2 : Without retarding pond and with pump station



Case 2-1 : With retarding pond and without pump station



Case 2-2 : With retarding pond and with pump station



LEGEND :

Channel Name	Chainage(km)
KN-14	6.800

FIG. D.28 SIMULATED DISCHARGE HYDRAOGRAPH OF SUB-DRAIANGE ZONE DC-4

SUPPORTING REPORT E
FLOOD MITIGATION AND STORMWATER DRAINAGE IMPROVEMENT PLAN

SUPPORTING REPORT E : FLOOD MITIGATION AND DRAINAGE IMPROVEMENT PLAN

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SUPPORTING REPORT E : FLOOD MITIGATION AND DRAINAGE IMPROVEMENT PLAN

1. Introduction

1.1 General

The study is composed of three (3) phases, and the objectives of each phases are introduced as follows :

Phase I : Preliminary Review Stage (Oct. 1990-Dec. 1990)

- To prepare a general study program based on the Scope of Work,
- To review the existing conditions and to prepare a detailed study plan.

Phase II : Master Plan Study (Jan. 1991-Aug. 1991)

- To carry out a master plan study on comprehensive flood control and Stormwater drainage for Dhaka Metropolitan area (850 km^2)
- Tot identify priority projects for a feasibility study.

Phase III : Feasibility Study for Priority Area (Sep. 1991-April 1992)

- To conduct a feasibility study on flood control and stormwater drainage for the priority area identified during the Phase II.

1.2 Study Areas and Projects Identified in the Master Plan

During the phase II, the following priority areas were identified for the feasibility study areas.

- Greater Dhaka West (FAP 8B, ADB)
- Greater Dhaka East
- Narayanganj DND
- Narayanganj West

However, the feasibility study of Greater Dhaka West was taken by ADB financed consultants, FAP 8B. Accordingly the feasibility study of FAP 8B has been decided to be carried out on the other three (3) priority areas (see Fig E.1.1).

1.3 Planning Concept Adopted in the Master Plan

1.3.1 Flood Mitigation Plan

1) Flood Mitigation Policy

By considering natural and social conditions of the study area the following flood mitigation policy were adopted :

- The future development area shall be protected as much as possible.
- The proposed flood mitigation will comprise both structural and non-structural measures.
- The structural measures shall include facilities which are to be constructed as early as possible and within the target yera 2010.

2) Flood Protection Level

Based on the flood mitigation policy economical evaluation and investment effectiveness of existing flood facility, which is designed for a 100-year flood frequency, a scale of highest design flood frequency of 100-years or the 1988 flood was selected.

3) Flood Mitigation System

The empoldering measure is determined to be most suitable for the study area based on the following consideration

- River training by dredging will not be effective for lowering the flood water level due to the peculiar hydraulic characteristics of the area
- It is very difficult to maintain the design river bed due to the sedimentation problem

4) Standard Empoldering Facilities

As standard design, the following types of polder are considered in principle.

- Embankment
- Flood wall (T and I Type)
- Road-Cum-Embankment

1.3.2 Storm Drainage improvement Plan

1) Planning Policy

A planning policy for preparation of stormwater drainage master plan are briefly summarized as follows :

- Plans are to be prepared to meet the population and land use in the target year 2010.

- For the existing urbanized areas of Dhaka city (approximately 137 km2). the plans shall meet the requirements of Storm Water Drainage System Improvement Project in Dhaka City and Dholai Khal Rehabilitation and Area Development Project committed by JICA and World Bank respectively.

- The plans are to consist of structural and non-structural measures.

- Scope of the structural measures for the existing built-up areas are construction of pumping stations with gates, and improvements of khals and trunk drain to mitigate the existing internal flood damages.

- For the future urbanized areas, only pumping stations and improvements of trunk khals are to be proposed as structural measures. Some non-structural measures are to be recommended in the form of guideline for the future urban development.

2) Design Concept

(1) Design Flood Water Level

The pump drainage system, shall be adopted for the most part of the future built-up areas. It is proposed that the frequent flood water level with 2-year return period is employed as the design outlet water level for demarcation of a gravity and pump drainage.

(2) Design Rainfall

- For Pumping Station and Retarding Pond

  2-days consecutive rainfall with a 5-year frequency is applied as the design rainfall for pumping station and retarding pond.

- For Khal Improvement and Trunk Drain

The rainfall intensity with a 5-year frequency is employed for the design of trunk drains and khal improvements. The rainfall intensity is to be applied for the Rational Formula.

(3) Design Discharge and Drainage Conditions

- Specific Peak Run-off
  Specific peak run-off is estimated by Rational formula
- Drainage Period

As discharge period 2-days discharge period by pumps is proposed in view of technical and economical reasons.

(4) Specific Requirement of Pump and Retarding Pond

- Specific pump capacity and storage requirements of the retarding pond in the pump drainage area are estimated by Storage basin Model.

- As the calculation results, specific requirements of both facilities are to be 1.14 m3/s/km2 and 0.120 x 106 m3/km2 respectively.

2. Outline of Related Project (FAP-8B)

2.1 General

The outline of related project : FAP-8B is introduced based on the "Executive Summary of FAP-8B"

- A feasibility study for the Dhaka Integrated Flood Protection Project, financed by the ADB, started in January 1991. The project is being formulated under the coordination of the FPCO in the context of an Integrated Environmental Management Plan (IEMP) as a long term integrated development strategy for Dhaka Metropolitan Area (260 km^2).

The Project objective is to undertake an integrated urban development program consisting of : (i) flood control and drainage works ; (ii) complementary environmental improvement programs in low cost water supply and sanitation programs for the low income residents, solid waste management, and slum and squatter area development; and (iii) institutional support for improved efficiencies in urban management and revenue generation.

The Project is being formulated as a five year program between December 1991 to December 1996 for a first stage integrated flood control and drainage program covering the westerly part of Dhaka city, in the context of progressively developing future facilities to ultimately provide full protection to all Dhaka over a period of about 10 to 15 years.

The BWDB will be the lead implementing agency, and primary responsibilities for execution of the Project components will be shared between : (i) the BWDB for Part A: flood protection ; (ii) DWASA for Part B: Drainage; and (iii) DCC for Part C: Environmental Improvements.

2.2 Project Components and Scope

As a first phase of a long term flood protection program, the Project will initially focus on the highest priority area, the westerly part of Dhaka City. The Project area (see Fig.E.2.1) covers approximately 136 sq.km, encompassing about 95% of the commercial and industrial properties and some 87% of the total city population. The Project scope covers mainly the completion and augmentation of the flood protection and drainage program initiated by GOB following the 1988 floods. It is designed to initially provide flood security against the 50 year recurrence interval flood levels, with complementary environmental improvements focused on the urban poor. The Project works are designed to be self-contained, but will be suitable for expansion in the future.

The Project components concerning the Flood Protection and Stormwater Drainage are described as follows :

Flood Protection (BWDB)

- Specialized remedial works and foundation stabilization on 7.8 km of the existing embankment ;
- Erosion control and slope protection over 11.5 km;
- Minor remedial works and slope protection over 24.2 km;
- Repair and stabilization of parts of 5.3 km of existing concrete flood wall;

- Construction of 1.6 km of new flood wall/embankment;
- Construction of 5 additional sluices along the existing embankment;
- Raising and flood proofing of the central spine road (Tongi Railway Bridge to Friendship Bridge);
- Construction of the first stage (22.5 cm3/s) of Pump Station No. 3 at Goranchatbari along the westerly embankment;
- Establishment of a maintenance program and supply of maintenance equipment to safeguard the flood protection investment.

Drainage (DWASA)

- Rehabilitation and upgrading of 21 existing priority khals (including completion of the crash program initiated by the government), for a total length 78.6 km;
- Rehabilitation and construction of 50.7 km of pipe drains;
- Establishment of a maintenance program and supply of maintenance equipment to safeguard the drainage improvement investment.

The Environmental Improvement Program Covers slum/squatter area improvement, solid waste management and sanitation improvements, Rehabilitation and extension of 131 km surface drains and installation of some Public water stand pipes in low income areas.

2.3 Project Cost and Implementation Schedule

The estimated Project costs are summarized as follows :

1.	Base Cost	$ 99.92	million
	1) Flood protection :	$ 46.66	million
	2) Drainage :	$ 37.38	million
	3) Environmental Improvement :	$ 9.94	million
	4) Project implement Assistance :	$ 5.94	million
2.	Contingency	$ 18.10	million
3.	Interest During Construction:	$ 3.20	million
	Total	$ 121.22	million

The Project implementation schedule is shown in Fig.E.2.1

According to the Fig.E.2.1, the drainage work and flood protection works are to be completed by middle of 1994 and 1996 respectively.

The environmental improvement program is to be completed by the end of 1996.

3. Greater Dhaka East

3.1 Review of Master Plan

3.1.1 General

Based on supplemental information, topographic and soil investigation results obtained in this F/S stage, the following review and supplemental study were carried out :

- A review of Alignment of Embankment for Nali River Portion
- Alignment Study on outlet of Begunbari Khal
- A review of compartmentalization by Sub-Embankment

3.1.2 Embankment Alignment of Nali River Portion

In the Master Plan, a portion of the alignment along Nali River was briefly studied based on the limited topographic and soil boring data, and it was suggested that for embankment construction an alignment along Nali River is better rather than that along Balu river alignment mainly due to poor sub-soil condition along Balu river.

However, the alignment is reviewed by using the supplemental topographic and soil survey results.

1) Alignment Alternative A

(1) Natural and Social Condition

This alignment was planned in Phased Program II of GOB by BWDB and information on land acquisition has been informally released to the local people.

This alignment runs on flood plain area along Balu river, where ground level ranges from about 1.5 m to 3.0 m P.W.D. The area of about 215 ha in between Balu and Nali Rivers is used for rice cultivation in the dry season, however it goes underwater in the rainy season.

The soil data on the alignment by BWDB shows that poor sub-soil condition (N-value is less than 4) prevails along the whole alignment (see Fig.E.3.1).

(2) Main Feature of Alignment Alternative A

For the embankment construction, foundation treatment is necessary for whole alignment stretch due to poor sub-soil condition. Furthermore, one sluice gate is required at the crossing of Nali river for local drainage. The main feature of the alternative is summarized in Table E.3.1. The alignment and longitudinal and typical cross-sections are shown in Fig. E.3.1.

The construction costs of the embankment and sluice gates are roughly estimated by using the Unit Cost used in the Master Plan.

The total construction cost which includes land acquisition is estimated at 900 million Taka.

2) Alignment Alternative B

(1) Natural and Social Condition

This alignment was planned along Nali river where ground level ranges from about 2.0 m to 5.0 m P.W.D.

This alignment was recommended in the Master Plan since good soil foundation was expected from the topographical condition.

The peripheral area along Nali river is being used for both residential and agricultural purposes.

The soil data investigated by the Study Team and FAP 8B show that good soil foundation prevails most portion of the alignment (see Fig. E.3.1).

(2) Main Feature of Alignment Alternative B

For the embankment construction, foundation treatment is required only 30% of the total alternative alignment.

One sluice gate is required for local drainage system at the crossing of Nali river. The main feature of the alternative is summarized in table E.3.1 and the plan and longitudinal section is shown in Fig. E.3.1.

The total construction cost which includes land acquisition is estimated at about 570 million Taka.

3) Selection of Alignment Alternative

The alternative is selected based on the following aspects :

(1) Economical aspects : Comparison between the expected benefit from additional protected land and the construction cost increased by the Alternative.

(2) Social aspects : Requirement of resettlement.

The study shows that the construction cost of alternative A is higher than that of alternative B by 330 million taka. However the benefit from additional protected land of alternative A is estimated at 538 million taka in terms of land acquisition cost. Accordingly, alternative A is better selection in terms of economical aspect.

For the social aspect, alignment A is much recommendable since it requires no resettlement of residence and social recognition of the land acquisition information. While, alternative B involves the replacement of some residential houses.

Based on the above condition, alternative A is recommended.

3.1.3 Alternatives for Navigation System of Begunbari Khal

1) General

Begunbari Khal is utilized as navigation canal as well as drainage channel for central part of Dhaka area.

Most of the commodities and construction material such as vegetable, fruit, timber, brick, soil, etc. are transported by boats from outer area to Dhaka city through Begunbari Khal.

Based on interview survey at Rampura bridge the maximum size of boat observed in the rainy season is said to be about 40 m in length and 8 m in width. The most of the big boats are used for soil transportation, while small boats are used for daily use

commodity and passenger transportation in the khal basin. Based on navigation survey at least 70 - 100 boats per day come to this area in the wet season. Even in dry season 15 - 20 boats per day come to this area. About 50% of these boats carry passengers and the rest carry wood, bamboo, sugarcane and other rural produce. About 700 to 1000 passengers come to this point in the wet season. After Tongi, Rampura is the most important in terms of income generated from navigational activities. Rampura handles an estimated 71.2 million Taka worth of material annually. (see Table E.3.2).

2) Alternatives for Navigation System

Two alternatives for navigation system are conceived in principle when embankment is planned along Balu river.

Alternative A

The alternative A is to construct a navigation lock at the outlet of Begunbari Khal and to maintain the existing navigation system in the future. (see Fig. E.3.3(1)).

This alternative involves large amount of Construction and Operation/Maintenance costs, however negative social impact is negligible small.

Alternative B

The alternative B is to construct the transportation road along the khal which connects the boat yard at the outlet of Begunbari khal to Rampura bridge instead of the lock construction. This alternative allow navigation with small boats during a low water level, below 3.5 m of drainage design water level by opening the sluice gate. This alternative suggest the changes of existing navigation system to road transportation in the future (see Fig. 3.3.(2)).

This alternative involves only small amount of operation and maintenance cost. This road is utilized for transportation system. However, some negative social impact such as employment problem by boat transportation is expected.

While, construction of back water levee from the outlet of the Khal to Rampura bridge is not considered as an alternative because this alternative involves far larger amount of construction cost than that of alternative A.

The main feature of the above two alternatives is described below :

(1) Alternative A : Construction of Navigation Lock

The dimension of navigation lock is determined with due consideration of the maximum size of boat and the number of shipping under the present navigation condition.

Based on this condition, the lock having Myter type gate with 9.6 m high, 20.0 m width and 100 m long is planned.

The construction cost is estimated at about 640 million taka. The operation and maintenance cost per year is estimated at 9.6 million taka, which is equivalent to 1.5 percent of construction cost.

(2) Alternative B : Construction of Road

The dimension of the sluice gate and road for the alternative B is determined as follows :

- Elevation of Road Top : 7.0 m (Approximately same elevation with Rampura Road)
- Road width : 7.0 m (Two lane traffic)
- Road Distance : 6.3 Km (Outlet of Begunbari Khal to Rampura Bridge)

The construction cost with land acquisition costs is estimated at about 640 million taka.

3) Selection of Alternative

The construction cost of alternative A of navigation lock is almost the same cost of Alternative B of transportation road construction.

The operation and maintenance cost of the lock, 9.5 million Taka per year is far bigger than the expected revenue of 7 million Taka which is assumed to be 10% of transported charge value.

The lock should be well maintained and operated for whole year and no mechanical / electric trouble is allowed in the rainy season as well as flooding period.

By consideration the above conditions, construction of transportation road is recommended for the future transportation system.

However, sudden abolishment of the navigation system gives serious impact to the social economy and social activity. In order to soften the impact, the present navigation system is to be kept upto certain stage by means of block-wise (compartmentalization) implementation program and its flood mitigation system.

3.1.4 Compartmentalization by Sub-Embankment

1) General

Sub-Embankments were planned in order to minimize the expected damage when main embankment was breached due to some unexpected reasons.

For this purpose, two alignments of sub-embankment were planned in the Master Plan.

This compartment was mainly determined by considering the existing drainage zones by three trunk khals.

In this F/S stage, the compartmentalization is to be reviewed with due consideration of implementation program which is deeply related to the tendency of urban development and urgency of flood protection.

2) Alternatives of Compartmentalization

Two alternatives, i.e, 1) Case A - Three (3) compartment and, 2) Case B- Four (4) compartment are considered from view point of implementation aspect.

The difference between Case A and Case B is that whether the previous southern component is divided into two or not.

The main feature of the implementation aspect of Case A and Case B is described below:

Case A: The whole area is to be divided into 3 compartments of 41, 32 and 46 km^2 from north to southern compartment (DC-1 to DC-3). However the drainage area, which has direct relation with the scale of project cost is about 31km2, 48km2 and 88 km2 respectively (see Fig. E.3.4).

By using the total project cost in the Master Plan and its areal proportions the each project cost is estimated to be about 4,200, 6,400 and 11,800 million taka respectively.

Based on the above cost condition, early implementation and completion of the southern part (DC-3) might be difficult.

Case B : The whole area is to be divided into 4 compartments. The sizes of project area allocated with FAP-8B, from northern compartment to southern compartment (DC-1 to DC-4) are about 41, 32, 15 and 31 km^2 respectively. While, the drainage area is 31, 48, 47 and 41 km^2.

The each project cost estimated is approximately 4,200, 6,400, 6,300 and 5,500 million taka respectively.

3) Selection of Alternatives

The alternative, Case B is recommended based on the following considerations :

- Implementation program can be formulated with much flexible manner with due consideration of the scale of the project cost and the development tendency.

- Drainage system can be designed with flexible manner depending on the topographic and areal development condition.

- Present navigation system of Begunbari khal will be kept upto certain stage by considering the implementation schedule.

4) Main Feature of Compartments

The Greater Dhaka is divided into two areas i.e. Greater Dhaka East and West. The divided boundary of these areas is recognized as the central spine road which runs from

Tongi to Saidabad. However the drainage zone of the compartments of Dhaka East includes some part of Dhaka West area.

The central spine road is going to have a function of flood protection having capacity of 50-year flood frequency level.

For effective use of the spine road, this road is planned as flood protection boundary with sub-embankments of each compartment. The main feature of each compartment is shown below :

Name of Compartment	Area of Compartment (km^2)	Trunk Khal	Drainage Area (km^2)	Remarks
DC-1	40.69	Boalia Khal	30.56	
DC-2	32.04	Rashidkhali Khal	47.88	
DC-3	14.57	Begunbari Khal	46.58	
DC-4	31.32	Dholai Khal	41.34	

3.2 Flood Mitigation Plan

3.2.1 Planning Conditions

1) Flood Protection Level

A scale of 100-years flood frequency is adopted for the design of embankment since the existing embankment in Dhaka West has been constructed with the same protection level.

2) Flood Protection System

A compartmentalization system by sub-embankment and flood wall proposed by FAP-8B along spine road is applied with due consideration of the bigger drainage size of whole area of 166.3 km^2.

3) Design High Water Level (H.W.L) and Design Top Levels of Poldering facilities

The design high water levels corresponding to 100-year flood recurrence and the design top levels of the embankment, sub-embankment and flood wall adopted in this study are shown below :

Place	H.W.L. (m PWD)		Top EL (m PWD)
Tongi	8.60	Embankment	9.80
Patira	7.99	Embankment	9.19
		Sub-Emb. (SA)	8.59
		Flood Wall. (R)	8.59
Nigur Aplaid	7.73		
		Embankment	8.93
		Sub-Emb. (SB)	8.33
		Flood Wall. (R)	8.33
Outlet of Begunbari	7.60		
		Embankment	8.80
		Khal	
		Sub-Emb. (SC)	8.20
		Flood Wall (R)	8.20
Demra	7.40	Embankment	8.60

While the freeboard of sub-embankment, 60 cm is determined as half of the main embankment with due consideration of the occurrence chance of breach, implementation schedule and the flood condition of the future flood plains.

3.2.2 Polder Facilities Plan

1) Route of Poldering Facilities

The embankment alignment is planned along Balu river as proposed by GOB in the Phase II program.

About ten percent (10%) of the required land has been acquisited by this present time by the BWDB and the remaining land acquisition procedure has been stopped so far because the FAP studies related to the matter is being conducted. The acquisited land portions are shown in Fig. E.3.5.

The sub-embankments are basically designed along the existing roads with due consideration of sub-soil conditions and future transportation system.

However, on the places nearby urbanized areas the routes are determined so as not to involve the displacement of residences as much as possible.

(1) Sub-Embankment

Considering the above, the alignment of sub-embankment is designed as follows :

1. Sub-Embankment : SA

   The alignments are designed along the existing road from Patira at Balu river to Khilkhet at the spine road for the sub-embankment.

2. Sub-Embankment : SB

   The alignments are designed along the existing road from Nigur Aplaid at Balu river site to Shahajadpur at the spine road.

3. Sub-Embankment : SC

   The alignments are designed along the Begunbari Khal from Balurpar to Rampura at the spine road.

(2) Flood Wall (R)

The alignment of flood wall is designed by FAP-8B along existing spine road from Tongi railway bridge to Saidabad (see Fig. E.3.5).

2) Longitudinal and Standard Cross-Sections

The longitudinal profile of the embankment is determined based on the design high water levels (H.W.L) at Tongi and Demra. The design top level of embankment and sub-embankment are accordingly obtained by adding 1.2 and 0.6 m of the freeboards respectively. The gradient of the main embankment ranges about 1 in 23,000, while the sub-embankment is designed in horizontal lines (see Fig. E.3.6(1) to E.3.6(3)).

The standard cross-section of the embankment is to be a compound cross-sections with berms on both river and land sides.

A ditch is also designed along the embankment of the land side in order to protect the foot portion of the embankment from some local scouring by stromwater flows.

For most streches of the embankment, foundation treatment is required due to poor soil condition. The detailed study is made in Supporting Report F.

The following dimensions of the standard embankment section are determined with due consideration of stability and maintenance :

Crest width	:	4.0 m
Side slope	:	1 V : 3 H
Berms	:	River side - 3.0 m
		Land side - 5.0 m

Revetment is designed in order to protect the bank toe and the slope from scouring by tractive forces due to mainly wave action and current flow pressure, etc.

The revetment is applied to some streches of the embankment.

The protection level by the revetment is determined by referring the erosion conditions of the existing embankment. The revetment is to be provided from the toe of embankment to top of the embankment.

The sub-embankment is also designed with berms, but is symmetrical the shape (see Fig. E.3.7).

The major dimension of the sub-embankment is the same with that of the embankment, however no revetment is applied taking small occurrence chance of breach into consideration.

The empoldering structure along spine road / railway is designed in a type of flood wall by considering the small raised height from the road / railway top and available space. The proposed flood mitigation facilities are summarized in Table E.3.

3.2.3 Sluice Gates

1) Location

Sluice gates are principally planned at crossing points of existing khal and proposed pump station. Some small drainage areas are integrated and to be drained by minimum number of sluice gates from view point of construction cost and easy maintenance.

The sluice gate without pump station is planned on.

- The ground level of the basin is to be totally higher than the design river water level of corresponding 2-year flood frequency, so that the basin is to be free from inundation by annual floods.

The sluice gate with pump station is generally applied to the basins where low-lying area is prevailing and reclamation is not feasible from economical aspects.

A total of 4 sluice gates with pump stations and 3 sluice gates without pump station are planned along the Balu River embankment and Sub-embankment, SA. The locations of proposed sluice gates is shown in Fig.E.3.5.

2) Main Features of Sluice Gates

Two types of sluice gates, i.e. (1) Box Culvert Type and (2) Open Channel Type are considered for design selection.

The selection of open channel type is only applied in the condition that the drainage channel / khal might be used for navigation.

Except the above condition, box culvert type is basically applied in view point of construction cost, and easy operation and maintenance.

The flow area of box culvert type sluice gates is determined based on the design discharges and its design velocity of 2.5 m/s.

However, the minimum size of flow area is to be more than 1 m^2 with due consideration to maintenance.

The elevation of outlet is determined referring to the existing bottom level of khals.

The main feature of proposed gates are summarized below :

No.	Sluice Gate No.	Station No.	Name of Khal	Type of Structure	Design Discharge (m3/S)	DL. of Outlet (m in PWD)	Remarks
1	14	E.68+150	KD-4	Box	22.57	+2.45	-
2	15	E. 55	KD-3	Box	37.34	+2.45	-
3	16	E. 45+320	Boalia Khal (KD-1)	Box	83.13	- 0.7	Pump Station : P. 5
4	17	E. 28+150	Jamair Khal (KD-5)	Box	114.61	- 1.0	Pump Station : P. 6
5	18.A	E. 11+340	Begunbari Khal (KD-11)	Box	129.49	- 1.3	Pump Station : P. 7A
6	18.B	E. 8+90	KD-14	Box	140.67	- 1.3	Pump Station : P. 7B
7	Sub-1	SA11+100	KD-5	Box	83.2	+ 0.64	Sub. Sa

3.3 Stormwater Drainage Improvement Plan

3.3.1 Present Conditions of Drainage Area

1) Drainage Area and Drainage System

In Master Plan study, Greater Dhaka area of approximately 260 km^2 surrounded by four rivers, Buriganga, Turag, Tongi and Balu rivers was identified as one of the priority areas. The area was finally divided into two zones, Greater Dhaka East of about 119 km^2 and Greater Dhaka West of about 141 km^2 and these feasibility studies was decided to conduct by JICA and ADB respectively.

As shown in Fig. E.3.8 most central part of Dhaka city of about 48 km^2 in Greater Dhaka West area including Motijheel commercial area, Dhanmondi residential area, Tejgaon industrial area and Gulshan-Banani high class residential area is drained into East area through the several khals. So, the actual drainage area of the study consists of the following two areas with a total area of 166.36 km^2.

- Greater Dhaka East : A = 118.62 km2 (F/S area)
- Part of Greater Dhaka West : A = 47.74 km^2 (Drainage Related area)

The existing built-up area of 66.7 km^2 (approx. 40% of the total area) situated above 6.0 m PWD is projected to be 95.7 km^2 (approx. 58% of the total area) in 2000 and 132.4 km^2 (approx. 80% of the area) in 2010. Almost 54% of the total drainage area is low-lying area situated in the eastern part of the area and is mainly used as an agricultural land in dry season. The population is estimated to be approximately 2.15 x 10^6 in 1990, 2.96 x 10^6 in 2000 and 4.47 x 10^6 in 2010. Table E.3.4 shows the present and future land use and population of the drainage area.

Stormwater collected by drainage pipes or open ditches is drained through the khals : Segunbagicha, Geraini, Begunbari, Jamair and Boalia khals into the Balu River by gravity flow. There are no pumping station. In flood season between June and November, the low-lying areas are under the flood water with a maximum depth of about 3.5 m because no embankment is provided for the overflow from the Balu River.

2) Drainage Facilities

The existing major drainage facilities consist of drainage pipes, khals and related structures. No pumping station is provided in Greater Dhaka East.

(1) Drainage Pipe

Drainage Related area of about 48 km^2 in Greater Dhaka West has been installed with drainage pipes of about 76 km in length corresponding to almost 70% of a total length of drainage pipes in the city of Dhaka. Pipe diameter ranges from 0.3 m to 3.0 m. The drainage pipes are made of brick with diameters from 1.2 m to 3.0 m, and of reinforced concrete with diameters below 1.2 m. The location of the trunk drainage pipes is shown in Fig. H. 2 in the Supporting Report H of Master Plan study.

No drainage pipes are provided in Greater Dhaka West of 118.62 km^2 .

(2) Khal

There are 6 major khals with a total length of about 20 km in Drainage Related area. These khals are listed below :

- Gulshan - Banani khal : l = 5,000 m
- Mohakhali khal : l = 3,200 m
- Begunbari khal : l = 5,800 m
- Paribag khal : l = 1,000 m
- Segunbagicha khal : l = 3,000 m
- Khilgaon - Basabo khal : l = 1,400 m

Stormwaters of part of Greater Dhaka West area collected by drainage pipes or open ditches are drained into the Greater Dhaka East through the above khals.

On the other hand, there are a number of major khals totalling 59.5 km long in Greater Dhaka East. Major khals including Begunbari, Gerani, Jamair and Bolia khals function both to drain stormwater for the Balu River and to supply irrigation water for paddy field or cultivated areas in dry season.

Existing drainage capacities of 27 major khals shown in Fig. E.3.8 are calculated based on the longitudinal and cross sectional survey results of the khals. According to the calculation results shown in Table E.3.3, khal sections having a required specific discharge capacity of approx. 8 $m^3/s/km^2$ are very few. These are mostly less than 3 $m^3/s/km^2$ and shall be improved to have an adequate discharge capacity.

3.3.2 Planning Policy and Criteria

1) Planning Policy

A planning policy for preparation of stormwater drainage improvement plan are briefly summarized below :

- Plans are to be prepared to meet the population and land use in the target year 2010. The whole area to be planned is approximately 119 km^2. The population and built-up area in 1990 and 2010 of the drainage area are shown in Table E.3.4.

- FAP 8B project (DIFPP) is on-going by financial assistance for ADB as mentioned in Section 2. Some khals in Greater Dhaka East for which khal improvements are proposed to be implemented by DIFPP, are to be excluded in this project. Location and list of the excluded khals are shown in Fig. E.3.9.

- Scope of countermeasures for the existing built-up areas are construction of pumping stations with retarding ponds, and improvements of khals and trunk drains to mitigate the existing internal flood damage. Secondary and tertiary drainage pipes are excluded in the proposal, taking into account that the investment for project implementation must be reasonable.

- For the future urbanized areas, only pumping stations with retarding ponds and improvements of trunk khals are to be proposed as countermeasures. Land acquisition will be recommended for the proposed countermeasures except the retarding ponds, for which it will be proposed that the required areas be preserved by land use regulation, in order to limit the project cost.

2) Planning Criteria

(1) Design Flood Water Level

The existing built-up areas in the study area are mostly formed on the high lands over 6.0 m PWD, which are free from habitual floods. Further built-up areas are, however, mostly expected to develop on the surrounding low lands below 3.5 m PWD, which will be protected from the external floods by the polder dikes.

Considering the above, the pump drainage system, which is more uneconomical than the gravity one, shall be adopted for the most part of the future built-up areas. So, in order to adopt a more efficient and economical pump drainage system, it is proposed that the frequent flood water level with 2-year return period is employed as the design outlet water level for demarcation of a gravity and pump drainage system.

The following design flood water levels are applied for each drainage area or zone based on the calculation results of probable water level at Tongi (BWDB Sta. 299) and Demra (BWDB Sta. 7.5) gauging stations. They are as follows :

- DC 1-A sub-zone : 6.40 m PWD
- DC 1-B sub-zone : 6.25 m PWD
- DC 2-C sub-zone : 6.15 m PWD
- DC 3-B sub-zone : 6.05 m PWD
- DC 4-B sub-zone : 6.00 m PWD

Note : Location of sub-zone is shown in Fig. E.3.1.2.

The pump equipment is designed to be operated during the flood of a 100-year flood frequency. Considering about 2 m difference in water levels between the floods of a 2-year and a 100-year flood frequency, the flood water level at the highest pump efficiency of 100% will actually be higher than that of a 2-year frequency flood.

The pump will be designed based on the most effective water level equivalent of the annual maximum water level on average which is equivalent about 2.3 - 2.8 return period.

(2) Design Rainfall

Considering that the investment for project implementation must be reasonable, the design rainfall for drainage facilities is usually adopted from an appropriate scale of rainfall occurrence. In this study, the following criteria are proposed from a practical point of view :

- For pumping Station and Retarding Pond

  2 day consecutive rainfall with a 5-year return period is applied as the design rainfall for required pumping capacity and retarding pond volume. The design rainfall and its hourly distribution are presented in Fig. E.3.10.

- For Khal Improvement and Trunk Drain

  The rainfall intensity with a 5-year frequency is employed for the design of trunk drains and khal improvements. The rainfall intensity to be applied for the Rational formula is calculated by the following two formulae :

  $i = 9005/t+50$ ..... ($t \leq 2$ hr)
  $i = 12437/t+115$ ..... (2 hr $< t <$ 24 hr)

  Where, i : Rainfall intensity (mm/hr)
  t : Duration (min)

  The applied rainfall intensity-duration curve is shown in Fig. E.3.11.

- Areal Reduction Factor

The above design rainfalls are made based on the point rainfall data at Dhaka station (B.M.D.). For the calculation of the design discharge, the areal reduction factor is to be considered. The areal reduction curves are illustrated in Fig. E.3.11.

(3) Run-off Coefficient and Run-off Ratio

The following values of run-off coefficient by land use projected for the target year 2010, are used for calculation of the design peak discharge by the Rational formula :

Land Use	Runoff Coefficient
Commercial Area	0.65
Industrial Area	0.55
High Class Residential Area	0.30
Middle and Low Class Residential Area	0.50
Green Zone and Others	0.20
Water Bodies	1.00

The runoff ratio (total runoff/total rainfall) of 0.80 is employed for estimating required pump capacity and retarding pond volume.

(4) Drainage Criteria

From both technical and economical point of view, short duration internal flooding with a low flood damage will be allowable. For pump drainage area, 2-days discharge period by pump is recommended.

3.3.3 Zoning

The drainage area of 166.36 km2 covers Greater Dhaka East (118.62 km2) and 47.74 km^2 of Greater Dhaka West (142.90 km2), which covers most part of Dhaka City. Apart from the small areas in the north, where drainages flow into the Tongi khal, the area that drains into the Balu River through the major khal systems consisting of the Segunbagicha khal, the Gerani khal, the Begunbari khal, the Jamair khal and the Boalia khal are shown in Fig. E.3.8.

As shown in Fig, E.3.12, the area is divided into four (4) drainage zones of DC-1 to DC-4 and nine (9) sub-zones considering the existing topographic condition, khal systems, road networks and the proposed four (4) compartments by embankments or sub-embankments.

Drainage areas by zone or sub-zone including main khal of each zone are listed as follow :

Zone	Sub-Zone	Area (km^2)	Name of Major Khal
DC-1	DC 1-A	8,45	
	DC 1-B	22.11	Nali River, Boalia Khal
	Sub-total	30.56	
DC-2	DC 2-A	5.71	
	DC 2-B	10.13	Jamair Khal
	DC 2-C	32.04	
	Sub-total	47.88	
DC-3	DC 3-A	32.01	Begunbari Khal, Gulshan Banani Khal
	DC 3-B	14.57	Begunbari Khal
	Sub-total	46.58	
DC-4	DC 4-A	10.02	Segunbagicha Khal
	DC 4-B	31.32	Gerani Khal
	Sub- total	41.34	
	Total :	166.36	

Note : 1) Refer to Fig. E.3.12

2) Stormwater of sub-zone DC 2-A is drained through sub-zone DC 2-B, which is part of the Northern compartment, into the Central compartment of sub-zone DC 2-C.

3.3.4 Countermeasures

Stormwater drainage countermeasures are proposed for each four zones with a whole area of approx. 119 km^2. As almost 80% of the area is still unurbanized, the proposed measures will consist of the followings :

- All the required pumping stations with retarding ponds
- Trunk khal improvements

Lateral drains and tertiary drainage pipes are excluded. Because a beneficial effect of lateral drains and tertiary pipes will be expected only after completion of the connected major drainage works in newly developed area.

Land acquisition of the proposed pumping stations and khal improvements are required for protection from illegal land development by the private sector. For the retarding ponds, however, land use regulation will be necessary to preserve their storage capacity and to limit the pump capacity.

3.3.5 Pump Drainage Plan

1) Pump Drainage Area

According to the existing topographic condition and the design flood water levels of a 2-year frequency flood, each drainage zone except sub-zone of 8.45 km2 in the northern part of DC-1, needs a pump drainage system. Gravity drainage system is adequate only for the sub-zone of DC 1-A. Pump drainage areas are summarized as below ;

Zone	Pump Drainage Area (km^2)	Gravity Drainage Area (km^2)	Total (km^2)
DC-1	22.11	8.45	30.56
DC-2	47.88	-	47.88
DC-3	46.58	-	46.58
DC-4	41.34	-	41.34

Note : 1) Refer Fig. E.3.12

2) Pump Operation Period

Climate of Dhaka and Narayanganj area is classified into the following three seasons ;

- monsoon season : May. to Oct., R = 1.825 mm
- cool season : Nov. to Feb., R = 60 mm
- hot season : Mar. to Apr., R = 175 mm

Almost 90% of the annual rainfall of 2,060 mm occurs during the season from May to October based on the rainfall data from 1953 to 1990. Maximum monthly rainfall of approx. 400 mm occurs in June. Variation of monthly rainfall is illustrated in Fig.E.3.13.

On the other hand, flood water levels of surrounding rivers start to rise in April, reach to a peak in mid. August and then fall down to February. Considering the relation between an average ground elevation of low-lying area (3.0m to 3.5 m PWD) in Greater Dhaka East and variation of annual monthly flood waters of Tongi Khal and Balu River, it can be noted that the required pump operation period will be at least five (5) months between June and October in very year as shown in Fig.E.3.13.

3) Required Pump and Retarding Pond Capacities

The application of retarding pond in urban stormwater drainage system economizes the total pump drainage cost by reducing the required pump capacity and khal cross section dimension.

Specific requirements of pump capacity and storage volume of retarding pond are estimated by utilizing the following storage basin model under the applied design criteria.

$$I - O = \frac{DS}{dt} \quad \text{..... (1)}$$

$$I = 10 \times f \times Rt \times A \quad \text{..... (2)}$$

$$O = Qp \times dt \quad \text{..... (3)}$$

Where,
- I : Inflow volume due to rainfall during dt (m^3)
- O : Outflow volume due to pumping during dt (m^3)
- dt : Calculation time interval
- S : Storage volume of retarding pond (m^3)
- f : Run-off ratio (0.8)
- A : Catchment area (ha)
- Rt : Rainfall during dt (mm)
- Qp : Pump discharge volume during dt (m^3)

As the calculation results, specific requirements of both facilities are to be 1.14 $m^3/s/km^2$ and 0.120 x 160 m^3/km^2 respectively as shown in Fig. E.3.10.

The required pump capacity and the storage volume of retarding pond of each pump drainage area are summarized below ;

Zone	Area (km^2)	Required Pump Capacity (m^3/s)		Required Storage Volume of Retarding Pond ($x10^6m^3$)	
		Specific	Total	Specific	Total
DC-1	22.11	1.14	25.6	0.12	2.65
DC-2	47.88	1.14	54.6	0.12	5.75
DC-3	46.58	1.14	53.1	0.12	5.59
DC-4	41.34	1.14	47.2	0.12	4.96
Total :	157.91	-	180.5	-	18.95

4) Proposed Pumping Station

(1) Proposed Site

In view of the existing khal conditions and the economic efficiencies, the pumping station having the required capacity is proposed for each drainage zone at the crossing of the trunk khal and the proposed embankment along the Balu River. Their locations are shown in Fig.E.3.14 and listed below :

Sub-Drainage Area	No. of Pumping Station	Station No. of Embankment	Name of Khal
DC - 1	P5	E 43+320	KD-1 (Boalia Khal)
DC - 2	P6	E 28-150	KD-5 (Jamair Khal)
DC - 3	P7A	E 11-340	KD-11(Begunbari Khal)
DC - 4	P7B	E 8-90	KD-14

(2) Design Water Level of Pump Station

The frequent flood water level with 2-year return period is basically applied as the design outlet flood water level (H.W.L.) of the pumping station, considering employment of a more efficient and economical pump drainage system. However, the pump equipment shall also be operated during 100-year frequency flood (H.H.W.L.), which is the design water level for flood embankment.

The average monthly water level of about 3.0 m PWD at the beginning of June (beginning of flood season) and end of October (end of flood season), is employed as the design outlet L.W.L. for the proposed pumping stations.

On the other hand, inner design L.W.L. and H.W.L. of the pumping stations shall meet the requirements of the proposed retarding ponds, which are 3.0 m and 4.0 m PWD respectively. These are described in next section.

The design and maximum static head for the pump equipment is calculated as follows;

- Design Static Head : H.W.L. of Balu River - L.W.L. of Inland
- Max. Static Head : H.H.W.L. of Balu River - L.W.L. of Inland

Table E.3.6(1) shows hydraulic requirements of the proposed four (4) pumping stations

5) Proposed Retarding Pond

(1) Proposed Site

The proposed sites of the retarding ponds are selected under the following concept.

- a vast low-lying area below 3.0 m PWD
- a low potential area for urban development
- an area with required for hydraulic effect
- an area with possibility of land use regulation

Number of the proposed sites of the retarding pond for each drainage zone is as follows :

DC - 1 : 2 sites (RP 5-1 and RP 5-2)
DC - 2 : 1 site (RP 6)
DC - 3 : 1 site (RP 7-1)
DC - 4 : 2 sites (RP 7-2 and RP 7-3)

Location of the above sites are shown.in Fig.E.3.14.

(2) Design Water Level and Area of Pond

The design L.W.L. of the retarding pond during flood season is proposed to be 3.0 m PWD due to the following consideration.

- to meet average ground elevation of the proposed site of the retarding pond
- to meet average water level of Balu River at the beginning and end of flood season as shown in Fig.E.3.13.

On the other had, the design H.W.L. of the retarding pond is related with the design L.W.L., the required storage volume and area of the pond. In this study, the design H.W.L. is proposed to be 4.0 m PWD taking into account of the case study results in Master Plan study.

The require area of retarding pond is estimated by the following formula;

$$A = \frac{S}{H.W.L - L.W.L}$$

Where, A : required area of retarding pond (m^2)
S : required storage capacity of retarding pond (m PWD)
H.W.L. : Design high water level of retarding pond (m PWD)
L.W.L. : Design low water level of retarding pond (m PWD)

Calculation results are shown in Table E.3.6(2).

3.3.6 Khal Improvement Plan

1) Design Discharge

(1) Division of Sub-drainage Zone

In order to estimate the design discharge at several distinct points of the khals for preparation of more deep khal sections, each drainage zone is divided into several sub-drainage zones taking into account of the existing topographic conditions and the proposed drainage khal networks. The number of sub-drainage zones are as follows :

DC - 1	Zone	:	9	sub-zones
DC - 2	Zone	:	15	sub-zones
DC - 3	Zone	:	12	sub-zones
DC - 4	Zone	:	19	sub-zones
Total	Zone	:	55	sub-zones

Fig. E. 3.15 shows the proposed khal networks and divided sub-drainage zones.

(2) Run-off Coefficient.

Run-of coefficients of sub-drainage zones are estimated based on the proposed standard run-off coefficient and the projected land use in 2010 shown in Table E.3.7.

Estimated run-off coefficients by sub-zone are shown in Table E.3.8 and Fig. E.3.15.

(3) Design Discharge

For the hydraulic design of khal improvement, flood run-off estimation has basically been made by Rational Method considering the following reasons ;

- Khal improvements are to be planned to meet the land use in 2010, during which almost 80% of the catchment area is projected to be urbanized.

- Rational method is one of famous, simple and reasonable methods for estimation of peak run-off of the khals in urbanized area.

- Application of unit hydrography model, Mike 11 NAM model and other mathematical models, of which formula have some hydrological parameters, will not be possible in this study. Because, at this stage, available hydrological data can not be obtained for calibration, which is necessary to fix the adequate value of hydrological parameters for these models.

Applied Rational formula is as follows :

$$Q = 360\ C \times I \times A$$

Where, Q : peak run-off (m3/s)
C : run-off coefficient
I : average rainfall intensity during time of concentration

Time of concentration (Tc) expressed in minutes is;

$$Tc = T\,in + L/V$$

Where, T in : in flow time of rain water (min.)
L : length of khal (m)
V : average velocity of khal (m/s)

In this study, the value of Tin and V for the khal are adopted 20 as minutes and 0.8 m/s respectively.

However, Rational formula is not able to calculate accurate run-off of the downstream stretches from the retarding pond in consideration of the hydraulic storage effect of the retarding pond. The run-off calculated by Rational formula will be larger than the actual run-off.

Accordingly, the design discharges of some trunk khals located at the downstream stretches from the retarding pond, are reviewed and modified by utilizing the hydraulic simulation results of Mike 11, details of which are mentioned in Supporting Report D.

The design discharges for the khal improvements are shown in Table E.3.9 and Fig. E.3.16.

2) Proposed Khal Improvement

As the design discharges of the most existing khals do not meet the design discharges, khal improvements by widening and dredging are required.

Planning concept for longitudinal and cross sections of the khals to be improved are as follows ;

(1) Bed elevation at the mouth of the khal is planned to be same or higher than that of Balu River.

(2) Khal bed slope is planned to be nearly same as the existing one.

(3) Whenever there is a change in khal bed slope, the ratio of variation between downstream slope and upstream slope is planned to be within 0.5.

(4) The following two types of khal cross section are proposed :

- Type (1) : Trapezoidal shape with 1:2 slope protected by sodding
- Type (2) : Trapezoidal shape with 1:1 slope protected by brick

Type (1) is applied for khal sections situated in existing agricultural land where comparatively easy land acquisition is expected. Type (2) are proposed for khal sections located in existing built-up areas where land acquisition is likely to be difficult.

Table E.3.10 shows the hydraulic design of khal improvements. Fig. E.3.17(1) to (4) illustrate the proposed longitudinal and cross section of the trunk khals of each drainage zone, KD-1, KD-5, KD-11 and KD-14 respectively.

As related structures, twelve (12) road bridges and one (1) railway bridge are planned to be reconstructed or newly constructed at the khal crossing with road and railway. Location of the proposed related structures are shown in Fig. E.3.18. Details of these structures are mentioned in Supporting Report F.

The proposed khal improvement works are shown in Table E.3.11 and Fig. E.3.19 and summarized below :

Zone	Open Channel (km)		Road Bridge (place)	Railway Bridge (place)
	Type (1)	Type (2)	New Construction	Reconstruction
DC - 1	12.70	-	-	-
DC - 2	24.30	-	8	1
DC - 3	12.10	-	-	-
DC - 4	21.90	2.0	4	-
Total :	71.00	2.20	12	1

4. Narayanganj Area - 1 (DND Triangle Area)

4.1 Flood Mitigation Plan

4.1.1 Planning Conditions

1) Existing Facilities

DND area is surrounded by flood wall and railway-cum-embankment. The I-shape concrete flood wall was built along the ring road of DND area after the 1988 floods.

The design top level was basically set at the level of 1988 flood water level plus 2 feet.

Accordingly, most portion of flood wall have a capacity of more than 50 years recurrence floods in terms of flood water level.

From the structural view point, the most part of the flood wall were evaluated as tentative structures due to its strength against expected external loads by heavy vehicle.

The railway track from Chasara to the crossing point at Demra road was heightened upto about 6.8 m to 7.4 m in P.W.D for flood protection purpose.

While, the 1988 flood water level at Launch Terminal of IWTA of Lakhya river is measured about 6.6 m PWD.

This railway top elevation is corresponding about 50 year flood frequency in terms of flood protection capacity.

The total length of the flood wall and railway-cum-embankment is measured at 31.5 km in length (see Fig. E.4.1).

2) Flood Protection Level and Improvement Requirements

DND area has been developed as agricultural project area. However, after the 1988 floods, DND area has been rapidly developed mainly due to existence of flood mitigation and stormwater drainage facilities and short distance to Dhaka centre area and surrounding industrial area.

Some land development projects by both RAJUK and Private sectors have been carried out in the DND area. A trunk road construction in the centre portion by RHD is being constructed.

By considering above social condition, the flood protection level is set basically at more than 1988 floods or 100-year flood occurrence level.

Most part of the existing flood wall is satisfied both to the design height and its strength against flood water pressure.

However, rehabilitation works is required for some portion according to the shortage of height and disturbed foot conditions of existing flood wall.

3) Flood Protection System

DND area may be protected by double polder on the eastern part when the embankment / flood wall of Narayanganj West is completed.

In this stage, flood protection is to be considered as one polder system, and the outer polder of Narayanganj area is to be considered as main polder.

4) H.W.L and Top Level of Polder

The design high water levels corresponding to 100-year flood recurrence or more are to be adopted for DND area. The design top levels of the flood wall are shown below :

Route/Location	H.W.L (m P.W.D)	Top E.L. (m P.W.D)	Remark
1. Chasara to Buriganga Bridge (DW)			
- Chasara(DW.0)	6.96	7.56	-----
- Panchabati(DW.6+200)	7.20	7.80 100-year	More than
- Buriganga Bridge(DW.27)	7.80	8.40	-----
2. Buriganga Bridge to Demra (DN)			
- Buriganga Bridge(DN.0)	7.80	8.40	-----
- Jatrabari(DN.6)	7.80 / 7.40	8.40 / 8.00	-----
- Demra (DN.22)	7.40	8.00	-----
3. Chasara to Hajiganj (DS)			
- Chasara (DS.0)	6.96	7.56	-----
- Hajiganj (DS.6)	6.96	7.56	-----
4. Hajiganj to Demra (DE)			
- Hajiganj (DE.0)	6.96	7.56	-----
- Existing Pump Station (DE.18)	7.29	8.49	-----
- Demra (DE. 26)	7.40	8.00	-----

4.1.2 Polder Facility Plan

1) Rout of Flood Wall

The existing flood wall is to be used for flood mitigation facility and only short distance of re-construction and rehabilitation work of the existing flood wall is designed for DND area.

For this reason, the alignment of flood wall is basically not changed from the existing one.

The alignment of existing flood wall is shown in Fig. E.4.1.

2) Longitudinal and Standard Cross-Sections

The longitudinal profile of the flood wall is decided based on the design high water levels. The design top level of the flood wall are accordingly obtained with the design high water level by adding 0.6 m of the freeboard (Fig. E.4.2).

The proposed rehabilitation work is classified into the following works according to the existing flood wall condition.

1. Heightening the wall
2. Strengthening of foot portion.
3. Repairing of damaged portion of flood wall.

The existing flood wall and typical rehabilitation works are shown in Fig E.10.

4.1.3 Sluice Gate

1) Location.

One sluice gate is planned at the proposed pump station of Adamjee Nagar. The location is shown in Fig. 4.1.

2) Main Features of Sluice Gates

A culvert type sluice gate is selected in view points of construction cost, operation and maintenance work.

The main feature of the proposed gate is shown below :

No.	Sluice Gate No.	Station	Name	Design Discharge (m3/S)	DL. of Outlet (m in PWD)	Remarks
1	20	DE. 10+300	KN-4	143.5	-1.4	Pump Station

4.1.4 Stop Log Structure

There are many openings on the existing flood wall. The openings are being used for private and publics for entrance to the ring roads.

As a crossing structure of the openings during the flooding period, stop log structure is planned for DND area. This stop log is designed only the entrance of public use.

For smaller openings less than 5m in width or 1.0 m in height, some simple counter measures such as sand bags, timber stopper are to be considered.

A total of 17 stop log structures are planned and the proposed location is shown in Chapter of "Preliminary Design".

4.2 Stormwater Drainage Improvement Plan

4.2.1 Present Condition of Drainage Area

1) Drainage Area and Drainage System

DND area of 56.79 km^2 is of triangular shape and surrounded by three major roads : The Demra road to the north, the Dhaka-Narayanganj highway to the west and south, and the Demra-Narayanganj highway to the east. The area has been developed as an agricultural land since 1968 by BWDB, and protected by the peripheral road-cum-embankment as polder dikes from floods of the Buriganga, Dhaleswari, Balu and Lakhya rivers. However, the area is rapidly changing to an urban area due to its high potentiality for development. Apart from a small area in the south and built-up areas on the north-west, the ground elevation of DND area is mostly less than 5 m PWD. Large areas in the center and east area below 2.5 m PWD.

The existing built-up area of 21.74 km^2 (approx. 38% of the area) is projected to be 36.14 km^2 (approx. 64% of the area) in 2000 and 42.70 km^2 (approx. 75% of the area) in 2010 . The population is estimated to be 0.45×10^6 in 1990, 0.88×10^6 in 2000 and 1.31×10^6 in 2010. Table E.4.2 shows the present and future built-up area and population of the DND area.

The entire area is crisscrossed by irrigation and drainage channels. The stormwater collected by open ditches is conveyed to Khasder Ghoshpara near the Katchpur bridge by the major khals under one drainage basin, and discharges into the Lakhya River through the Demra pumping station as shown in Fig. E.4.6.

2) Drainage Facilities

The existing major drainage facilities are classified into khal, pumping station and related structures. No drainage pipe is provided in the DND area.

(1) Khal

There are eighteen (18) major khals with a total length of 34.7 km as shown in Fig. F.4.6. These khals collect stormwater and surplus water from paddy field through the connected secondary channels, and convey them to the Demra pumping station.

Existing drainage capacities of the khal are calculated based on the longitudinal and cross-sectional survey carried out by the study team. Calculation results are shown in Table E.4.3. The existing khal sections are mostly insufficient for the future requirements, which can carry only a specific discharge of 8 $m^3/s/km^2$. Khal improvement by widening and dredging will be necessary for future development.

(2) Demra Pumping Station

This pumping station was constructed by BWDB in 1968 in connection with DND irrigation project. It serves both as a stormwater drainage and as an irrigation facility for the DND project area. The specifications of the pumping station are as follows :

- Total design discharge : 3.63 m3/s x 4 unit = 14.52 m3/s
- Design H.W.L. (suction side) : 1.8 m PWD
- Design L.W.L. (suction side) : 1.0 m PWD
- Design H.W.L. (discharge side) : 5.94 m PWD
- Pump head : 4.9 m
- Pump type : Vertical axial flow pump
- Pump diameter : 1300 mm
- Number of pump : 4 units

Fig. E.4.7. shows the plan and section of the existing Demra pumping station.

According to the annual operation record between 1970 and 1989 shown in Table E.4.4, annual operation hour and five (5) months operating hour between June and October for irrigation and stormwater drainage works are as follows :

- For irrigation

  Annual : Max. = 5,099 hr, Min. = 2,382 hr, Ave. = 3,114 hr
  5 months : Max. = 693 hr, Min. = 146 hr, Ave. = 415 hr

- For stormwater drainage

  Annual : Max. = 7,921 hr, Min. = 2,160 hr, Ave. = 4,827 hr
  5 months : Max. = 7,214 hr, Min. = 2,059 hr, Ave. = 4,223 hr

So, annual operating hour per one pump is approx 1,200 hr in average for stormwater drainage works.

Through the field investigation, it is found that the pump equipment is sometimes not operated because of stoppage of power supply. It is required to connect an additional power line or to install a generator with enough capacity.

4.2.2. Planning Policy and Criteria

1) Planning Policy

A planning policy for preparation of stormwater drainage improvement plan are briefly summarized below :

- Plans are to be prepared to meet the population and land use in the target year 2010. The whole area to be planned is approximately 57 km^2. The population and built-up area in 1990 and 2010 of the project area are shown in Table E.4.2.

- Scope of countermeasures for the existing built-up areas are construction of pumping station with retarding pond, and improvements of khal and trunk drain to mitigate the existing internal flood damage. Secondary and tertiary drainage pipes are excluded in the proposal, taking into account that the investment for project implementation must be reasonable.

- For the future urbanized areas, only pumping station with retarding pond and improvements for trunk khals are to be proposed as countermeasures. Land acquisition will be recommended for the proposed countermeasures except the retarding ponds, for which will be proposed that the required areas be preserved by land use regulation, in order to limit the project cost.

2) Planning Criteria

(1) Design Flood Water Level

The design flood water levels of 2-year frequency are applied based on the calculation result of probable water levels at Demra (BWDB Sta. 179) and Narayanganj (BWDB Sta. 180). They are;

- NA - 1 zone : 5.75 m PWD
- NA - 2 zone : 5.65 m PWD

Note: Location of zone is shown in Fig. E.4.8.

The pump equipment is designed to be operated during the flood of a 100-year flood frequency. Considering about 2 m difference in water levels between the floods of a 2-year and a 100-year flood frequency, the flood water level at the highest pump efficiency of 100% will actually be higher than that of a 2-year frequency flood.

The pump will be designed based on the most effective water level equivalent of the annual maximum water level on average which is equivalent about 2.3 - 2.8 return period.

(2) Design Rainfall, Run-off Coefficient, Run-off Ratio and Drainage Criteria

They are applied all the same criteria as Greater Dhaka East (refer to Section 3.3.2, 2, Fig. E.3.10. and E.3.11)

4.2.3 Zoning

DND area is planned to be protected against the external flood from the Buriganga, Balu and Lakhya rivers by road-cum-embankment with concrete flood wall as shown in Fig. E.4.1.

In order to cope with the increasing run-off due to the future forecast urbanization, another pumping station which drains stormwater into the Lakhya River will be required. The area is proposed to be divided into two drainage zone, northern and southern zones (NA-1, NA-2) as shown in Fig. F.4.8, considering the topographic condition and the existing khal networks. Their drainage area and main khals are summarized below ;

Zone	Area (km2)	Main Khal
NA - 1	25.10	Shampur Khal
NA - 2	31.69	Pagla Khal, Fatualla Khal
Total :	56.79	

4.2.4 Countermeasures

Stormwater drainage countermeasures are proposed for the whole area of 56.79 km2. As almost 62% of the area is still an urbanized, the proposed measures will consist of the followings :

- All the required pumping stations with retarding ponds
- Khal improvements

However, lateral drains and tertiary drainage pipes are excluded in this project. Because a beneficial effect of these facilities will be expected only after the completion of the connected khals in newly developed areas.

Land acquisition of the proposed pumping station and khal improvement is required to prevent illegal land development by the private sector. For the retarding pond, however, land use regulation will be necessary to preserve their storage capacity and to limit the pump capacity.

4.2.5 Pump Drainage Plan

1) Pump Drainage Area

The existing built-up areas of approx. 22 km^2 are situated on the slight high land between 5 to 6m PWD. Remaining area of approx. 35 km^2 is low-lying, where ground

elevation varies from 2.5m to 5m PWD. The entire DND area of 56.79 km^2 needs to adopt the pump drainage system.

2) Pump Operation Period

As mentioned is Section 3.3.5, the required pump operation period will be at least five (5) months between June and October in every year. This situation is almost same as that of Greater Dhaka East.

3) Required Pump and Retarding Pond Capacity

A pump drainage system combined with retarding ponds is also recommended to economize the pump drainage cost by reducing the required pump capacity.

The required pump and retarding pond capacities are estimated based on the both specific requirements, P = 1.14$m^3/s/km^2$ and V = 0.0120x$10^6 m^3/km^2$ respectively as shown below :

Zone	Area (km^2)	Required Pump Capacity		Required Storage Volume of Retarding Pond	
		Specific ($m^3/s/km2$)	Total (m3/s)	Specific (m^3/km^2)	Total (m^3)
NA-1	25.10	1.14	28.6	0.12	3.01
NA-2	31.69	1.14	36.1	0.12	3.80
Total :	56.79	-	64.70	-	6.81

4) Proposed Pumping Station

(1) Proposed Site

In view of the continuous demand for irrigation in DND and the economized pump drainage cost, the existing Demra pumping station will be utilized in the plan. The existing pump capacity of 14.5 m^3/s is, however, less than the required pump capacity of zone NA-1 (28.6 m^3/s).

Since it is difficult to get the construction space for additional pump facilities at the Demra pumping station, the pump capacity of 14.1m^3/s is to be added to the new pumping station planned at Siddirgonj in Zone NA-2.

Location of the proposed pumping stations are shown in Fig.E.4.9 and listed below :

Sub zone	No. of pumping Station	Station No. of Embankment	Name of Khal
NA-1	P10 (Demra P.S)	DE 17+350	KN-1
NA-2	P11	DE 10+300	KN-4

(2) Design Water Level of Pumping Station

As topographic, hydrological and hydraulic conditions of DND area are very similar with those of Greater Dhaka East, the design water levels of pump station is planned to apply the same value as Greater Dhaka East pumping station, except the H.H.W.L. of the Lakhya River.

Hydraulic requirements of the proposed pumping stations are shown in Table E.4.5 (1).

5) Proposed Retarding Pond

(1) Proposed Site

The Proposed sites of the retarding ponds are selected under the following concept.

- a vast low-laying area below 3.0m PWD
- a low potential area for urban development
- an area with necessary hydraulic effect
- an area with possibility of land use regulation

A number of the proposed site of the retarding pond for each drainage zone is follow:

NA-1 : 3 sites (RP10-1, RP10-2 and RP11-3)
NA-2 : 3 sites (RP11-1, RP11-2 and RP11-3)

Location of the proposed six (6) sites are shown in Fig. E.4.9.

(2) Design Water Level and Area of Pond

The design L.W.L. of the retarding pond during flood season is planned to be 3.0m PWD due to the followings:

- to meet average ground elevation of the proposed site of the retarding pond
- to meet average water level of the Lakhya River at the beginning and end of flood season as shown in Fig. E.3.13.

On the other hand, the design H.W.L. of the retarding pond is proposed to be 4.0m PWD considering an effective storage depth of 1.0m which is same as that of Greater Dhaka East. Because topographic conditions of low-lying areas in DND and Greater Dhaka East are very similar.

Table E.4.5 (2) shows the hydraulic requirements of the retarding pond.

4.2.6 Khal Improvement Plan

1) Design Discharge

(1) Division of Sub-drainage Zone

In order to calculate the design discharges at several distinct points for preparation of more deep khal sections, each drainage zone is divided into approximately 20 sub-drainage zones based on the existing topographic condition and the proposed khal networks as shown in Fig. E.4.10. The number of sub-drainage zones are,

- NA - 1 : 17 sub-zones
- NA - 2 : 21 sub-zones
  Total : 38 sub-zones

(2) Run-off Coefficient

Run-off coefficient of each sub-zone is estimated based on the standard run-off coefficient by land use and the projected land use plan in 2010 mentioned in Supporting Report A. Estimated run-off coefficients by sub-zones are shown in Table E.4.6 and Fig. E.4.10.

(3) Design Discharge

Design discharges for khal improvements are calculated by Rational method, the same method as Greater Dhaka East.

As mentioned before, however, Rational formula can not be used to evaluate the hydraulic storage effect of retarding pond, by which the actual discharges of downstream stretches of the retarding pond will be decreased.

Accordingly the design discharges of some downstream stretches of the retarding pond are reviewed and modified by utilizing the hydraulic simulation results of Mike 11, details of which are mentioned in Supporting Report D.

The design discharges are shown in Table E.4.7 and Fig. E.4.11.

2) Proposed Khal Improvement

The discharge capacities of the existing khals in the DND area mostly do not meet the design discharge. Khal improvement by widening and dredging are required.

Planning concept for longitudinal and cross sections of the improved khals is as follows :

(1) Bed elevation at the mouth of khal is planned to be same or higher than that of Lakhya River.

(2) Khal bed slope is planned to be nearly same as the existing one.

(3) Ratio of upstream bed slope and downstream bed slope at inflection point is planned to be within 0.5.

(4) The following two types of khal cross section are proposed :

- Type (1) : Trapezoidal shape with 1:2 slope protected by sodding
- Type (2) : Trapezoidal shape with 1:1 slope protected by brick

Type (1) is applied for khal sections situated in existing agricultural land where comparatively easy land acquisition is expected. Type (2) are proposed for khal sections located in existing built-up areas where land acquisition is likely to be difficult.

Table E.4.8 shows the hydraulic design of khal improvements. Fig. E.4.12 (1) and E.4.12 (2) show the proposed longitudinal and cross section of khal No. KN-1 and KN-4 respectively.

As related structures, road bridge, railway bridge and aqueduct are planned to be reconstructed or newly constructed at khal crossing with road, railway, and irrigation canal. The number of related structures are as follows :

- Road bridge : reconstruction; 28 places, new construction; 6 places
- Railway bridge : reconstruction; 4 places
- Aqueduct : reconstruction ; 2 places

Location of he above structures are shown in Fig. E.4.13. Detailed of the related structures are mentioned in Supporting Report F.

The proposed khal improvement works are shown in Table E.4.9 and Fig. E.4.14, and summarized below :

Zone	Open Channel (km)		Road Bridge (place)		Railway Bridge (place)	Aqueduct (place)
	Type (1)	Type (2)	Recons-truction	New Construction	Reconstruction	Reconstruction
NA-1	15.80	8.10	9	3	0	1
NA-2	17.90	9.40	19	3	4	1
Total :	33.70	17.50	28	6	4	2

5. Narayanganj Area - 2 (Narayanganj West)

5.1 Flood Mitigation Plan

5.1.1 Planning Condition

1) Flood Protection Level

A scale of 100-year flood frequency is adopted for the design of embankment with due consideration of importance of the area and consistency with the flood protection level of DND area.

2) Flood Protection System

After the completion of polder facility along the Buriganga and Sitalakhya river, the flood protection system is to be one system for whole Narayanganj area.

Accordingly existing flood wall along the ring road / railway on the southern and eastern part become secondary flood mitigation facility.

3) Design High Water Level (H.W.L) and Design Top Level

A design high levels corresponding to 100-year flood recurrence are determined based on the result of statistic analysis of water level. The design top levels of the embankment and flood wall are calculated by adding freeboards of 1.2 m and 0.60 m respectively.

The H.W.L and design top levels at specific point are shown below :

Route/Location		H.W.L (m P.W.D)	Top E.L. (m P.W.D)	Remarks
1.	Narayanganj to Panchabati (NW)			
	Narayanganj(NW.0) Flood wall	6.80	8.00/7.40	Embankment/
	Panchabati(NW.29)	7.20	8.40	Embankment
2.	Narayanganj to Demra (NE)			
	Narayanganj(NE.0)	6.80	7.40	Flood Wall
	Adamjee Nagar Back Levee(NE.48)	7.10	7.70/8.30	Flood Wall/ Embankment
	Existing Pump Sta. Back Levee(NE.72)	7.29	8.49	Embankment
	Demra (NE.88)	7.40	8.60/8.0	Embankment/ Flood Wall.

5.1.2 Polder Facility Plan

1) Alignment of Polder

(1) Narayanganj to Panchabati (NW)

The embankment and road-cum-embankment type are planned from Panchabati to Narayanganj along Panchabati via Saiyedpur on western part. The road-cum-embankment along the existing road is planned to start from Saiyedpur and connected to the flood wall of DND area at Panchabati.

While the embankment is planned form Narayanganj to Saiyedpur.

(2) Narayanganj to Demra (NE)

The alignment composed of flood wall and embankment is planned from Narayanganj to Demra along Lakhya river.

This alignment is planned along the river bank in order to protect the existing buildings,industrial asset as much as possible.

The alignment is shown in Fig.E.5.1.

2) Alternatives of Flood Wall Type

(1) Alternatives

For the stretch from Narayanganj to Siddirganj Power station along the Lakhya river (NE), many houses, godowns, loading and unloading facilities etc. are densely located on the peripheral area of river bank. For this area, embankment type polder required wider space of construction is not much available. While, for the remaining strech the construction space for the the embankment construction is available.

Accordingly, the flood wall types applicable to this stretch may be the following 4 types (see Fig. E.5.2).

Type 1 : Concrete Wall I/T - type
Type 2 : Concrete Sheet Pile
Type 3 : Reinforced Concrete Retaining Wall
Type 4 : Concrete Block Retaining Wall

After the cost estimate I/T type which are proposed in the Master Plan is selected for the basic type of flood wall.

The main features of I type is described below :

This I or T types flood wall is planned in the Master Plan. This is to be constructed on the high land nearby buildings or the place of buildings after resettlement. The I type is applied for lower wall, while the T type is for higher wall. Both I and T type requires land acquisition, resettlement and its compensation.

(2) Longitudinal and Standard Cross-Sections

(a) Longitudinal Profile

The longitudinal profile of the road-cum-embankment (NW) is decided based on the design high water levels of Hariharpur and Rekabi Bazar water level Gauging stations.

The longitudinal profile of flood wall and embankment along Lakhya river also decided in the same manner of that western side polder. The H.W.L at Narayanganj down stream is decided based on the water levels of Kalagachia and Rakabi Bazar gauging stations and Demra for upstream. The freeboards adopted are 1.2 m for embankment and 0.6 m for flood wall.

b) Standard Cross Sections

The shape of standard cross-section of road-cum-embankment is almost the same geometry with the embankment (see Fig. E.5.4).

However, the road-cum-embankment is to be connected to the existing road space in addition to the berm on land side.

The standard cross-section of the embankment along Lakhya river is the same as that of Greater Dhaka East.

The standard cross-section of flood wall along the Lakhya river is proposed after the detailed study of type selection. Some variation will be made to particular portion according to the soil conditions at site.

For this strech, foundation treatment is required about 14% of its streches due to the poor soil foundation.

The longitudinal section and standard cross-sections proposed are shown in Fig E.5.3 and E.5.4.

5.1.3 Sluice Gate

1) Location

A total of 14 sluice gates are planned at crossing points of existing khals and at the proposed pump stations. The location is shown in Fig.E.5.1.

2) Main Features of Sluice Gates

A culvert type of sluice gate is selected for every proposed location in view point of construction cost and easy maintenance.

The main feature of proposed sluice gate are summarized below :

No.	Sluice Gate No.	Station No.	Name of Khal	Type of Structure	Design Discharge (m3/S)	DL. of Outlet (m in PWD)	Remarks
1	21	NE.84+120	KN-18	Box	7.33	+3.30	----
2	22	NE.77+160	KN-19	Box	16.72	±0.0	With Pump Station (NE)
3	23	NE.69+100	KN-20	Box	20.04	±3.0	With Pump Station (NE)
4	24	NE.49+100	KN-22	Box	21.90	+2.63	----
5	25	NE.46+180	KN-23	Box	10.54	+3.12	----
6	26	NE.40+170	KN-24	Box	10.31	+3.11	----
7	27	NE.32	KN-25	Box	8.83	+3.06	----
8	28	NE.26+150	KN-26	Box	9.18	+3.04	----
9	29	NE.19	S-1	Box	10.47	+3.33	----
10	30	NE. 8+50	S-2	Box	6.17	+3.00	----
11	31	NE.5+70	KN-27	Box	7.18	+2.98	----
12	32	NE. 5+70	S-3	Box	3.89	+3.25	----
13	33A	NE.1+150	KN-28	Box	26.97	+0.50	With Pump Station (NW)
14	33B	NE.14+190	KN-30	Box	43.15	+0.50	With Pump Station (NW)

5.1.4 Stop Log Structure

For the flood wall along Lakhya river, many stop log structure are required for the openings of public use.

On this plan, a total of 58 stop log structures are planned at the entrance from public roads to river bank for the public use.

The proposed locations are shown in Chapter of "Preliminary Design".

Table E.3 Proposed Flood Mitigation Facility : Dhaka East

5.2 Stormwater Drainage Improvement Plan

5.2.1 Present Condition of Drainage Area

1) Drainage Area and Drainage System

The drainage area of 18.63 km^2 identified one of the priority areas covers the narrow strip between the Demra - Narayanganj Road and the Lakhya River, and Narayanganj town on the west bank of the Lakhya River. The area has developed as a business and industrial areas. The urbanized area is situated on high land about 6.0 m PWD, which is free from habitual flood. The rural area is located in low land, which is under the water of max. 2.5 m depth in flood season and is mainly used as a paddy field in dry season. Narayanganj town is under the jurisdiction of Narayanganj Municipality and the other areas are under the Zila Parishad.

The existing built-up area of 13.12 km^2 (approx. 70% of the area) is projected to be 17.20 km^2 (approx. 92% of the area) in the target year 2010. The population is estimated to be 0.47 x 10^6 in 1990, 0.70 x 10^6 in 2000 and 0.93 x 10^6 in 2010. Table E.5.2 shows the present and future built-up area and population of the Narayanganj West area.

Industrial areas along the Lakhya River are filled up and drained directly into the river by their own drains under the gravity flow. Stormwater of low lands surrounding the industries is drained into the Lakhya River through several khals.

Narayanganj town has provided U-type or covered type brick masonry drains on one side or both sides of the roads. The total length of the drain is almost 9.5 km. Some main drains, which convey stormwater to the Lakhya River, have inadequate sections causing mainly internal flood when there is heavy rainfall. Secondary and tertiary drains are filled up at many places with town garbage and earth causing hindrance to stormwater flow.

The western parts of Narayanganj town are rapidly and adhock developing. Almost 25% of the area has internal flood problem due to lack of sufficient drainage facilities. This area is drained into the Kashipur - Bholai Khal, which drains to the Dhaleswari River, through the Shasongaon and Mondal Para khals.

2) Drainage Facilities

The existing major drainage facilities consist of brick masonry drain and khals. No pumping station and drainage pipe are provided in Narayanganj West area.

(1) Brick Masonry Drain

Brick masonry drains are provided at one side or both side of the roads in the eastern part of Narayanganj town between the Bangabandhu Road and the Lakhya River. There are two types, open ditch type and covered channel type. The width of drain vary from 0.25 m to 1.0 m and its depth vary from 0.30 m to 1.5 m as per elevation of road. The total length of the drains including secondary drain is reported to be about 9.5 km by Narayanganj Municipality.

(2) Khal

There are eight (8) major khals with a total length of 6.21 km as shown in Fig. E.5.6. These khals are mainly used for stormwater drainage except two khals in western Narayanganj town, Shasongaon and Mondal Para khals, which are also used for irrigation in dry season.

Based on the longitudinal and cross sectional survey results, the existing drainage capacity of the above khals are calculated. According to the calculation results shown in Table E.5.3, almost a half of the khals have sufficient sections for the required specific discharge capacity of about $8m^3/s/km^2$. Small scale khal improvement only will be required.

5.2.2 Planning Policy and Criteria

1) Planning Policy

A planning policy for preparation of stormwater drainage improvement plan are briefly summarized below :

- Plans are to be prepared to meet the population and land use in the target year 2010. The whole area to be planned is approximately 19 km^2. The population and built-up area in 1990 and 2010 of the project area are shown in Table E.5.2.

- Scope of countermeasures for the existing built-up areas are construction of pumping station with retarding pond, and improvements of khal and trunk drain to mitigate the existing internal flood damage. Secondary and tertiary drainage pipes are excluded in the proposal, taking into account that the investment for project implementation must be reasonable.

- For the future urbanized areas, only pumping station with retarding pond and improvements of trunk khals are to be proposed as countermeasures. Land acquisition will be recommended for the proposed countermeasures except the

retarding ponds, for which it will be proposed that the required areas be preserved by land use regulation in order to limit the project cost.

2) Planning Criteria

(1) Design Flood Water Level

The design flood water levels of 2-year frequency are applied for each drainage zone based on the calculation results of probable water levels at Demra (BWDB Sta. 179), Narayanganj (BWDB Sta. 180), Hariharpara (BWDB Sta. 43) and Kalagachia (BWDB Sta. 71) gauging stations. They are as follows :

- NB 1 Zone : 5.80 m PWD
- NB 2 Zone : 5.70 m PWD
- NB 3 Zone : 5.45 m PWD
- NB 4 Zone : 5.50 m PWD
- NB 5 Zone : 5.45 m PWD

The pump equipment is designed to be operated during the flood of a 100-year flood frequency. Considering about 2 m difference in water levels between the floods of a 2-year and a 100-year flood frequency, the flood water level at the highest pump efficiency of 100% will actually be higher than that of a 2-year frequency flood.

The pump will be designed based on the most effective water level equivalent of the annual maximum water level on average which is equivalent about 2.3 - 2.8 year return period.

(2) Design Rainfall, Run-off Coefficient, Run-off Ratio and Drainage Criteria

The criteria applied are the same as that of Greater Dhaka East. (refer to Section. 3.3.2, 2), Figs. E.3.10 and E.3.11.

5.2.3 Zoning

Narayanganj West area is planned to be protected against the external floods from the Dhaleswari River and the Lakhya River by embankment, flood wall and road-cum-embankment as shown in Fig. E.5.1.

As shown in Fig. E.5.7, the area is divided into small five (5) drainage zones, NB-1 to NB-5, based on the proposed alignment of the flood protection facilities, inner drainage

system and road networks. The drainage area and the main khal of each zone are summarized below :

Zone	Area (km^2)	Main Khal
NB-1	2.30	K-19
NB-2	3.99	K-20, 21
NB-3	5.33	K-23, 24
NB-4	2.36	Shasongaon Khal (K-25)
NB-5	3.65	Mondal Para Khal (K-26)
Total :	18.63	

Note : Refer to Figs. E.5.6 and E.5.7.

5.2.4 Countermeasures

Stormwater drainage countermeasures are proposed by five (5) zones for the whole area of 18.63 km2. As almost 70% of the area is already urbanized, the proposed measures will consist of the followings :

- All the required pumping stations with retarding ponds
- Improvements of khal and trunk drain

However, lateral drains and tertiary drainage pipes are not included in this project in order to limit the project cost.

5.2.5 Pump Drainage Plan

1) Pump Drainage Area

Each drainage zone is demarcated into pump and gravity drainage areas based on the following demarcation criteria.

- The area above the design flood water level plus 0.5 m can drain stormwater by open channel under the gravity flow.
- The area below the design flood water level plus 0.5 m can not drain stormwater by gravity flow. Pump drainage system is required.
- Future urbanized areas in the existing low-land will be built-up by land filling of min. 2.0 m.

Pump and gravity drainage areas by each zone are summarized below :

Zone	Area (km^2)		
	Pump Drainage	Gravity Drainage	Total
NB-1	1.73	0.57	2.30
NB-2	1.92	2.07	399
NB-3	----	5.33	5.33
NB-4	2.36	----	2.36
NB-5	4.65	----	4.65
Total :	10.66	7.97	18.63

Note : Refer to Figs. E.5.7.

2) Pump Operation Period

As mentioned in Section 3.3.5, the required pump operation period will be at least five (5) months between June and October in every year. This situation is almost the same as that of Greater Dhaka East and DND.

3) Required Pump and Retarding Pond Capacities

In order to economize the total pump drainage cost by reducing the required pump capacity, it is proposed to adopt a pump drainage system combined with retarding pond.

Specific requirements of pump capacity and storage volume of retarding pond are estimated to be P = 1.14 $m^3/s/km^2$ and V = 0.120 x 106 m3/km2 respectively by utilizing storage basin model as shown in Fig. E.3.10.

The required pump capacity and storage volume of retarding pond for each zone are summarized below ;

Zone	Area (km^2)	Required Pump Capacity Specific ($m^3/s/km^2$)	Required Pump Capacity Total (m^3/s)	Required Storage Volume of Retarding Pond Specific ($\times 10^6 m^3/km^2$)	Required Storage Volume of Retarding Pond Total ($\times 10^6 m^3$)
NB-1	1.73	1.14	2.0	0.12	0.21
NB-2	1.92	1.14	2.2	0.12	0.23
NB-4	2.36	1.14	2.7	0.12	0.28
NB-5	4.65	1.14	5.3	0.12	0.56
Total :	10.66	---	12.2	---	1.28

4) Proposed Pumping Station

(1) Proposed Site

Considering the required pump capacity, one small pumping station by each zone is proposed at the crossing of the main khal and the proposed embankment.

Location of the proposed pumping stations is shown in Gig. E.5.8 and listed below:

Sub-Zone	Pumping	No of Embankment station	Station No. of Name of khal
NB-1	P12	NE 77 + 160	KN - 19
NB-2	P13	NE 69 + 100	KN - 20
NB-3	P14A	NW 23	KN - 28 (Shasongaon Khal)
NB-4	P14B	NW 14 + 190	KN - 30 (Mondal Para Khal)

Note: 1)Refer to Fig. E.5.8

(2) Design Water Level of Pumping Station

Design flood water levels of pumping stations are determined through the same technical approach as Greater Dhaka and DND. However, ground elevation of low-lying areas (expected retarding pond) in NB-2 and NB-5 is almost 3.5m PWD, which is 0.5m higher than others. Accordingly, the design flood water levels of P13 and P14B pumping stations is planned to be 0.5m higher than that of other stations.

Hydraulic requirements of the proposed pumping station are shown in Table E.5.4 (1)

5) Proposed Retarding Station

(1) Proposed Site

Even if this area is expected to be urbanized fast, low-lying areas having sufficient storage potential are proposed as retarding pond areas. The number of retarding ponds drainage zone is as follows;

NB-1 : 1 site (RP12)
NB-2 : 1 site (RP13)
NB-3 : 1 site (RP14-1)
NB-4 : 1 site (RP14-2 and RP 14-3))

(2) Run-off Coefficient

Run-off coefficients of sub-zones are estimated based on the proposed standard run-off coefficient mentioned in Section 3.3.2 and land use in 2010. Calculation results are shown in Table E.5.5 and Fig. E.5.8.

(3) Design Discharge

Design discharges for improvements of khal and trunk drain are calculated by Rational formula, the same method as Greater Dhaka East and DND.

Calculation results are shown in Table E.5.6. and Fig. E.5.9.

5.2.6 Khal and Trunk Drain Improvement Plan

The conveyance capacities of the existing khals and trunk drains located in the Narayanganj town do not meet to the design discharges. Improvement of khal channels by widening and dredging, or replacement of trunk drainage channels or pipes are required.

The proposed types for khal and drainage improvement are as follows :

1) Open Channel

- Type (1) : Trapezoidal shape with 1:2 slope protected by sodding
- Type (2) : Trapezoidal shape with 1:1 slope protected by brick

2) Covered Channel / or Pipe

- Type (1) : Brick pipe (Max. diameter : Ø 3,000)
- Type (2) : Concrete box culvert (Discharge capacity : more than $10m^3/s$)

Open channel type (1) is applied for khal sections situated in agricultural land where comparatively easy land acquisition is expected. Open channel type (2) are proposed for khal sections located in built-up areas where land acquisition is likely to be difficult. O & M roads with a minimum width of 4.0 m is proposed to provide for the both banks of each khal. Typical section of the khal improvement is shown in Fig.F.5.1 in Supporting Report F.

The covered channel type (1) is basically applied for trunk drains. However the type (2) is proposed for the trunk drains sections, of which the design discharge is estimated to be more than $10m^3/s$. Typical sections of the proposed trunk drain are shown in Fig. F.5.5 in Supporting Report F.

As related structures, construction of eleven (11) road bridges and three (3) railway bridges will be required for crossing of new khal and road/railway. Location of these structures are shown in Fig. E.5.12. Details are mentioned in Supporting Report F.

The proposed khal improvement works are shown in Table E.5.8 and Fig. E.5-13, and summarized below :

Zone	Khal Improvement (km)		Trunk Drain (km)		Bridge (Place)	
	Type (1)	Type (2)	Type (1)	Type (2)	Road	Railway
NB-1	1.20	0.40	---	---	1	---
NB-2	0.90	2.20	---	---	2	1
NB-3	---	2.60	0.90	0.50	---	2
NB-4	1.40	1.40	---	---	2	---
NB-5	0.80	4.90	---	---	6	---
Total :	4.30	11.50	0.90	0.50	11	3

TABLE E.2.1 PROJECT IMPLEMENTATION SCHEDULE OF RELATED PROJECT : FAP 8B

Year	'91		'92				'93				'94				'95				'96				Remarks
Quarter	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Project Preparation																							
A.Flood Protection (Part A)																							
- Construction Works																							
- Incremental Maintenance																							
B.Drinage (Part B)																							
- Construction Works																							
- Incremental Maintenance																							
C.Enviromental Improvement Program (Part C)																							
- Improvement Works																							
- Incremental Maintenance																							

Note:
1).Construction Works includes preparatory activities

TABLE E.3.1 MAIN FEATURES OF ALIGNMENT ALTERNATIVE

Description of Alternatives	Total Length of Embankment (km)	Average Ground Level (PWD)	Embankment Volume (x 1000 m^3)	Foundation Treatment Required (km)	No. of Sluice Gates (No)	Total Construction Cost (million taka)	Protected Area (ha)	Remarks
Alternative A	4.4	1.5 ~ 3.0	868	3.94	1	900	+ 215	Recommended
Alternative B	4.4	2.0 ~ 5.0	553	1.33	1	570	± 0	

TABLE E.3.2 NAVIGATION SURVEY RESULT IN DHAKA EAST ZONE

(Unit : TK.)

Boat Terminals	Boat - Days per Year		Average No. of Trips per Day	Share of Commodity Transport Services	Total No. of Trips for Commodity Transport Services		Share by size of Boats				Value of Commodities per Trip		Valut of Commodities			Share
	Wet Season	Dry Season			Wet Season	Dry Season	Wet Season		Dry Season				Wet Season	Dry Season	Total	
							Small Boat	Big Boat	Small Boat	Big Boat	Small Boat	Big Boat	G1 = D1x(E11xF1+ E12xF2)	G2 = D2x(E21xF1+ E22xF2)	H = G1+G2	
	A1	A2	B	C	D1=A1xBxC	D2=A2xBxC	E11	E12	E21	E22	F1	F2				(%)
Rampura	17,850	2,700	1.5	50%	13,388	2,025	0.65	0.35	0.25	0.75	1,000	10,000	55,558,125	15,693,750	71,251,875	12.42
Meradia	308	0	11.0	20%	678	0	0.33	0.67	0.25	0.75	1,000	10,000	4,743,200	0	4,743,200	0.83
	546	0	11.0	20%	1,201	0	0.33	0.67	0.25	0.75	1,000	10,000	8,408,400	0	8,408,400	1.47
Madartek	12,600	2,700	2.5	50%	15,750	3,375	1.00	0.00	1.00	0.00	1,000	10,000	15,750,000	3,375,000	19,125,000	3.33
Shahjadpur	4,830	0	3.0	10%	1,449	0	0.00	1.00	1.00	0.00	1,000	10,000	14,490,000	0	14,490,000	2.53
Khilkhet	9,870	0	2.0	10%	1,974	0	0.00	1.00	1.00	0.00	1,000	10,000	19,740,000	0	19,740,000	3.44
Tongi	57,750	11,250	1.0	60%	34,650	6,750	0.45	0.55	0.00	1.00	1,000	10,000	204,750,000	39,150,000	243,900,000	42.51
Mainer Tek	2,310	900	11.0	10%	2,541	990	1.00	0.00	1.00	0.00	1,000	10,000	2,541,000	990,000	3,531,000	0.62
Kaskura	1,680	0	1.0	10%	168	0	1.00	0.00	1.00	0.00	1,000	10,000	168,000	0	168,000	0.03
Patira	4,200	1,400	3.5	70%	10,290	3,430	0.53	0.47	1.00	0.00	1,000	10,000	53,508,000	18,865,000	72,373,000	12.61
	1,232	880	3.5	70%	3,018	2,156	0.53	0.47	1.00	0.00	1,000	10,000	15,695,680	11,858,000	27,553,680	4.80
Bora Beraid	2,100	1,200	2.5	50%	2,625	1,500	0.53	0.47	1.00	0.00	1,000	10,000	13,650,000	8,250,000	21,900,000	3.82
	1,456	1,040	2.5	50%	1,820	1,300	0.53	0.47	1.00	0.00	1,000	10,000	9,464,000	7,150,000	16,614,000	2.90
Kaetpara	9,800	2,500	1.5	50%	7,350	1,875	0.64	0.36	1.00	0.00	1,000	10,000	30,975,000	8,906,250	39,881,250	6.95
	2,022	1,040	1.5	50%	1,517	780	0.64	0.36	1.00	0.00	1,000	10,000	6,327,750	3,705,000	10,032,750	1.75
Total	128,554	25,610											455,769,155	117,943,000	573,712,155	100.00

Note : Results of the interview survey towards boatmen.
Source : JICA