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THE PEOPLE'S REPUBLIC OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

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

FAP 8A

SUPPORTING REPORT II

NOVEMBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

LIST OF SUPPORTING REPORTS

ABBREVIATIONS

ADB	Asian Development Bank
AIT	Asian Institute of Technology
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CAAB	Civil Aviation Authority of Bangladesh
DIT	Dhaka Improvement Trust (now RAJUK)
DMAIUDP	Dhaka Metropolitan Area Integrated Urban Development Plan
DMC	Dhaka Municipal Corporation
DND Triangle	Dhaka - Narayanganj - Demra Triangle
DPHE	Department of Public Health Engineering
DOE	Department of Environment
DWASA	Dhaka Water and Sewerage Authority
ERD	External Resources Division Ministry of Finance
FAP	Flood Action Plan
FPCO	Flood Plan Coordination Organization
GDPP	Greater Dhaka Protection Project
GDFCD Project	Greater Dhaka Flood Control and Drainage Project
GOB	Government of Bangladesh
JICA	Japan International Cooperation Agency
MIWDFC	Ministry of Irrigation, Water Development and Flood Control
MPO	Master Plan Organization
PDB	Power Development Board
PHD	Public Health Department
PWD	Public Works Department
RHD	Roads and Highways Department

RAJUK	Rajdhani Unnayan Katripakha (Capital Development Authority)
RRI	River Research Institute of the Ministry of Irrigation, Water Development and Flood Control
SOB	Survey of Bangladesh
SWMC	Surface Water Modelling Center
SPARRSO	Space Research and Remote Sensing
UNCHS	United Nations Center for Human Settlements
UNDP	United Nations Development Programme
WAPDA	Water and Power Development Authority
WASA	Water and Sewerage Authority
WMO	World Meteorological Organization

SUPPORTING REPORT G

FLOOD MITIGATION

SUPPORTING REPORT G
FLOOD MITIGATION

Table of Contents

List of Tables

List of Figure

SUPPORTING REPORT G: FLOOD MITIGATION

1. Existing Conditions and Evaluation

1.1 General

Several flood control and the tormwater drainage plans for Greater Dhaka have been prepared by the GOB with the cooperation and assistance of various international agencies. However most of the major existing flood control facilities have been constructed after the 1988 flood (ref. Table G.1).

In order to protect the Greater Dhaka Area from flooding, the Greater Dhaka Flood Control Committee, with the Planning Minister as its chairman was established immediately after the 1988 flood.

The Committee, with the assistance of a Dutch expert, Mr. T.G.H. Jansen, considered various possibilities based on former studies. The Committee's proposal was submitted to the President and approved in March 1989.

Flood mitigation projects in the surrounding towns were also proposed and in addition facility plans for Savar, Tongi and Narayanganj were proposed by the Institute of Diploma Engineers.

The Committee's plan, with phasing of activities, is summarized as follows :

- Phase I

1) Embankment from the Tongi Railway Bridge to Shirnir Tek via Satmasjid Road along the Turag River, with five (5) sluice gates ;
2) Road raising and flood wall along the Buriganga River from the Friendship bridge to Kellar More and flood wall surrounding the DND project ;
3) Embankment surrounding Dhaka International Airport ;
4) Clearing of khals in the city ;
5) Repair and restoration of the sewerage system ; and
6) Temporary flood control structures.

- Phase II

7) Road/embankment from Demra to the Tongi Railway Bridge along the Balu River;

8) Installation of five (5) pumping stations ; and

9) Re-excavation and restoration of twelve (12) khals.

Most parts of the proposed works for the phase - I have already been commenced as urgent measures under the supervision of various agencies i.e. BWDB, DDC, RHD, RAJUK, DWASA and CAAB. Some parts of the works have already been completed, but others are still on going.

On completion of the works for the phase - I, the major part of Dhaka City will be enclosed by embankment, flood walls and raised roads and would become flood free.

The flood protection plans proposed for the phase II still have no implementation program, except two pump stations in Dhaka City. One of them was committed as a JICA grant project by the Government of Japan and is on going, and the other by the World Bank.

The DND project was developed by BWDB as an irrigation project, protected from floods by polders and drained by pumps. The area however will be developed as an urban area by RAJUK and a development plan is being prepared. The area will be safe to the river stage of the 1988 flood, after completion of the flood walls proposed in the phase - I.

Though a number of flood prevention facilities have been constructed both in the Greater Dhaka and in the DND project, no major flood prevention facilities exist in Tongi, Savar, Narayanganj and Keraniganj town areas.

1.2 Design Standards

1.2.1 Existing Conditions

After the 1988 Flood, a number of flood control facilities have been constructed based on the Committee's Proposal, both in the Greater Dhaka and in Narayanganj areas.

The structural types and the locations of the flood control facilities are :

1) Embankment - Greater Dhaka Northern and Western Bank

2) Flood Protection Wall (R.C.C Wall) - Greater Dhaka Western Bank and Narayanganj DND project area.

3) Road - cum - embankment /Raising of road height - Tongi to Jatrabari along fringe of developed area of Greater Dhaka.

4) Regulators - Greater Dhaka Northern/Western Bank

The details are summarized in Table G.2.(1) and shown in Fig. G.3, G.5. The design criteria, construction specifications and standard sections of the flood control facilities were presented by BWDB and BUET for the flood control facilities (see Fig. G.4).

The main points of design criteria are summarized as follows :

1) Embankment

(1)	Scale of Flood	:	100 - years flood frequency
(2)	Design Flood Level	:	8.8^{m} + PWD
(3)	Top of Embankment	:	10.0^{m} + PWD
(4)	Freeboard	:	1.2^{m}
(5)	Set Back	:	30^{m} from bank sholder of river
(6)	Embankment Cross Section	:	See Fig. 5.4
(7)	Water Ponding Elevation	:	5.0^{m} + PWD
(8)	Compaction of Earth	:	90% dry density
(9)	Embankment Material	:	No peat soil or other poor soil

2) Flood Wall

(1)	Design Flood Level	:	1988 flood mark
(2)	Top of Flood Wall	:	2.0 ft. above the 1988 flood mark
(3)	Free board	:	2.0 ft.
(4)	Flood Wall Cross Section and Construction Specifications	:	See Fig. G.4

3) Road - cum - embankment

The designed top surface of roads is up to the flood stages of the 1988 flood.

No freeboard was designed for the road - cum - embankment.

4) Regulators

The following design criteria have been adopted for the design of existing regulators located along Greater Dhaka Western Bank.

(1) Rainfall

One day rainfall with 5-year frequency.

(2) Discharge Volume

80% of the rainfall is to be the drainage flow through the regulators within 24 hours under maximum water head of one meter.

1.2.2 Evaluation of Design Criteria

1) Embankment

(1) Scale of Design Flood

Adoption of 100 years flood frequency, in view of the extent of damage, predominant loss of human lives of Greater Dhaka.

The 1988 flood has been estimated to be about a 70 - year frequency flood.

(2) Design Flood Level

The design high water level (D.H.W.L) 8.80 m PWD is higher than that of the recorded water level of 8.35 m at Mirpur Gauging Station in the 1988 flood and is evaluated as being higher than a 100 - year frequency.

(3) Freeboard

The freeboard will be evaluated based on the wave run up calculation condition.

(4) Design Cross Section

The standard cross section is safe in case of good subsoil condition.

However, in case of poor subsoil condition, the embankment section shall be modified based on stability analysis.

(5) Water Ponding Elevation

This elevation is closely related to area of development as well as embankment stability and necessary pump capacity. For this reason the background of the elevation shall be clarified.

(6) Construction Specification

The specifications of embankment material and compaction density are appropriate.

However, specifications of banking speed shall be added for the case of poor subsoil condition in order to avoid settlement due to failure of banking.

2) Flood Wall

(1) The Scale of design flow and the high water level have been determined referring to the 1988 flood. The top of the flood wall was set at 2.0 ft. above the 1988 flood mark.

This design scale and high water levels would not meet the design criteria for this master plan study.

(2) Freeboard

A freeboard of 0.6m is adopted for the flood wall. This value is sufficient if the flood wall is to be constructed at good subsoil base.

(3) Design Cross Section

The flood wall is not a self standing structure as can be seen in Fig G.4. If erosion or disturbance around the structure occurs, the stability of the flood wall can easily be endangered.

For the stability and maintenance of the flood wall, the set back distance shall be more than 2.0 ft. of the present design criteria. The set back distance shall be determined based on the site conditions which may be categorised as river, road and housing sites.

Some damage of the flood wall has been observed during site visits, breakages being mainly due to traffic vehicles or human negligence. The strength of the Flood Wall along trunk roads is not sufficient against collision of trucks.

For this reason, the existing flood wall is evaluated as a temporary structure and will not be used as a Master Plan facility.

3) Road - Cum - Embankment

The road - cum - embankment with raising of road elevation was constructed as a temporary measure for flood protection. For this reason permanent measures shall be designed, based on the long term Master Plan Study.

4) Regulators

The Hydraulic Design Criteria for the design of regulators will be determined taking future land development process and its rate of progress into account.

1.3 Flood Control Facilities

The existing embankment and flood wall are evaluated in terms of crown elevation and stability.

The design high water levels (H.W.L) determined in Section 2.4 in comparison with the design crown levels are shown below:

Station		H.W.L	1/100	'88 flood
Tongi (sta. No. 299)	:	8.6^{m}	8.30^{m}	7.96^{m}
Mirpur (sta. No. 302)	:	8.6^{m}	8.53^{m}	8.39^{m}
Mill Barack (Sta. No. 42)	:	7.8^{m}	7.72^{m}	7.54^{m}
Hariharpara (Sta. No. 43)	:	7.2^{m}	7.10^{m}	7.17^{m}
Rakabi Bazar (Sta. No. 71A)	:	6.7^{m}	6.65^{m}	6.43^{m}
Demra (Sta. No. 7.5)	:	7.4^{m}	7.32^{m}	7.10^{m}
Kalagachia (Sta. No. 71)	:	6.4^{m}	6.40^{m}	5.97^{m}
Savar (Sta. No. 69)	:	9.7^{m}	9.36^{m}	9.68^{m}

The design crown levels are calculated by adding a freeboard of 1.2^{m} for embankment and 0.6^{m} for flood wall.

The stability of embankment and flood wall are evaluated from the site observation results and the stability analysis.

1.3.1 Greater Dhaka Area

1) Embankment Top Level

About 29.2 km of the embankment between Tongi Railway Bridge and Kellar More have been constructed. Most of it has been completed on the basis of the standard cross section (see Fig G.4). When this study was started, the crown elevation of most parts of this embankment was higher than the 10.0 m specified in the BWDB design, as verified by spot elevation survey. Subsequently, following a levelling survey (ref. Fig. G.7), it is clear that most parts of the crown is below the design height. This conclusion may be partly reached because of the shrinkage of the embankment itself. But there will also have been, significant drop in crown level height because of foundation settlement in some parts. The crown elevation of most of the embankment is now considered to have insufficient elevation compared to the proposed design crown level (9.8 m) at Mirpur.

The standard cross section is sufficiently safe against settlement and slope failure in places of ordinary sub-soil conditions. However settlement and slope failure are observed in some portions. The main reason is poor soil foundation. The top elevation of the settlement portion, at about 7.0 m to 8.5 m, is some 1.5 m to 3.0 m lower than the design top level. This elevation of 7.0 m corresponds to a 6 year flood frequency. Spot elevations of the embankment surfaces are also shown on Fig. G.7.

2) Embankment Stability

Many sections of the existing embankment between Tongi to Kellar More through Mirpur have been settled or failed mainly due to poor soil foundation and inadequate compaction.

(1) Soil Foundation Characteristics

Based on the existing boring data and soil survey result, the following soil characteristics and some indices are recognized:

- Poor soil (N<4) is found in most parts of the foundation layer along the existing embankment.
- The soil is classified as soft silt with clay, with the dry density being about 1.5 t/m^3
- Unconfined compression strength is about 2.0 t/m^2
- The relation between the N value of the standard penetration test and Cohesion (C) is roughly estimated as C = 0.6 x N.

Soil property observed by soil test conducted by the Study Team are as follows :

- Wet Density (rt) : 1.7 - 1.9 t/m^2
- Chohesion (C) : 2 - 4 t/m^2 (1-2 t/m2 for poor soil)
- Natural Void Ratio (eo) : 0.9 - 2.0
- Coefficient of Compression Index (Cc) : 0.15 - 0.20
- Coefficient of Consolidation (Cv) : 2.0 - 10.0 x 10^{-4} m^2/s

(2) Evaluation of Stability

The stability of an embankment is mainly evaluated by stability analysis,the bearing aspect of its soil foundation and observation of slope failure of the embankment body.
Bassd on stability analysys,the following facts are recognized :

a) Standard section of existing embankment specified by BWDB is recognized as a stable section in a condition of ordinary sub-soil foundation.
b) Excavation at foot of embankment is likely decrease safety factor of embankment stability.
c) The failure Settlement of the existing embankment is caused by both weak bearing capacity and poor shearing strength.

The detail informations are described below :

- Settlement and Critical Embankment Height
  The critical embankment height is estimated about 5.8 ^{m} in case of N-value 5. This analysis is roughly justified by the fact that sudden settlement has occured when the banking height reaches to about 6^{m}.

On this basis,an embankment more than 6^{m} in height needs some foundation treatment.

- Slope Failure
  The slope failure of embankment is observed only in few instances in the whole length.
  This failure is recognized as shallow slope failure, which is mainly due to weak shear strength of the embankment body, and supposed to be caused by inadequate compaction.
  Furthermore, erosion by wind mave at the lower part of the embankment slope is considered one of the causes of failure.

- Other failure
  Cracking was observed in the vicinity the failed partions. This could create weakness of shearing strength in the embankment and lead to slop failure.
  Along the areas beside the existing embankment,borrow pits were observed. Some borrow pits were located too close to the toe of the embankment. This would cause toe failure or base failure if the slip surface is affected by the borrow pit.

(3) Rehabilitation Works

- For the settlement problem, the following basic concept of the foundation treatment are generally considered:
  1. Replacement of the poor foundation soil.
  2. Strengthening of foundation layer.

  From the cost aspect and with due consideration of the poor foundation soil which extent to more than 15^{m} depth, the later approach is conceived.

  The strengthening of the foundation layer is to be carried out by means of consolidation by sand drains, wick drains, paper drains, geotech drains and other appropriate technologies.

- For the slope failure, re-banking with the following construction specifications are required:
  1. Adequate compaction by machinery is to be carried out

2. Design moisture content is to be kept
3. Strengthening of the toe portion by geotextile or other materials.

3) Flood Wall Top Level

The construction of the Flood Wall was planned around Sirnir Tek and between Kellar More to Syedabad via Buriganga Bridge. Most of the flood wall has been built based on the proposals prepared by the Committee, however the reach between Kellarmore to Mitford Hospital (1.6 km) was not constructed due to lack of space and land acquisition problem (see Fig. G.3).

The Top elevation of most of the flood wall near Sirnir Tek is measured about 8.9m to 9.3m the lowest portion is below 0.3m lower than the design top level at Mirpur gauging station. For the reach between Mitford Hospital to Syedabad, the top elevation is measured between 8.1m to 8.6m. The lowest portion is 0.3m lower than the design top level at Millbarack gauging station, while the water level in 1988 flood was at 7.5m in P.W.D.

The stability of the flood wall near Sirnir Tek and the reach from Mitford hospital to Buriganga Bridge is evaluated to be satisfactory at present. However it is recommended that the flood wall should be heightened and its base should be protected in order to ensure the stability of the flood wall.

The spot elevation of the top of the flood wall is shown in Fig. G.7 (1)

4) Road - Cum - Embankment

The roads between Tongi bridge to Sydabad are raised up to the flood stage of the 1988 flood.

The typical section paved by asphalt has a 10m width and the banking height as measured from ground level is around 1.0 to 2.0m.

This section is evaluated to have sufficient strength for flood protection.

The top level of the road ranges from 7.3m to 8.3m, while the 1988 flood H.W.L at Tongi and Demra are 7.96m and 7.10m respectively. The top level corresponds to about a 50 - year flood frequency. The spot elevation of the top of road - cum - embankment is shown on Fig. G.7.

5) Regulators

Five regulators have been constructed along Greater Dhaka Western Bank, however one of them is not functioning due to lack of connection of drainage channels. One regulator at Kallayanpur is still under construction. The flow area of these regulators ranges 2 m^2 to 14 m^2 and depend on the size of drainage basin and its discharges.

However these flow areas seem to be not sufficient for quick drainage of ponding water.

The flow areas of the regulators should be reviewed and determined if required.

1.3.2 Narayanganj Area

1) Flood Wall Top Level

The DND project area is protected from floods by flood wall and railway -cum-embankment. This flood wall was constructed along trunk roads which surround most of the DND project Area (see Fig. G.5).

The top elevation of the flood wall from Buriganga Bridge to Fattulla ranges from 8.0m to 7.6m with it's road elevation being about 7.0m, while the tentative design top levels at Millbarack and Hariharpara gauging station are 8.4m and 7.8m respectively. For this section, the height is not sufficient.

In the reach from Syedabad to Demra, the top elevation of the flood wall ranges from 7.8m ~ 8.0m with the road elevation being about 7.2m, while the design top level at Demra (sta no. 7.5) is 8.0m.

In the reach from Demra to Hajiganj along the Lakaya river, the top of the flood wall ranges from 8.1m to 7.5m with the road elevation being about 7.0m, while the design top levels at Demra and Hajiganj are 8.0m and 7.7m respectively. The top levels of the flood wall are not sufficient to meet the design criteria.

Furthermore the wall strength is not sufficient to withstand impact of trucks or other heavy vehicles. The existing flood wall along the trunk road is evaluated to be insufficient for long duration facilities. The spot elevations of the wall top are shown in Fig. G.7.

2) Flood Wall Stability

The stability of the concrete flood wall is evaluated as follows.

(1) Strength of Concrete Wall.

Most flood wall was constructed along the heavily traffic roads

The existing concrete wall is 13^{cm} to 20^{cm} thick with single reinforcement. In some portion, shrinkage cracks and settlement cracks have been observed and breakage due to collusion of heavy vhicles were observed at some factorygateways.

Considering the above, the concrete wall strength is insufficient adjacent to roads used by heavy vhicles. Accordingly the flood wall is evaluated as a short term flood mitigation measure.

(2) Stability of Flood Wall

Along the flood walls, some drainage channels are observed, and the foundation parts of the flood wall have been disterved by these structures. This could lead to failure of the flood wall during periods of high water, even where the present condition seems stable.

3) Railway - Cum - Embankment

Railway - cum - embankment was constructed along the southern part of the DND Project area. The top elevation of the railway between Chasara to Hajiganj ranges from 6.8m to 7.3m, while the design crown level at Hajiganj is planned at 8.3^{m}. The top level is to be raised by about 1.5^{m} in height.

The summary of evaluation of existing and on-going facilities is shown in Table G.3.

1.4 Flood Warning System

1.4.1 Existing Condition

1) Present Project

Flood forecasting and warning were started in 1972. However the activities were not carried out continuously due to inadequate project financing base.

The present project has been carried out with UNDP assistance. This project was planned to be executed during the third five year plan period (1985 ~ 1990), but has been delayed.

The project consists of the following sub-projects :

(1) Surface Water Survey and Investigation
(2) Ground Water Survey and Investigation
(3) Flood forecasting and Warning
(4) Investigation of new project.

2) Existing Organisation

The Flood forecasting and warning project is under the responsibility of the Director, Surface Water Hydrology - 2 (see Fig.G.8).

This project includes :

(1) Data Processing Division
(2) Flood Forecasting & Warning Centre
(3) Construction & Instrumentation Division.

3) Flood Information Monitoring Network and Installation

Within Bangladesh, real time water level data from 35 stations and rainfall data from 34 stations are being monitored in the Flood Forecasting and Warning Centre. Real time and forecast water levels from 5 stations in India are also monitored through the BMI network of teleprinter circuit. Satellite imagery of cloud formation are monitored in the Flood Forecasting and Warning Centre at

WAPDA Building by SPARRSO for flood information and formulation of forecast. Besides rainfall data, synoptic situations from Bangladesh Meteorological Department are also monitored in the Flood Forecasting & Warning Centre.

The flood information monitoring installations are shown in Table G.4.

4) Flood Information

The Flood Forecasting and Warning centre issues the following information in the form of a daily base bulletin.

The issuing period is limited to the flood season between May to October.

(1) Water levels of each monitoring station

- Recorded Highest Water level
- Danger Level
- Daily Highest water levels of 3 consecutive days
- Daily Highest Water level of previous year

(2) Rainfall amount of each monitoring station

- Monthly Maximum Rainfall
- Monthly Normal Rainfall
- Daily (for last 24 hrs) Rainfall of 3 consecutive days
- Cumulative Rainfall amount of the year and the previous year

Based on the above information, models are run for forecasting. Presently quantitative forecasts are limited to Ganges, Brahmaputra, Buriganga and Lakhya and Old Brahmaputra with lead time varying from 24 hours to 96 hours.

The issue of Flood Information and Flood Forecasting & Warning is to be made by the Flood Forecasting and Warning Centre through the chief engineer of hydrology.

5) "Emergency Standing Order for Floods"

In order to meet the flood emergency, the Government of Bangladesh issued an Emergency Standing Order for Flood defining the duties and responsibilities of different Ministries prior to flood, during the flood and after the flood.

In pursuance of the said order, the BWDB maintains a flood information centre during the flood time, issues the flood warning, and delegates officials to the Ministry of Relief and Rehabilitation or to the President's Flood Monitoring Centre.

1.5 Existing Flood Mitigation Plans

Before the 1988 flood, several studies had been carried out for flood prevention purpose. Most of the studies, however, have not been executed.

The most recent approved plan for flood control facilities is the so called 'GDFCD project plan' proposed by the Committee.

Most of the facilities proposed for the Phase - I have already been constructed.

1.5.1 Greater Dhaka Area

1) Existing Plan

Regarding embankment from Tongi to Demra for protection of the Eastern part of Greater Dhaka, proposed by the Committee for Phase II, BWDB has commenced the following :

Soil investigations along the proposed alignment of embankment : more than 40 bore holes have been drilled along the Balu river between Tongi and Demra.

- Survey/Design and its supporting data
- Cross-Sections of Embankment
- Longitudinal profile of Embankment (Tongi to Demra)
- Typical design sections of Embankment

Land acquisition notices have been issued to some inhabitants.

The Flood Wall from Mitford Hospital to Kellar More for the Phase - I has not been implemented yet, due to lack of construction space and some technical problems.

DMC, the executing agency, has investigated the site and proposed alternative plans to the Committee for its approval. However, the above activities are presently suspended by the authorities concerned.

1.5.2 Narayanganj Town

1) Existing plan

The town of Narayanganj is affected by flood water from the Buriganga and the Dhaleswari Rivers in the west, by the Dhaleswari River in the south, by the Lakhya River in the center. The town is divided into two parts by the Lakhya River with one side being the West Bank and the other the East Bank. These two areas contain industrial concentrations. In order to protect the town area from floods, the following plan was proposed by IDE (see Fig G.5).

(1) West Bank Protection

This involves the construction of 5km of earthen embankment, and 5 to 6 km of reinforced concrete retaining wall, raising the existing road and the provision of 4 regulators.

(2) East Bank Protection

The existing abandoned railway track will be raised and treated as an embankment for a distance of some 8.70 km with the construction of flood embankment along both sides of the Lakhya River, totalling some 13.7 km, with the provision of 4 regulators.

The principal idea of this plan is :

i) To protect the area from floods of 1988 scale.

ii) To obtain maximum benefit by minimum investment, only small scale flood protection facilities are to be introduced.

1.5.3 Tongi Town

1) Existing Plan

The flood control plan proposed by IDE is as follows (see Fig. G.6) :

- Raising of the road from the Gazipur Bus Station, west through Shatash and south through Kokil Mouja up to Kathalia Tek, for a distance of 5.50 km.

- Construction of a road/embankment (including land acquisition) from Kathalia Tek to the Tongi Bridge, 2.5 km.

- Construction of a flood protection wall from the road bridge to the railway bridge, 1.4 km.

- Construction of an embankment/road (including land acquisition) from Tongi Railway Bridge to Pubail Railway line, 6 km.

- Construction of flood protection wall, from Pubail Railway crossing to the railway line east of Earshadnagar, 3.5 km.

- Construction of an embankment /road (including land acquisition) from Tongi-Mymensingh railway line toward north to Tongi -Joydebpur road, 2.0 km.

- Construction of flood protection wall from Ershadnagar to Gazipr Road, 0.3 km.

- Provision of 2 pump stations and 10 regulators.

1.5.4 Savar Town

1) Existing Plan

During the 1988 flood, Savar was not so much affected as others due to its relative high ground level compared to flood stages. The proposed work by IDE is summarized as follows (see Fig. G.6) :

(1) Construction of an embankment from the bridge opposite Kohinoor Spinning through Nabinagar up to the north boundary wall of the Atomic Energy Commission. Total distance is approximately 10 km.

(2) Construction of an embankment/road from Nayarhat Bridge along the east bank of the Bangshi River up to the bridge over the Bannyabari Khal on the Dhaka - Aricha road, approx. 16 km.

(3) Raising of the road from the north wall of the Atomic Energy Commission up to Sadullapur including construction of 700 feet of flood protection wall, approx. 3.5 km.

(4) Raising of the road from Sadullapur up to Barta, approx. 1 km.

(5) Construction of a road/embankment from Barta village to the bridge over the Bannyabari Khal, approx. 2 km.

(6) Provision of 2 pump houses and 16 regulators.

2. Flood Mitigation Plan

2.1 Flood Mitigation Policy

2.1.1 Natural Condition

The study area is located on the alluvial plain of the three major international rivers i.e. the Ganges, the Brahmaputra and the Meghna river.

The land form is as low as 2 m to 13 m above mean sea level and the land from 6 m and above seems to be marginally free from annual flood.

The water levels in all the rivers gradually rise from May and reach their peaks in August and September and fall from October onwards.

The average annual rainfall in Dhaka is about 2,000 mm, 90% of which occurs during the monsoon season from May to October.

Most of major floods are caused when heavy rainfall is late in the area and coincides with high river stages of the Ganges and Brahmaputra rivers.

The study area is recognized as a flood plain area of the three international rivers and is habitually damaged by floods.

The detailed river system and characteristics of hydraulic conditions are referred to Supporting Report D.

2.1.2 Flood Condition

1) External Floods

The 1988 floods, estimated as a flood of about 70-year return period, was the worst in living memory. The flooding was caused by an unprecedented flood flow of the Brahmaputra in concurrent to very high flows of Ganges and Meghna rivers.

The entire flood plain of the Ganges, Brahmaputra and the Meghna river system of the country including the study area was engulfed by flood water.

Out of 850 km^2 of the study area, an area of about 620 km^2 and 2.2 million population of the study area have been seriously affected by this floods (ref. Supporting Report E, Fig.E.4).

Since the disaster, the GOB has intensified the construction of flood mitigation facilities in Greater Dhaka area (ref. Fig.G.3, 5).

2) Internal Floods

The study area is divided into higher lands and low-lying areas in terms of the flood inundation condition.

Most of the existing high land are developed as residential areas. While the low-lying area is mainly used for agriculture.

The location and the extension of the higher land (area) is roughly presented in Fig.G.10 by means of a flood inundation map of the 1987 flood (10-year frequency).

The inundation conditions are also presented by means of the typical cross-sections of Greater Dhaka (see Fig.G.11).

The characteristics of the internal drainage system is described below:

(1) In case of a low external water stage, the stormwater run-off of the higher land is discharged by a network of small khals which enter the main (trunk) khals of the low-lying area.

(2) In case of a high external water stage, the stormwater run-off of the higher land is directly discharged to the low-lying area which is already inundated by external floods.

2.1.3 Social Condition

Urban land development around Dhaka has accelerated to meet the increasing population pressure despite its flood risk.

Present and future (2010) population in the study area are estimated at 6.5 million and 13.4 million respectively.

During the 1988 flood Dhaka suffered tremendous casualties. More than 80% of its area were inundated and about 11,500 million TK of assets and 149 lives were lost by this flood.

In the wake of this flood, the Government planned the construction of an embankment, road-cum-embankment and flood walls around the western part of Greater Dhaka and the DND Project Area. Most of the planned facilities have been constructed but some portions of the west bank were not completed due to settlement of the embankment.

The planned flood wall from Kellar More to Mitford Hospital was not constructed due to land acquisition problems.

2.1.4 Flood Mitigation Policy

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

1) The future development area shall be protected as much as possible.

2) The proposed flood mitigation will comprise both structural and non-structural measures.

   The non-structural methods of flood plain management will be applied to those areas that will remain undeveloped rural areas. The structural measures will be applied to developed urban areas.

3) The structural measures shall include facilities which are to be constructed as early as possible and within the target year 2010.

   The scale of the facilities shall be determined with due consideration of economic effectiveness and financial viability of the project.

2.2 Flood Protection Level

For surrounding rivers and khals the degree of protection with respect to flood mitigation is determined by the adoption of a suitable scale of design flood.

Generally speaking, a design scale of flood frequency of 50-100 years is adopted for long term measures of flood mitigation schemes for large scale rivers.

For this study, the design scale of flood is determined with due consideration to the following basic concept and economic evaluation results.

2.2.1 Basic Consideration

1) Past Floods and Importance of the Area

   In general the scale of design flood is determined according to the degree of the importance of the study area and the largest flood level experienced in the past.

The study area is considered to be the most important area in this country. The 1988 flood, the largest flood one experienced in the past, is estimated to be of a 70-years flood frequency in most areas. Accordingly, a higher than 70-years flood frequency is recommended.

2) Design Flood Scale of the Existing Embankment

The existing embankment of the western part of the Greater Dhaka has been constructed by adopting a 100-year flood frequency.

3) Flood Protection Levels in South Asian Capitals.

In most capitals of South Asian Countries, a flood frequency of 50-150 years has been adopted for long term measures.

Country	River	City	Flood Frequency
Thailand	Chao Phraya River	Bangkok	100 - year
Philippines	Pasing River	Manila	100 - year
Indonesia	Generally, for large river	--	50 - year
Malaysia	Klang River	Kuala Lumpur	100 - year
Japan	Generally, for large river	--	100 - 150 year

2.2.2 Economic Assessment

Economic consideration of the alternative designs was roughly made by estimating economic internal rate of return (EIRR). Five flood scales i.e. 10, 50, 100, 200 and 500-year flood frequency and the Greater Dhaka area were selected for this study.

For this study, the following conditions were used for the calculation :

1) Benefits of the alternatives are estimated based on the flood damage investigation results (10-year and 70-year floods).

2) The construction cost only includes emplodering facilities i.e. the embankment and the flood wall of Greater Dhaka.

The cost of the already constructed western embankment is estimated using the same cost interia as for the eastern embankment.

3) The project costs are disbursed over ten years (1991 thru 2000).

The results show that the flood frequency between 50 and 100-year is the most economical design scale of flood.

2.2.3 Flood Protection Level

Based on the above basic concept, 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 is selected.

2.3 Flood Mitigation System

2.3.1 Basic Concept

In general, three (3) types of structural measures, namely, 1) dredging of river 2) empoldering and 3) combination of dredging and empoldering are employed for flood mitigation.

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

1) River training by dredging will not be effective for lowering the flood water level due to the peculiar hydraulic characteristics of the area

2) It is very difficult to maintain the design river bed due to the sedimentation problem

In order to confirm the above aspect 1), the hydraulic calculation was carried out by using the estimated discharge in the 1988 flood.

At the time of the 1988 floods, about 76 percent of the study area was inundated. The flood discharge estimated on the surrounding rivers were as follows:

Turag River	:	700 ~ 2,700 m^3/s	(upper to down reach)
Buriganga River	:	2,700 m^3/s	
Bansi River	:	2,700 m^3/s	
Dhaleswari River	:	1,000 ~ 20,800 m^3/s	(upper to down reach)
Tongi Khal	:	600 m3/s	
Balu River	:	100 ~ 800 m^3/s	(upper to down reach)
Lakhya River	:	2,600 ~ 350,000 m^3/s	(upper to down reach)

The hydraulic calculation results of the Turag river shows that excavation of about 50 m width and 5 m height, which is approximately the same dimension as the existing low-water channel,only lowers the flood water level by 27cm in 37 km river length.

For the Lakhya river, excavation about 100 m width and 10 m height contributes to 22 cm of lowering the flood water level in 24 km river length at the confluence of the Balu river.

Thus an empoldering system is the most realistic and recommendable structural measure for the flood mitigation of the study area.

2.3.2 Alternatives of the Empoldering System

The following two alternative empoldering systems are conceivable for the study area.

1) Independent System : To empolder each area independently
2) Integrated System : To empolder as many areas by a wriggle polder system

As for the integrated systems, the following mitigation system in the two sites are selected for a comparison with the Independent System (see Fig.G.12).

A. Tongi Site : Greater Dhaka with Tongi Area are protected by one polder system.

B. Keraniganj Site : Greater Dhaka and Narayanganj with Keraniganj Area are protected by one polder system.

This alternative study is conducted mainly by comparing the construction costs.

1) Comparative Facilities

The comparative facilities for the two areas of the alternative systems are summarized below:

(1) Integrated System:

Tongi Site	-	2 gates with navigation lock, (height 10m x width 40 m x3 span) are to be constructed in Tongi Khals.
Keraniganj Site	-	2 gates with navigation locks (height 15m x width 50m x 5 span) are to be constructed at Buri Ganga river on the upper and lower reaches.
		Embankment about 15km with 6^{m} in height in Kamrangir Char and Keraniganj western and eastern sides are to be constructed.

(2) Independent System:

Tongi Site	-	Embankment, about 12km with 5m in height along Tongi Khal is to be constructed.
Keraniganj Site	-	Embankment about 23k m with 5m in height surrounding the Keraniganj area and flood wall about 12 km with 1.5 m in height along the western part of Grater Dhaka and Narayanganj western part are to be constructed.

The standard sections of the embankment and flood wall are referred to in Fig. G.9, while the dimensions of the gates with navigation lock were estimated by referring to the existing river width and depth.

2) Cost Estimate

The cost estimate is roughly made, based on the above quantity. The unit costs of the embankment, flood wall and gate with navigation lock are assumed, based on data of construction works executed in South Asian Countries.

The cost estimate are summarized below

Unit : Million TK

Case	Unit Cost	Integrated System Quantity	Integrated System Cost	Independent System Quantity	Independent System Cost
A. Tongi					
1) Gate	100/m^2	2,400	240,000	-	-
2) Embankment	100/km	-	-	12	1,200
B. Keraniganj					
1) Gate	100/m^2	7,500	750,000	-	-
2) Embankment	100/km	15	1,500	23	2,300
3) Flood Wall	20/km	-	-	12	240
Total Cost		-	991,500	-	3,740

3) Proposed Flood Mitigation System

The result of the cost estimate shows that the Independent System is much more economical than the Integrated System for both Tongi and Keraniganj cases. Furthermore if the operation and maintenance costs are considered, the cost of Integrated System is much higher than that of the Independent System while, hydraulic effects i.e. the rise of water level, the flow velocity due to empoldering will not be of a great difference.

The Independent empoldering system is therefore recommended.

2.4 Design Criteria

2.4.1 Hydraulic Design Criteria

1) Design High Water Level

The design high water level is to be determined based on the probable flood water level and the rise of the water level by the proposed empoldering facilities.

The following flood levels (H.W.L) are employed as the design flood levels. The calculation results of the probable water level and the water rise based on the hydraulic simulation are shown in the Supporting Report D and summarized below.

Water Level Gauging Station	H.W.L (m)	Design Scale of Water Level (m)	Rise of Water Level (m)	Design Scale of Flood (years)
Tongi (Sta. No. 299)	8.6	8.30 m	0.08	100 Frequency
Mirpur (Sta. No. 302)	8.6	8.53	0.01	100 "
Mill Barak (Sta. No. 42)	7.8	7.72	0	100 "
Hariharapara (Sta. No. 43)	7.2	7.17	0	('88 Flood)*
Rakabi Bazar (Sta. No. 71A)	6.7	6.65	0	100 "
Demra (Sta. No. 7.5)	7.4	7.32	0.03	100 "
Kalagachia (Sta. No. 71)	6.4	6.40	0	100 "
Savar (Sta. No. 69)	9.7	9.68	0	('88 Flood)*

Note : * The flood water levels are assessed to be more than a 100-years flood frequency.

2) Design Freeboard

The freeboards are to be determined with due consideration of stability/strength in the case of overflow and temporary rise of the water level caused by wind and waves on the occasion of a flood. The following freeboards are employed based on the calculation results of water rise by wind waves. A 15 m/s of the wind speed is adopted based on the wind data.

- Embankment : 1.2 m
- Flood Wall : 0.6 m

3) Design Crown Level

The design crown level is to be determined based on the design high water level and the design freeboard.

- Embankment : H.W.L + 1.2 m
- Flood Wall : H.W.L + 0.6 m

4) Polder Alignment

The alignment is to be as smooth as possible based on the condition of land use, the flow regime during floods, the existing condition of river course, maintenance and construction expenses of the river in future, etc.

The following aspects are to be especially examined.

(1) In the case of a concave curve, it is desirable to recede the inside alignment of the curve and thus extend the river width and slacken the water hammer.

(2) Congested residential areas and the old river portion shall be avoided as much as practically possible.

(3) The land acquisitions by B.W.D.B for the embankment construction along the Balu river shall be considered as much as possible.

2.4.2 Standard Sections of Empoldering Facilities

The form of polder is to be selected with due consideration to the land use pattern, land availability for the polder construction, subsoil conditions, topographical conditions, etc.

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

1. Embankment
2. Flood Wall (T and I Type)
3. Road-Cum-Embankment

1) Embankment

In principle the following dimensions of the embankment are adopted with due consideration to the slope stability and maintenance:

(1) Embankment Crest Width: 4 m

(2) Berm of Embankment:

The berm shall be provided at every 4 m internal from the crest on the riverside and at every 3 m internal from the crest on the landside, while the width shall be 3 m or more.

(3) Slope Gradient:

The slope gradient of the embankment shall be a gentle gradient of 1:3 or less.

(4) Foundation Treatment:

If subsoil is considerably poor, some foundation treatment is required. A conceivable foundation treatment is by means of Consolidation of poor soil foundation by sand drain/sand compaction methods with step by step embankment.

2) Flood Wall

The following dimension are adopted in principle.

(1) T Type Flood Wall:

a) The wall thickness is 0.3 m at the top and 0.5 m at the foot base.
b) The relation between the height (H) and the base width (B) is to be about 0.8 to 1.0.

c) This type is to be applied on good foundation and no foundation treatment is assumed.

(2) I Type Flood Wall:

a) The wall thickness from top to bottom is to be 0.3 m or more.

b) The height of the upper part and below ground level is to be the same length.

3) Road-Cum-Embankment

The dimensions of most parts are to be the same as an embankment. However, the embankment crest width shall be 7 m or more with due consideration of traffic purpose. In cases of existing roads with width over 7 m, the road width shall be adopted.

When the rise of roads is less than 2 m, the slope of banking is to be 1:2.

2.5 Alignment of Polder

Alignment of polder is determined by considering the social aspect, hydraulic aspect, and economic effectiveness of the proposed facilities in the protected areas.

2.5.1 Policy of Alignment Planning

The areas to be protected are basically 1) existing urban area and 2) future urban area by the target year 2010. Special attention to on-going projects or plans is to be made for the future protection area.

The detailed information on urban areas is provided in Supporting Report C.

Beside the above, the alignment will be determined with due consideration to existing flood mitigation facilities and project plans, the planning concept of smooth alignment, good subsoil condition, least land acquisition, minimum quantities of earth work and retarding pond area for drainage system.

2.5.2 Planning Criteria

The empoldering facilities are planned based on the hydraulic design criteria and standard of empoldering facilities (refer to Chapter 2.5). The planning criteria applied in this study is described below.

1) Crown Level

Crown level is determined based on the design high water level at each gauging stations by adding freeboard.

The freeboard for embankment and flood wall are set at 1.2^{m} and 0.6^{m} respectively.

2) Land Required

The land required for the embankment and flood wall include space for construction, and operation and maintenance. The following figures are adopted by considering stability, maintenance and operation of the facilities.

(1) Embankment: Banking space + 30 m

(2) Flood Wall

a) With river bank protection : Construction Space + 3^m
b) Without river bank protection : Construction Space + 5^m

3) Applied Standard Sections

The types of empoldering facilities are selected on the basis of site survey along the alignment alternative. The basic concept of the application of the empoldering facilities to the sites are shown below :

(1) Embankment

a) Site Condition Applied
The suitable/applicable site conditions are the places where

- Required large scale land acquisition is possible
- Poor sub-soil condition
- New roads are required

Embankment is suitable mostly in the rural area or the flood plain area.

b) Standard Cross-Sections

- Embankment with ordinary sub-soil condition:

For this type, no foundation treatment is to be required. The major dimensions of the standard cross-section are shown in Fig. G.9(1).

- Embankment with poor sub-soil condition:

The dimensions of embankment is the same as that of embankment with ordinary sub-soil, except that foundation treatment is required. The foundation treatment is to be carried out by sand piling or other applicable methods.

(2) Flood Wall

a) Site Condition Applied

The suitable / applicable site conditions are where

- Available space is very limited

- Subsoil condition is good

  This type is applied mostly in urbanized area.

b) Standard Cross-Section

- T Type Flood:

  This type of structure is of reinforced concrete and no foundation treatment is required. The standard section is shown in Fig. G.9(2).

- I Type Flood Wall:

  This type of structure is applicable to the straight form of reinforced concrete. The wall thickness shall be 30 cm or more.

  The standard section is shown in Fig. G.9(2).

(3) Road - Cum - Embankment

a) Site Condition Applied

The applied site condition is where the existing road is expected to be utilized for the flood protection.

b) Standard Cross Sections.

The standard sections are categorized as follows :

- Type A: Embankment height is relatively low (H<2^{m})
- Type B: Embankment height is considerably high (H>2^{m})

The crest width for both types shall be 7^{m} (minimum) with due consideration of the road function. The standard cross-sections are shown in Fig. G.9(2).

2.5.3 Alignment Alternatives

Alternatives of polder alignment are selected with due consideration of the existing flood mitigation facilities, social aspect, hydraulic aspect, land use and urban planning in the study areas.

The selected alignment alternatives are described below.

1) Selected Alignment Alternatives

(1) Greater Dhaka

a) Eastern Part

- Case A

The principal purpose of Case A is to protect the existing and potential future urbanized area.

The alignment covers most urbanized areas being developed along the Tongi to Syedabad trunk roads and the higher land of the northern part of Greater Dhaka area. The low-lying area around Ulan is included for the use of regulation pond (see Fig. G.3).

- Case B

The principal purpose of Case B is to protect both the existing urban area and the large area of potential future developed area.

The alignment is along Balu river and is almost the same as the plan proposed by the Committee. However, some revision was made at the area of poor sub-soil area identified from BWDB soil investigation. The embankment line at Bhaturia is revised on higher ground level portion near the original line. The revised portion is shown in Fig. G.13.

b) Kamrangir Char

Kamrangir Char, identified as a developed sand bar in the Buriganga River, is located between Old Dhaka and Keraniganj. Although the present population is estimated to be more than 35,000, this area was left unprotected in the phase I program.

Based on the flood survey results, the whole area was completely inundated during the 1988 flood and most of the area was inundated during the 1987 flood that corresponds to 10-year flood frequency.

For this area, three cases i.e. Case A, B and C are conceived as alignment alternatives:

- Case A

The principal purpose of Case A is to protect the existing urbanized area.

The alignment covers most of the urbanized area by one polder system which is separate from the existing embankment.

- Case B

The protection area is the same as Case A. However, the alignment of the polder is connected to the existing embankment.

The proposed embankment extends from the Dakshin Sonatenga site of the existing embankment along the left bank of the Buringanga river and is connected to the proposed phase I embankment further down stream.

In this case, stormwater from the neighboring western Dhaka area is discharged into this area and consequently extra pump capacity is required for the drainage facility.

- Case C

The principal purpose of Case C is to protect the whole Kamrangir Char area which is composed of both the existing urban area and the low-lying area of Katasur.

This alternative is an extremely costly one because of the large quantity of land-reclamation needed for the development of the area.

For this reason, this case will not be discussed any further here.

c) Western Part

The Western Part is defined as the area between the road-cum-embankment along the eastern fringe of existing Dhaka urban area and Buri Ganga river.

For this area, no alternative is considered due to existing embankment and the on-going project.

The major work for this area includes rehabilitation work of existing embankment and flood wall, constructions of flood wall type structure between Kellar More to Mitford Hospital.

(2) Narayanganj area

a) Western Bank

The Western Bank area is composed of DND Project area and Narayanganj Town.

The DND Project area is presently protected by the flood wall and railway-cum-embankment, while the Narayanganj densely populated area and industrial area located alongside of the Lakhya river are not free from a 1988 scale flood.

The alternatives are basically prepared focusing on whether, economically, the narrow strip of industrial area can be protected or not.

- Case A

The alignment covers the areas of DND project surrounded by the existing flood wall and railway-cum-embankment, and the centre of Narayanganj town. However it excludes the narrow strip of industrial area along the Lakhya river (see Fig. G.13).

- Case B

The alignment covers almost the whole area of the Western Bank including the narrow strip of industrial area (see Fig. G.13).

b) Eastern Bank

The Eastern Bank is defined as the area between the road from the Tarabo via the abandoned railway and the Lakhya river (see Fig. G.13).

For this area, no alternative is considered due to its small size and long shape.

Economic feasibility for protection is checked and the hydraulic adverse effect will be analysed later.

(3) Tongi Area

Tongi Town is an industrial area which is rapidly developed partly due to its higher ground level.

Two alternatives are selected with due consideration to the high development potential of the area.

a) Case A

The principal concept of this case is to protect the existing urbanized area.

The alignment covers most of Tongi Union and is planned to use the existing road to the maximum extent. The portion that is not included by this alignment is the western low - lying area along the local khal (see Fig. G.13).

b) Case B

The principal concept of the case B is to cover the potential development area to the maximum extent. The alignment of Case B is different only for the western part of Tongi area (see Fig. G.13).

(4) Savar Area

Most parts of the area were not inundated during the 1988 flood.

However, the center of Savar town was inundated for more than two weeks and seriously affected.

For protection of the town center, an alignment which empolders the town center and its suburban area is proposed. The alignment runs along the Bansi river to the west and Bannyabari Khal to the East by utilizing existing roads.

(5) Keraniganj Area

A bridge construction project linking old Dhaka area and town centre of Keraniganj, and a new port development project at Pangaon have been envisaged by the Government.

The following alternatives are selected taking the above situation into account.

a) Case A

The principal concept of this case is to protect the existing urbanized area. The alignment is basically along the fringe of the existing village and roads on the Dhaleswari River side, while for the Buriganga side, the alignment is along the existing river bank. The southern end of the alignment is connected to the existing trunk road extending to Char Kondalia.

b) Case B

This alignment includes the Port Development Project area at Pangaon and some potential development areas along the Buriganga river. The alignment along the Dhaleswari river side is designed to be a smooth line and incorporates residential area to the maximum extent.

c) Case C

This alignment includes large parts of the flood plain area having high potential for future development provided that low-lying area is developed economically.

However, this alignment is not recommendable from the viewpoint of a hydraulic aspect.

The Water level will rise considerably due to the blocking off of the existing waterway . This adverse hydraulic effect will necessitate heightening of the embankment on the upstream as well as the strengthening of revetment on the downstream.

For this reason, Case C will not be discussed as an alternative.

2) Index of Comparative Evaluation of Social Aspect and Flood Condition

The social aspect and flood condition are closely related to the beneficial effect and can be used as a component of index for the evaluation of comparative alignments.

The main items of the above social aspect and flood condition of the protected areas by the respective alternatives are selected below :

(1) Size of Protected Area (km^2)
(2) Land Use at present and future 2010
(3) Population at present and by the target year 2010
(4) Flood Condition in 1988 and 1987 Floods
Inundation area, depth and duration.

These aspects are summarized in Table G.5.

3) Cost Estimate

Cost estimate of respective alternatives are prepared based on the following conditions.

(1) Empoldering Facility Plan

The type of empoldering facilities is determined by considering land use, topography and geological conditions.

The empoldering facilities and plans for the alignment alternatives are proposed and shown in Table G.6 and Fig. G.13 respectively while, the topographic and geological conditions for the facility are based on the following data and assumption.

a) Topographic and Geological Conditions

The ground levels and geological conditions of the selected alignments are prepared based on 1:7,920, 1:10,000 and 1:15,840 Topo maps, spot level survey and bore hole data.

The geologic data on the alignments are very limited except the Balu river. For determining the geological condition, regarding the bearing capacity of the soil foundation for proposed embankment, it is assumed that :

- If the ground level is sufficiently high, and flood free with respect to the annual average flood, the area is assumed to have sufficient bearing capacity for the embankment construction.

- If the ground level is lower and assumed to be a part of the flood plain, soil condition of the area is assumed to be of poor sub-soil condition.

The topographic condition is shown on longitudinal sections of the alignment alternatives (see Fig. G.14).

(2) Cost Estimate

a) Basic Condition

The cost, which includes construction and land acquisition cost, is roughly estimated based on the following policy and conditions.

- The cost of only major works i.e. embankment work with the foundation treatment, concrete work for the flood wall, the construction of pump stations, sluice gate, khal improvement are to be estimated.

- The unit cost for the construction work is estimated as shown in Supporting Report J.

b) Quantity

The work quantity is estimated on the basis of the typical cross-section and the longitudinal section.

The land acquisition area is estimated on the basis of the cross-section with required space for operation and maintenance work.

The bill of quantity for all alternatives is shown in Table G.7.

c) Cost Estimate

The cost estimate for all alternatives is summarized in Table G.8.

4) Number of Resettlement

The construction of proposed empoldering facility involves land acquisition of right-of-way and consequently involves resettlement of residents.

The number of people and households to be resettled are approximately estimated from the proposed land acquisition area and the population distribution data.

The result shows that in the case of the proposed alignment about 75,000 people would be subject to resettlement, while protected land and population in 2010 are about 420 km^2 and 12.5 million people respectively.

The amount of resettlement for each alternative is summarized in Table G.10.

5) Hydraulic Aspect

Flood water level of the 1988 flood without and with proposed empoldering facilities were calculated by means of a hydraulic simulation model (refer to Supporting Report D).

The existing embankment and proposed polder do not obstruct much the main stream flow which are analysed by using the satellite colored image taken between February to March 1989 flood (see Fag. G.15)

The result shows that the rise in river stage by empoldering facilities at Kamrangir Char is about 1 cm only. The maximum rise in water stage by the empoldering is 8 cm at the upper reach of the Balu river (ref. Table G.9 and Fig.G.5). This upsurge is evaluated to be negligible.

For this reason, hydraulic aspect is not considered as a factor for the selection of alignment alternatives.

2.5.4 Proposed Alignment

Since the resettlement and hydraulics do not exert any appreciable effects on alignment alternatives, the proposed alignment selection is based entirely on the cost effectiveness, which is expressed as the cost per population in the target year (2010).

The comparison of cost effectiveness and proposed alignments proposal are shown below:

	Area/Case	Protected Population (2010)	Cost (x 10^6 Tk)	Cost Effectiveness (Cost/Pop.)	Proposal
1.	Greater Dhaka				
	A. Greater Dhaka East:				
	Case A	1,251,000	14,638	11,701	Case B
	Case B	2,322,000	15,284	6,582	
	B. Kamrangir Char :				
	Case A	192,000	1,126	5,926	Case B
	Case B	211,000	1,006	5,295	
	C. Greater Dhaka West: (One case only)	6,053,000	19,840	3,278	Accepted
2.	Narayanganj				
	A. Western Bank :				
	Case A	1,949,000	8,159	4,186	Case B
	Case B	2,241,000	9,225	4,116	
	B. Easter Bank: (One case only)	266,000	2,840	10,677	Accepted
3.	Tongi				
	Case A	653,000	3,022	4,628	Case A
	Case B	725,000	3,685	5,080	
4.	Savar Area (One case only)	250,000	1,436	5,241	Accepted
5.	Keraniganj				
	Case A	273,000	2,924	10,710	Case B
	Case B	457,000	4,866	10,648	

The detailed comparison is shown in Table G.10. The proposed alignments and their major facilities are shown in Fig. G.13.

2.6 Proposed Flood Mitigation Facility

2.6.1 Project Areas

The study area is divided into five(5) sub areas based on river alignments and embankments. However the project areas for structural flood mitigation measures is divided into seven (7) divisions with due consideration to the implementation of the project see. (Fig G.16). These seven (7) divisions are as follows:

1) Greater Dhaka Area

   (1) Dhaka West Project Area
   (2) Dhaka East Project Area

2) Narayanganj Area

   (3) Narayanganj West Project Area
   - DND Area
   - Narayanganj West

   (4) Narayanganj East Project Area

3) Tongi Area

   (5) Tongi Project Area

4) Savar Area

   (6) Savar Project Area

5) Keranignj Area

   (7) Keraniganj Project Area

2.6.2 Design Sections of the Facilities

1) Standard cross section of the polder

The empoldering facilities are composed of embankment, road-Cum-embankment, and flood wall T and I Types as mentioned in the previous section on planning criteria.

The types of facilities for the sites are mainly determined on the basis of availability of land and sub soil conditions.

The applied types of the facilities are shown in Fig G.16 of proposed longitudinal sections.

While, the standard cross section is shown in Fig G. 9.

2) Longitudinal Section of the polder

The proposed longitudinal sections of polders are based on the design high water level of major water level gauging stations (see 2.4 Design Criteria) and design freeboards of 1.2^{m} (Embankment) and 0.6^{m} (Flood wall).
The proposed sections are shown in Fig G. 16(2) to Fig G. 16(4)

3) Sluice Gate (Regulators)

Sluice gates are designed at the outlet of Khals and proposed pump stations (see Fig. G. 16 (1).

The proposed flow areas of the sluice gates are basically determined by means that design discharges divided by design flow velocity of 2.5 ^{m}/s.

The number of sluice gates and their design discharge, flow areas are summarized in table G.11(2) and G.11(3).

2.6.3 Proposed Facility/Rehabilitation Work

The rehabilitation works of the existing facilities and the proposed facilities in the following project areas are proposed based on the previous alignment study and by taking the implementation program into consideration. The proposed project areas with major facilities and their longitudinal sections are shown in Fig G.16. The major flood mitigation facilities and rehabilitation works are shown in Table G.11(1) and listed below:

1) Greater Dhaka

(1) Greater Dhaka West

- Western part

a) Rehabilitation Works (R) and Construction Facilities

- Embankment (R) : 16.7 km of repairing, strengthening works of failure and settlement portion (3.0 km of foundation treatment)

- Flood Wall (R) : 4.7 km of Rehabilitation Work
- Embankment : 0.3 km nearby Kellar More (0.3 km of foundation treatment)
- Flood Wall : 3.0 km between Kellar More to Mitford Hospital
- Sluice Gate : 11 places (On-going Projects by JICA and IBRD are not included)

- Kamrangir Char

a) Proposed Facility
- Embankment : 6.0 km for Kamrangir Char area (2.0 km of foundation treatment)
- Sluice Gate : 1 places

(2) Greater Dhaka East

a) Proposed Facility
- Embankment : 26.7 km along the Balu river (14.6 km of foundation treatment)
- Sub Embankment : 11.3 km
- Sluice Gate : 5 places

2) Narayanganj

(1) Narayanganj - West Project Area

- DND Area

a) Rehabilitation Works
- Flood Wall (R) : 20.2 km of strengthening work for the eastern part of the existing flood wall

b) Proposed Facility
- Flood Wall : 10.0 km along the western part of the national road and existing railway track
- Sluice Gate : 2 places

- Narayanganj - West

a) Proposed Facility
- Embankment : 6.1 km on the north and southern part of Narayanganj town
- Road-Cum-Embankment : 4.3 km on the western part of Narayanganj

- Flood Wall : 10.5 km along the Lakhya river
- Sluice Gate : 7 places

(2) Narayanganj - East

a) Proposed Facility

- Embankment : 6.6 km on the north part of the area
- Railway-Cum-Embankment : 6.5 km on the northern part of the area
- Flood Wall : 26.0 km along the Lakhya river and abandoned railway
- Sluice Gate : 12 places

3) Tongi

a) Proposed Facility

- Embankment : 13.0 km on the eastern part of the area (10.4 km of foundation treatment)
- Road-Cum-Embankment : 6.2 km on the northern and western part of the area
- Flood Wall : 2.2 km along the Tongi Khal
- Sluice Gate : 7 places

4) Savar

a) Proposed Facility

- Embankment : 9.3 km on the Western and Southern part of the area (3.1 km of foundation treatment)
- Sluice Gate : 3 places

5) Keraniganj

a) Proposed Facility

- Embankment : 23.3 km on the eastern and western part of the area (5.1 km of foundation treatment)
- Flood Wall : 3.7 km along the Buriganga river
- Sluice Gate : 10 places

3. Guidelines for the Flood Plain Management

3.1 General

The study area of the flood control and drainage master plan encompasses an area of 850 km^2. Of this area the structural mitigation measures cover an area of 456 km^2 (as delineated in the previous section) which would form the future potential urban area until the year 2010.

The remaining area of 324 km^2 lying almost in between the Buriganga and Dhaleswari river would remain unprotected as a flood plain, in which urbanization would be restricted in order to ensure no significant change in land use. However the total rural area is 362 km^2, if high land agricultural area of 38 km^2 in Savar which is not a flood plain is also included.

However, in order to protect the isolated rural farming communities from potential flood damage, an effective flood plain management plan is a prerequisite. Accordingly, the necessary guidelines of flood plain management are formulated.

The proposed guidelines are composed of two principal elements:

1) Flood forecasting, warning and evacuation system
2) Land use regulation to mitigate uncontrolled urbanization.

3.2 Proposed Flood Prone Area and Population

Out of the study area of 85,000 ha, high lands of 20,000 ha are free from flood and selected low-lying areas of 29,900 ha will be protected by the proposed polders to a safety level of 100 year probability. However, the remaining low-lying areas of 32,800 ha will be left unprotected even in future, while major river areas of 2,300 ha are not included in the flood plain area. Such unprotected flood plains are as follows (see Fig. G.13).

1)	Buriganga/Dhaleswari River Flood Plain	:	15,200 ha
2)	Turag River Flood Plain	:	10,000 ha
3)	Savar South Flood Plain	:	4,900 ha
4)	Savar North Flood Plain	:	1,600 ha
5)	Buriganga Lower Left Bank Flood Plain	:	1,100 ha
	Total	:	32,800 ha

The above flood plains were consecutively damaged by severe floods in 1987 and 1988. The 1988 floods with a 70-year return period affected the whole population of the flood plains. Even the 1987 floods with a 10-year return period affected 90% of the population of the flood plains. The total affected population by the 1987 and 1988 floods are estimated to be 0.49 million and 0.58 million respectively. The affected population in the respective flood plains are shown below.

		1987 Flood	1988 Flood
1)	Buriganga/Dhaleswari	280,000	292,000
2)	Turag	55,000	63,000
3)	Savar South	123,000	178,000
4)	Savar North	5,000	21,000
5)	Buriganga Lower Left	27,000	30,000
	Total	490,000	584,000

The above affected population are further broken down into the respective constituent unions as shown in Table G.12.

3.3 Proposed Organization

3.3.1 Present Condition

Flood plain management involves the activities of flood forecasting and warning, flood evacuation and relief and land regulation.

Presently such activities are carried out by the respective organization. Flood forecasting and warning has been carried out by BWDB. Evacuation and relief activities involved with the municipal body, the Ministry of Relief and Rehabilitation, the President's Flood Monitoring Center, the Army, etc. Land development has been progressed by RAJUK, the Ministry of Local Government and the municipal body.

In consideration of the above situation and in order to have a smooth and effective flood plain management, some integrated organization or committee comprising all the concerned organizations shall be organized

3.3.2 Proposed Organization and Its Role

For the smooth and effective implementation of the flood plain management, the establishment of a committee is recommended.

The major task of the committee is to assess and examine the following items.

1) Review of the guidelines of flood plain management
2) Examination of land use
3) Assessment of the flood forecasting and warning system
4) Assessment of the flood evacuation and relief

The implementation of the above items is to be carried out by the respective organization.

The committee is to have periodical meetings throughout the year. Urgent meetings will be held in occasion of 1) The danger water level is observed, 2) During the flooding period, 3) Occurrence of land regulation problems and 4) If the majority of the members request for a meeting.

The committee is to be composed of members of the following organization i.e. BWDB, SPARRSO, BUET, BMD, DWASA, MOLG, MORR, DDC, Army, respective Municipal Body, and other related authority.

3.4 Flood Forecasting and Warning System

3.4.1 Existing Condition

The flood forecasting and warning has been carried out by the Flood Forecasting and Warning Center of Hydrology-2, BWDB in cooperation with MPO, SPARRSO and other agencies concerned.

The existing flood forecasting mechanism is limited to a few water level monitoring stations along the Ganges, Brahmaputra Buriganga and Lakhya river due to lack of hydrological observation equipment, telecommunication equipment and trained personnel.

There are only two (2) river stage monitoring stations located within the study area. They are Dhaka and Narayanganj stations along Buriganga river and Lakhya river respectively.

These two (2) stations are inadequate for the forecasting of flood water levels of the Upazila considering the vast expanse of the flood plains.

3.4.2 Proposed Strengthening Measures

The following strengthening measures to the existing flood forecasting and warning system are proposed in order to realize a more practical flood forecasting and warning system.

1) The establishment of water level gauging stations in the flood plain area. The proposed locations are Abdullahpur in the Buriganga/Dhaleswari flood plain and Qusimpur in the Turag flood plain. (See Fig. G.17)

2) Establishment of telecommunication/wireless link between major water level monitoring stations and the Flood Forecasting and Warning Center. The proposed monitoring stations are to be in the upazila offices of Savar, Tongi, Keraniganj and Narayanganj.

3) The upgrading of a regional model for detailed regional forecasting, in cooperation with the authorities/agencies concerned.

4) The improvement of the flood warning system up to the Upazila level by establishing/strengthening the flood warning section in the Upazila Office of the flood plain area.

In addition, bilateral cooperation with the concerned flood forecasting/warning agencies across the border in India at the upstream reaches, for the exchange of information, is necessary.

3.5 Flood Evacuation System

3.5.1 General

During the 1988 floods, flood levels at Dhaka and Narayanganj were announced on the radio and television. However, an evacuation order was not issued by the authorities concerned.

Therefore the people in the inundated area were forced to determine for themselves the time for evacuation, the place of safety, and to obtain necessary information.

Some people in the flood plain evacuated their homes when the depth of inundation had already reached 1 m.

This type of evacuation scheme is very inadequate and may cause higher flood damages during future floods.

3.5.2 Proposed Evacuation System

In view of the above inadequacies, the following improved evacuation system is proposed for the respective flood plains.

1) For the flood plains which are located mostly more than 2 km away from the neighboring flood free land, a flood evacuation and relief section in the Upazila Office shall be established/improved and equipped with the necessary tele-communication facilities to be able to communicate between the Upazila Office and the Evacuation & Relief Center.

2) The determination of danger water levels which indicate the commencement of the evacuation in the respective flood plains.

   The danger water levels recommended are set about 0.3 m lower than the existing mean residential ground level for the respective water monitoring station in due consideration of the rise in flood level in one day during the 1988 floods.

   The proposed danger levels are shown in Table.G.13 Fig.G.17.

3) Evacuation shelters shall be constructed in order to avoid flood casualties. The shelters are only proposed in the Buriganga/Dhaleswari and Savar south flood plains considering the distance from the neighboring flood free lands.

The shelters are to be used as relief centers and to accommodate the following people:

(1) Some residents such as pregnant women, patients, etc. who are unable to evacuate to neighboring flood free lands because of illness or other reasons.

(2) The members who are assigned to supervise the property of residents.

(3) The people who work in relief activity. The accommodation capacity of a shelter is to be assumed to be 5% of the population of the proposed flood unit (about two third of the whole area). The other people should be evacuated to the nearest flood free lands.

The necessary facilities and equipment for the shelter are as follows:

a) Medical treatment facilities and medicine for emergencies
b) Water supply facilities and some amount of food for temporary supply
c) Clothing, tents, and other necessary commodities
d) Telecommunication equipment, etc.

The main feature of the evacuation centers is proposed as follows :

a) Mounted ground level : HWL + 1.2 m
b) Accommodation Capacity per Shelter : 2,000 people
c) Land of evacuation center : 3,000 m2
d) Type of builbing : Reinforcing Concrete Structure

The location of the shelters shall be selected by taking into consideration the flood risk map, flood stream, proximate to a trunk road and distribution of the population.The flood risk map based in the 1988 flood survey is shown in Fig.G.18.

4) The evacuation roads shall be improved/constructed to link the evacuation center and the villages within the flood plain.

The proposed minimum road requirement are as follows:

(1) The top elevation of the evacuation roads is to be 0.6 m above the ground level of the house base considering the evacuation time allowance.

(2) The road width should be more than 2 lanes.

(3) The road should be strong enough even in submerged condition.

(4) The road should have guide posts in order to indicate its location when submerged.

The proposed locations and the length of the road improvement are shown in Table G-13 and Fig.G.19.

3.6 Land Regulation

3.6.1 General

Land development in the low-lying area of flood plain is to be controlled Because:

1) In general, land development in these area is very costly and the developed land is not strong enough against flood flow. This may lead to tremendous damages to the local residents and the economy as a whole.

2) The banking of the developed area obstructs the flood flow and would cause the rise of the flood water level or changes in flow direction which may lead to adverse hydraulic effects to the whole area.

The flood plain areas are therefore to be controlled by means of land use regulation which include the prohibition of land development and control of land use pattern with due consideration of the flood flow characteristic in the area.

3.6.2 Land Use Control by Zoning

In principle, flood plain areas are not to be used for land development. However, the implementation is a very difficult matter because of the limited available space in the suburban area.

Zoning of flood plain areas have been adopted in many countries as a controlling tools of the land development in flood plain areas.

For this study, the zoning method is to be applied by considering the flood flow characteristic with the following definition:

1) Main Flood Flow Zone : The area is to be recognized as main flood flow zone.
2) Sub Flood Flow Zone : The area is to be less affected by flood flow.

The above zoning should be based on the flood flow information, observation of satellite image and hydraulic simulation results during the 1988 flood (see Fig. G.20).

3.6.3 Proposed Zones

1) Main Flood Flow Zone

Most of the area of this zone is used as agricultural land. In this zone, land development for residential, commercial and industrial use should prohibited. However, the following land pattern or usage will be allowed provided that the land development causes no adverse hydraulic effect to the flood flow.

(1) Agricultural land use
(2) Open space for recreation
(3) Ferry terminal
(4) Recreation facilities (only for dry season)
(5) Material deposit
(6) Bricksyards

2) Sub Flood Flow Zone

At present, the land use pattern is composed of villages and rice fields. The land development for this area is only allowed provided that:

(1) The developed land is raised more than the design flood water level, on the buildings are on columns above high water level

(2) The slope of the banking land is gentle enough to prevent slope failure and is to be protected against erosion by flood flow.

(3) The direction of the structure on the land is to be designed so as not to disturb the flood flow.

(4) The damage of the structure is expected to be small even in the flood stage.

(5) The floor elevation of warehouses for poison, burning materials or other items which cause danger to the human being or livestock should be higher than the design flood water level. The structure should be strong enough to cope with expected external forces by flood or any other cause.

Table G.1 Review of Previous Studies

No.	Title of Study	Year of Publication	Authority Concerned	Study Area	Content of Study	Scale of Flood Water level in Frequency	Major Flood Control Facilities/ Recommendation	Project Implimentation
1	Master Plan and Feasibility Report For Storm Drainage and Flood Control for the City of Dhaka	1968	DPHE	Dhaka City 75 km2	M/P & F.S: Flood Control and Storm Drainage	50 years (Rainfall Intensity:5 years)	Embankment, Concrete wall, Pump Sta., Open&Pipe Drains, Reservior	Not - due to Financial constraint
2	Sir William Halcrow &Partner's Study	1973	BWDB	Dhaka City & Surroundings 260 km2	F.S: Flood Control and Storm Drainage	500 years	-Ditto-	-Ditto-
3	Dhaka Metropolitan Area Integrated Urban Development Project	1981	ADB/ UNDP	Dhaka Metro-politan Area 256 km2	M/P:Integrated Development and Flood Control	--------------	Northern part of high area is proposed for the development area-No embankment policy	Not duly approved by the Government
4	Study on Storm Water Drainage System Improvement Project In Dhaka City	1987	DPHE/ JICA	Dhaka City & Surroundings 137 km2	M/P &F.S: Storm Water Drainage and Flood Control	30 years (Rainfall Intensity:5 years)	Embnkment,Punp Sta.,Open &Pipe drains, Reserviors	Revised in 1990's study
5	Mr. Jansen's Recommendation	1988	--------------	Greater Dhaka Area 260 km2	Recommendation on Flood Control Measures by consider-ing 1988 's Flood	500 year	Principal idea of Sir William Halcrow 's Study was recommended	Taken into considera-tion by the committee for phased inplementa-tion (on-going)
6	Greater Dhaka Flood Control and Drainage Project (GDFCD)	1988	COMMITTEE	Dhaka Metro-politan Area	Flood Control Project Plans by Phased Program	Scale of 1988 year's flood	Embankment,Flood wall,road-cum-embankment Regulators	Phase I: Complition/ under Construction
7	26 Action Plans (FAP)	1989	WORLD BANK	Whole Country	T/R of Flood Action Plans	--------------	Plans composed of broad countermeasures for Flood control and Storm water problems	Study is in progress.
8	UNDP/UNCHS Proposal	1989	UNDP/ UNCHS	Dhaka and Chittagong	Drainage and Flood Control, Water Supply and Sewrages, Land Development Projects Implimentation	(Rainfall Intensity:10 years)	Dhaka:Pump sta., Reservoir, Khal improvement	Tendering Procedure is being taken
9	Updating Study on Storm Water Drainage System Improvement Project in Dhaka City	1990	DWASA/ JICA	Dhaka City & Surroundings 137 km2	M/P and F.S:Revision of Previous JICA Study	Not mentioned (Rainfall Intensity:5years)	Pump Sta.,Sluice,Road culvert, Khal Dredging	- Ditto -
10	Dhaka Integrated Flood Protection Project (FAP NO. 8B)	1990	FPCO/ ADB	Dhaka Metropoli-tan Area 260 km 2	Basic Plan&F.S of Integrated Flood Protection and Drainage Progect	--------------	--------------	Study Schedule: Dec,1990-Aug,1991
11	North Central Regional Study (FAP NO. 3)	1990	FPCO/ EEC&France	North Central Region 12,000 km2	M/P&F.S of Water Development Strategies and Plan	--------------	--------------	Study Schedule: Phase I:Mar,-June 1990 Phase II:Sep,1990-Oct,1991

Note:
DPHE : Department of Public Health Engineering
BWDB : Bangladesh Water Development Board
ADB : Asian Development Bank
UNDP : United Nations Development Programme
COMMITTEE : Committee for "Flood Control and Drainage of Grea
UNCHS : United Nations Centre for Human Settlement
DWASA : Dhaka Water Supply and Sewerage Authority
M/P : Master Plan Study
F.S : Feasibility Study
FPCO. : Flood Plan Co-ordination Organisation

Table G.2(1) Flood Control Facilities

A. Existing and On-going Facilities

Executing Agency	Component of Work	Location	Quantity	Elevation/Capacity
Army	Embankment	E1 : Tongi to Diabati	8.00 km	10.0 m +PWD
		E5 : Satmasjid to Kellar More	5.80 km	10.0 m +PWD
BWDB	Embankment	E2 : Diebati to Sirnir Tek	9.69 km	10.0 m+PWD
	Sluice	S1-S6	6 nos.	
	Pump sta.	DND Project	1 No.	14.5 cubic meter/sce.
DMC	Embankment	E3 : Sirnir Tek to Mirpur bridge	1.50 km	10.0 m+PWD
	R.C.C Wall	W1 : - Ditto -	0.75 km	2' above flood mark
	Rising of BWDB Dam			
	Embankment	E4 : Mirpur bridge to Kallyanpur	1.42 km	10.0 m+PWD
	R.C.C Wall	W2 : - Ditto -	0.16 km	10.0 m+PWD
	Embankment	E4 : Kallyanpur to Satmasjid	2.75 km	10.0 m+PWD
	R.C.C Wall	W3 : Mitford Hospital to Buriganga bridge	4.31 km	2' above flood mark
	Rising of road	R1 : Rampura main road	0.98 km	7.9 m+RWD(Approx.)
	* Dholai Khal Project (UNDP/World Bank Project)			
	Improvement of Khal		2.35 km	
	Pump Station	Pmd1:Confluence of Buriganga river	1	80,000 m3/hr
	Reservoir	Narinda,Dayaganji areas	1Nos	205,000 m3
	Removal of Pump Sta.	Existing Narinda Pump Sta.		
CAAB	Embankment	E6 : Surroundings of Zia Airport	10.53 km	9.8 m-10.5 m+PWD
RAJUK	Rising of road	R2 : Joar Sahara to Rampura	6.00 km	7.9 m+PWD(Approx.)
		R3 : Rampura to Syedabad	5.90 km	8.4 m+PWD(Approx.)
		R4 : Sirnir Tek	0.77 km	10.0 m+PWD
RHD	R.C.C Wall	W4 : Surroundings of DND Project area	26.61 km	2' ~ 3' above flood mark
DWASA	Reexcavation of 12 khals	Greater Dhaka Area	---	---
	* Japan's Grant Aid Project			
	Pump station	Pmw 1: Kallyanpur		20(Tentative 10)m3/sec
	Sluice	Smw 1: Kallyanpur		
Railway	Raising of Railway	R5 : Southern part of DND Area	2 km (Approx.)	6.8 m

Note:

1) Location : See Fig. G.3 and G.5
2) * : On-going Project

Contd.

Table G.2(2) Flood Control Facilities

B-1. Proposed Flood Control Plans by the Committee

Executing Agency	Component of Work	Location	Quantity	Elevation/Capacity
BWDB	Embankment Pump Station Suluice	Emb 1:Tongi to Demra Pmb1-Pmb5: Smb1-Smb5:	29 km (Approx.) 5Nos	
DWASA	Road Culvert Khal Dredging			
DMC	Flood wall/Embankment	Mitford hospital to Kellar More	1.6 km	
Narayanganj town	West and East Bank project			
	Embankment	Emn1:Along the east bank of Lakhya river Emn2:North part &south part of the town		
	R.C.C Wall	Wmn1:Along the West part of Lakhya river Wmn2:Along the old Dhaleswari river		
	Raising Road	Rmn1:Dhaka-Munshiganj road Rmn2:Abandoned railway track embankment		
	Regulators	No detailed indication	8 Nos	

Note:
1) Location : See Fig. G.3 and G.5

Contd.

Table G.2(3) Flood Control Facilities

B-2. Proposed Flood Control Plans by the Committee

Executing Agency	Component of Work	Location	Quantity
Tongi Town	West and East of Railway Line		
	Embankment	Emt1:Tongi Railway bridge to Simlun	6.0 km
		Emt2:Ershad Nagar to Railway bridge	2.0 km
	R.C.C Wall	Wm t 1:Railway bridge to Road bridge	1.4 km
		Wmt 2:Simlun to Ershad Nagar	3.5 km
		Wmt 3: Gazipur bus stand to Ershad Nagar	0.3 km
	Road Rising	Rmt 1:Gazipur bus stand to Kathaldiatek	5.5 km
		Rmt 2: Kathaldiatek to Road bridge	2.5 km
	Pump Station	No detailed indication	2Nos
	Regulators	No detailed indication	10Nos
Savar Town			
	Embankment	Ems 1: Bannyabari khal to Nayarhat bridge.	16 km
		Ems 2: Bartaq to Bannyabari khal	2 km
	R.C.C WALL	Wms 1: Nayarhat bridge to Atomic energy commission	10 km
	Road Rising	Rms 1: Atomic energy commission to Sadu	3.5 km
		Rms 2: Barta to Sadullahpur	1.0 km
	Pump Station	No detailed indication	2Nos.
	Regulators	No detailed indication	16 Nos.

Note:
1) Location : See Fig. G.6

Table G.3 Evaluation of Existing and On-Going Facilities

Area	Location (See Fig G.3, G.5)	Top Elevation (PWD) Existing	Design Criteria	Designed by BWDB/BUET	1988 Flood Level (Near the Site)	Evaluation Stability & Strength	Top Evaluation	Stability
1. Greater Dhaka Western Bank								
A. Embankment								
Settlement Portion	E2	7.0 - 8.5 m	9.8m	10.0 m + PWD	Mirpur : 8.39 m	11 Places (Approx. 7,700m)	Not sufficient	Not sufficient
Completed Portion	E1 - E5	9.4 - 10.2			Mill Barak : 7.54 m	Stable	Partly not	Sufficient
	E4	9.4 - 10.1				Section not enough	Insufficient	-
B. Flood Wall								
B.1 Nearby SIRNIR TEK	W1, W2	9.3 m	9.2m	2'above 1988 Flood Mark : 9.0 m	Mirpur : 8.39 m	Stable but revetment required	Insufficient	Sufficient
B.2 Nearby Buriganga Bridge	W3	7.6 - 8.1 m	8.4m	-ditto - : 8.1m	Mill Barak : 7.54 m	- ditto -	Not sufficient	Sufficient
C. Road-Cum-Embankment	R1 - R3	8.1 -7.6m	-	1988 Flood Mark :7.96 ~ 7.10 m	Tongi : 7.96 m Demra : 7.10 m	Stable	Sufficient (As Tentative)	Sufficient
D. Regulators	S1 - S6	Sill Level : 0.6-2.5 m	-	-	-	Pile Foundation	-	Stable
2. Narayanganj, (DND Project Area)								
A. Flood Wall								
A.1 Syedabad to Demra	W4-1	8.0 - 8.4 m	8.0m	2' above 1988 Flood Mark : 7.7 m	Demra : 7.10 m	Wall Strength : Net enough for Vhecle Collision Force	Sufficient	Not Sufficient
A.2 Syedabad to Narayanganj	W4-2	8.2 - 7.8 m	8.4- 7.8m	- ditto - : 7.8 m	Hariharpara : 7.17 m	- ditto -	Not Sufficient	"
					Demra : 7.10 m	- ditto -		"
A.3 Demra to Hagiganj	W4-3	8.1 - 7.5 m	8.0 - 7.7m	- ditto - 7.5 ~ 7.7 m	-		- ditto -	
B. Railway-Cum-Embankment	R5	6.8 - 7.3 m	8.3m	1988 Flood Mark : 6.8 m	-	Stable	- ditto -	Sufficient

Note :
1) Designed : Designe dby the BWDB and Approved by the Committee
2) 1988 Flood Level : Ajusted Value by Using the result of Check Survey in 1987 JICA Study
3) Stability : Judged by Observation
4) Evaluation : Based on Designed Criteria /Observation result.

Table G.4 Existing Flood Monitoring Facilities

	Items	No.
1.	SSB Wireless station	51 Nos.
2.	Telemetric station network with Central Station at Moulvi Bazar	6 Nos.
3.	Hydrological Radar with Bangladesh Meteorological Department with microwave link to Flood Forecasting & Warning Centre	1 No.
4.	Calibrating rain gauges at two places with three rain gauges and associated repeater station	2 Sets
5.	Dedicated teleprinter link between Bangladesh meteorological Department (BMD) and FF & W.	1 No.
6.	Telephone	2 Nos.

Table G.5 Social and Flood Damage Aspects of Alignment Alternatives

Area	Protected	Population		Present Land Use		Future Land Use		Flood Inundation (1988)			Flood Inundation (1987)		
	Area (ha)	1990	2010	Built Up	Agricultural	Built Up	Agricultural	Area (ha)	Depth (cm)	Duration (day)	Area (ha)	Depth (cm)	Duration (day)
1. Greater Dhaka													
A. Eastern Bank													
Case A	1) 4,700	529,000	1,373,000	1,260	3,440	3,710	990	4,580	78	23	2,000	31	9
Case B	2) 12,390	682,000	2,284,000	2,470	9,920	7,260	5,130	11,280	81	22	9,900	29	9
B. Western Bank	3) 400	70,000	174,000	400	0	400	0	400	202	36	330	100	26
B1. Kamrangir Char													
Case A	390	70,000	190,000	390	0	390	0	380	198	35	340	99	25
Case B	430	70,000	190,000	390	40	430	0	410	191	34	360	98	24
B2. Dhaka West	13,910	3,690,000	6,115,000	9,050	4,860	11,900	2,010	9,300	106	24	6,500	52	12
2. Narayanganj Area													
A. Western Bank													
Case A	6,640	820,000	1,955,000	1,900	5,690	5,310	2,280	1,080	86	23	600	33	8
Case B	7,540	932,000	2,222,000	2,410	6,190	6,320	2,280	2,020	80	21	820	30	8
B. Eastern Bank	1,280	108,000	241,000	590	790	1,200	180	1,280	74	23	930	26	8
3. Tongi													
Case A	2,430	101,000	597,000	850	1,580	2,070	360	1,850	80	17	100	43	10
Case B	2,770	121,000	630,000	950	1,820	2,350	420	2,310	80	17	380	43	10
4. Savar	4) 2,070	77,000	274,000	440	1,630	1,860	210	1,490	93	17	420	39	10
5. Keraniganj													
Case A	1,260	157,000	339,000	430	830	1,040	220	1,260	130	25	1,070	41	10
Case B	2,430	187,000	589,000	560	1,870	2,060	370	2,430	123	23	2,340	37	10
Case C	5,520	271,000	1,288,000	1,010	4,500	4,690	830	5,520	122	24	5,240	38	10

Note :

Protected Aea

1) : The area between Tongi to Syedabad road and the Case A alignment

2) : The area between Tongi to Syedabad road and the Case B alignment

3) : The island of Sand-bar between old Dhaka and Keraniganj Area

4) : The area between flood free boundary of 1988 flood and the alignment

Table G.6 Summary of Empoldering Facilities

(Unit : km)

Area	Embankment		Flood Wall		Road-Cum-Embankment		Total Length	Remarks
	Type A	Type B	T - Type	I - Type	Type - A	Type - B		
1. Greater Dhaka								
A. Eastern Bank								
Case A	17.8	11.0	-	-	-	-	28.8	Incld. Sub Emb 2.5 km
Case B	23.4	14.6	-	-	-	-	38.0	Incld. Sub Emb 11.3km
B. Western Bank								
B1. Kamrangir char								
Case A	4.5	4.8	-	-	-	-	9.3	
Case B	4.0	2.0	-	-	-	-	6.0	
B2. Dhaka West	-	7.7	-	3.0	-	-	10.3	Emb:Rehabilitation
2. Narayanganj Area								
A. Western Bank								
Case A	1.9	-	19.9	5.3	-	4.3	31.4	Exclud Northen Bank
Case B	6.1	-	10.5	10.5		4.3	31.4	-ditto-
B. Eastern Bank	6.6	-	14.0	12.0	-	6.5	39.1	
3. Tongi								
Case A	2.6	10.4	1.0	1.2	6.2	-	21.4	
Case B	2.6	15.5	1.0	1.2	2.2	-	22.5	
4. Savar	6.2	3.1	-	-	-	-	9.3	
5. Keraniganj								
Case A	4.5	7.1	3.7	-	-	3.5	18.8	
Case B	18.2	5.1	3.7	-	-	-	27.0	

Note :

Embankment
- Type-A : Ordinary Sub-soil Condition
- Type-B : Poor Sub-soil Condition - Foundation Treatment is required

Road-Cum-Embankment
- Type-A : Entire road raising to form an embankment
- Type-B : Road is a part of new embankment

Table G.7 Quantity and Construction Cost of Alignment Alternative (1)

Area	Empoldering Facilities														Total Cost
	Embankment								Concrete Wall				Sluice gate		
	Distance (km)	Banking Volume($x10^3m^3$)	Cost ($x 10^6$ Tk.)	Foundation (m)	Cost ($x 10^6$ Tk.)	Land (ha)	Cost ($x 10^6$ Tk.)	Total Cost ($x 10^6$ Tk.)	Distance (km)	Cost ($x 10^6$ Tk.)	Land (ha)	Cost ($x 10^6$ Tk.)	Places (No)	Cost ($x 10^6$ Tk.)	
1. Greater Dhaka															
A. Eastern Bank															
Case A	28.8	4,363	2,312	165,910	91	232	2,089	4,492	-	-	-	-	4	520	5,012
Case B	38.0	5,948	3,152	613,080	337	318	1,020	4,509	-	-	-	-	5	760	5,269
B. Western Bank															
B1. Kamrangir Char															
Case A	9.3	716	394	192,000	106	61	215	714	-	-	-	-	-	-	714
Case B	6.0	350	193	80,000	44	37	129	367	-	-	-	-	1	20	387
B2. Dhaka West													6		
2. Narayanganj Area															
A. Western Bank															
Case A	6.2	349	185	-	-	33	169	354	22.7	571	14	73	6	444	1,442
Case B	10.4	524	278	-	-	58	303	581	21.0	489	11	56	9	575	1,701
B. Eastern Bank	13.1	764	406	-	-	85	443	849	21.5	540	11	55	6	210	1,654
3. Tongi															
Case A	19.2	1,125	596	197,090	108	100	270	974	2.2	35	1	3	7	340	1,352
Case B	20.3	1,669	884	312,930	172	119	322	1,378	2.2	35	1	3	7	358	1,774
4. Savar	9.3	1,056	560	119,940	66	62	137	763	-	-	-	-	3	234	997
5. Keraniganj															
Case A	15.1	1,846	978	-	-	101	344	1,322	3.7	211	3	10	5	197	1,740
Case B	23.3	3,053	1,618	125,930	69	161	546	2,233	3.7	211	3	11	5	295	2,750

Embankment : Include Sub Embankment
– : Study on-going

Table G.8 Quantity and Construction Cost of Alignment Alternative (2)

Area	Drainage Facilities										Total Cost (x 10⁶ Tk.)	Grand Total Cost (Polder+Drainage)
	Pump Station			Regulation Pond		Khal Improvement						
	No.	Capacity (m^3/S)	Cost (x 10^6 Tk.)	Land (ha)	Cost (x 10^6 Tk.)	Distance (km)	Excavation (x10^3 m^3)	Cost (x 10^6 Tk.)	Land (ha)	Cost (x 10^6 Tk.)		
1. Greater Dhaka												
A. Eastern Bank												
Case A	3	128.4	3,047	1,352	6,082	16.5	1,204	289	46	208	9,626	14,638
Case B	3	178.8	3,986	1,882	4,705	54.5	3,941	946	151	378	10,015	15,283
B. Western Bank												
B1. Kamrangir char												
Case A	1	4.39	111	53	185	4.0	174	87	85	30	412	1,12[illegible]
Case B	1	7.93	198	84	292	4.0	192	96	93	33	619	1,00[illegible]
B2. Dhaka west	1	65.2		686	3,088	31.4	722	173	36	162	4,838	
2. Narayanganj Area												
A. Western Bank												
Case A	3	71.8	1,799	756	3,930	42.4	1,988	477	98	511	6,717	8,15[illegible]
Case B	5	80.9	2,060	851	4,428	44.4	2,082	500	103	536	7,524	9,22[illegible]
B. Eastern Bank	4	12.5	381	131	684	7.4	201	48	14	73	1,186	2,84[illegible]
3. Tongi												
Case A	2	25.2	685	265	716	22.0	641	154	43	115	1,670	3,02[illegible]
Case B	2	29.0	780	305	824	25.0	728	175	48	130	1,909	3,68[illegible]
4. Savar	-	-	-	-	-	30.0	1,220	293	66	146	439	1,43[illegible]
5. Keraniganj												
Case A	1	14.4	391	151	514	15.0	685	164	34	115	1,184	2,92[illegible]
Case B	1	27.7	706	292	991	22.5	1,028	247	51	172	2,116	4,88[illegible]

Table G.9 Flood Water Levels With and Without Project in the 1988 Flood

River (Location)	Without-Project (m)	With Project (m)	Δh (cm)	Discharge (m3/s)	Remarks
G. DHAKA-WEST (A)					
1. BURI GANGA					
0	7.21	7.21	0	2690	Hariharapara (Sta.43)
4.85	7.25	7.25	0	2690	
10.5	7.35	7.35	0	2690	Mill Barack (St. 42)
14.55	7.42	7.42	0	2690	
17.5	7.49	7.49	0	2680	
	2. TURAG				
0	7.49	7.49	0	2680	
5.3	7.66	7.67	1	2680	
10.2	7.9	7.91	1	2680	Mirpur (St.302)
15	8.04	8.04	0	760	
20.2	8.05	8.06	1	730	
25.4	8.23	8.29	6	760	
29.98	8.42	8.48	6	1360	
37.5	8.66	8.7	4	1350	
G.DHAKA-WEST(B)					
1. DHALESWARI					
0	5.97	5.97	0	20780	
5.7	6.16	6.16	0	17410	
10	6.66	6.66	0	17410	
14.5	7.21	7.21	0	17410	
19.6	7.57	7.57	0	14680	
24.6	7.91	7.91	0	14680	
29.4	8.37	8.37	0	14680	
34.6	8.88	8.88	0	14680	
40.5	9.34	9.34	0	14680	Kalatia (St.70)
44.58	9.57	9.57	0	1010	
49.6	9.58	9.58	0	1010	
55.48	9.58	9.58	0	1010	
60.2	9.59	9.59	0	2670	
2. BANSI					
0	9.59	9.59	0	2670	Savar (St.69)
5.13	9.67	9.67	0	2670	
9	9.85	9.85	0	2660	Nayarhat (St.14.5)
G.DHAKA-EAST					
1. LAKHYA					
0	6.01	6.01	0	3480	Kalagachia (St.71)
4.95	6.1	6.1	0	3480	
10.8	6.28	6.28	0	3470	
14.27	6.47	6.48	1	3460	
20.3	6.83	6.86	3	3000	Demra (St.179)
23.9	7.02	7.05	3	2570	
2. BALU					
0	6.83	6.86	3	840	Demra (St.7.5)
5.2	7.06	7.08	2	800	
9.7	7.25	7.3	5	770	
14.5	7.37	7.45	8	730	
20.5	7.62	7.7	8	730	
3. TONGI					
0	7.65	7.73	8	630	
4.65	7.75	7.82	7	630	
9.6	7.95	8.01	6	630	Tongi (St.299)
14.7	8.04	8.11	7	630	

Table G.10 Comparison of Alternative Alignment

Area	Protected Area (ha)	Future Social Aspect (2010)			Cost (x 10^6 Tk.)			Economic Effectiveness (Cost /Pop.)	Resettlement Population	Remarks
		Population	Land Use (ha)		Polder	Drainage	Total			
			Built up	Agriculture & Open Space						
1. Greater Dhaka										
A. Eastern Bank										
Case A	4,270	1,251,000	3,330	940	5,012	9,626	14,638	11,701	15,800	
Case B	12,390	2,322,000	8,680	3,710	5,269	10,015	15,284	6,582	16,400	
B. Western Bank										
B1. Kamrangir Char										
Case A	390	192,000	370	20	714	412	1,126	5,926	7,700	
Case B	430	211,000	410	20	387	619	1,006	5,295	4,900	
B2. Dhaka West	13,490	6,053,000	11,960	1,530	2,950	12,440	15,390	2,543	4,400	ADB
2. Narayanganj Area										
A. Western Bank										
Case A	6,780	1,949,000	5,230	1,550	1,442	6,717	8,159	4,186	6,900	
Case B	7,610	2,241,000	5,990	1,620	1,701	7,524	9,225	4,116	12,300	
B. Eastern Bank	1,210	266,000	1,150	60	1,654	1,186	2,840	10,677	9,800	
3. Tongi										
Case A	2,430	653,000	1,940	490	1,352	1,670	3,022	4,628	5,700	
Case B	2,770	725,000	2,150	620	1,774	1,909	3,683	5,080	6,500	
4. Savar	2,070	250,000	1,820	250	997	439	1,436	5,241	3,500	
5. Keraniganj										
Case A	1,260	273,000	850	410	1,740	1,184	2,924	10,710	13,700	
Case B	2,430	457,000	2,000	430	2,750	2,116	4,866	10,648	18,400	

Table G.11(1) List of Proposed Flood Mitigation Facilities

Area	Flood Mitigation		
1. Greater Dhaka			
1) West	a) Embankment (R)	:	16.7 km
	b) Flood wall (R)	:	4.7 km
	c) Embankment	:	6.3 km
	d) Flood Wall	:	3.0 km
	e) Sluice Gate	:	11 plcs
	f) Land Acquisition	:	37.0 ha
2) East	a) Embankment	:	26.7 km
	b) Sub Embankment	:	11.3 km
	c) Sluice Gate	:	5 plcs
	d) Land Acquisition	:	317.4 ha
2.Narayanganj			
1)DND Area	a) Flood Wall (R)	:	20.2 km
	b) Flood Wall	:	10.0 km
	c) Sluice Gate	:	2 plcs
	d) Land Acquisition	:	5.8 ha
	a) Embankment	:	6.1 km
2) West	b) Road-Cum-Embankment	:	4.3 km
	c) Flood Wall	:	10.5 km
	d) Sluice Gate	:	7 plcs
	e) Land Acuqisition	:	61.5 ha
	% Evacuation Facilities		1 L.S
	a) Embankment	:	6.6 km
3) East	b) Road-Cum-Embankment	:	6.5 km
	c) Flood Wall	:	26.0 km
	d) Sluice Gate	:	12 plcs
	e) Land Acquisition	:	99.2 ha
	a) Embankment	:	13.0 km
3. Tongi	b) Road-Cum-Embankment	:	6.2 km
	c) Flood Wall	:	2.2 km
	d) Sluice Gate	:	7 plcs
	e) Land Acquisition	:	100.9ha
	% Evacuation Facilities	:	1 L.S
	a) Embankment	:	9.3 km
4.Savar	b) Sluice Gate	:	3 plcs
	c) Land Acquisition	:	62.3 ha
	% Evacuation Facilities	:	1 L.S
	a) Embankment	:	23.3 km
5. Keraniganj	b) Flood Wall	:	3.7 km
	c) Sluice Gate	:	10 plcs
	d) Land Acquisition	:	163.7 ha
	% Evacuation Facilities	:	1 L.S

Note :
1) Embankment (R) : Rehabilitation Work of Embankment
2) Flood Wall (R) : Rehabilitation Work of Flood Wall
3) Land Acquisition : Retarding Pond is not included
4) Pump station (No.) : Total Capacity (Number of Pump Station)
5) On-Going Projects by JICA and IBRD are not included.

Table G.11(2) Proposed Sluice Gates

Project Area		Gate No.	Design Dischange (m^3/s)	Dimention of Gate ($A\ m^2$)	Remarks
1. Greater Dhaka	(1) West	No.1	10.40	10.2	G_1 : Refer toJICA previous study
		No.2	3.70	4.8	G_2 : - do -
		No.3	7.40	4.8	G_3 : - do -
		No.4	3.40	4.8	G_4 : - do -
		No.5	12.50	6.3	G_5 : - do -
		(No.6)	61.60	13.6	On-going Project by JICA-Karayanpur S(3 Vent) :A=13.8 m2
		No.7	127.40	51.0	S4 (8 Vent) : $A=14.1\ m^2$
		No.8	28.22	11.3	S5 (2 Vent) : $A= 3.5\ m^2$
		(No.9)	-	-	On-going Project by IBRD-Dholai Khal
		No.10	45.25	18.1	Kamrangir Char
		No.11	39.93	16.0	S3 (2 Vent) : $A= 3.5\ m^2$
		No.12	71.59	28.6	S2 (4 Vent) : $A= 7.1\ m^2$
		No.13	17.31	6.9	S1 (1 Vent) : $A= 1.1\ m^2$
	(2) East	No.14	25.19	10.1	
		No.15	36.84	14.7	
		No.16	123.11	49.2	
		No.17	114.45	45.8	
		No.18	199.37	79.7	
2. Narayanganj	(1) DND	No.1	113.28	45.3	
		No.2	105.57	42.2	
		No.3	20.69	8.3	
		No.4	38.08	15.2	
	(2) West	No.5	10.88	4.4	
		No.6	20.42	8.2	
		No.7	9.02	3.6	
		No.8	22.29	8.9	
		No.9	27.57	11.0	
	(3) East	No.10	10.13	4.1	
		No.11	6.47	2.6	
		No.12	26.01	10.4	
		No.13	19.94	8.0	
		No.14	17.16	6.9	
		No.15	28.23	11.3	
		No.16	10.13	4.1	
		No.17	6.47	2.6	
		No.18	26.01	10.4	
		No.19	19.93	8.0	
		No.20	17.16	6.9	
		No.21	28.23	11.3	
3. Tongi		No.1	30.86	12.3	
		No.2	35.12	14.0	
		No.3	22.88	9.2	
		No.4	13.54	5.4	
		No.5	33.73	13.5	
		No.6	38.96	15.6	
		No.7	8.40	3.4	
4. Savar		No.1	40.94	16.4	
		No.2	23.47	9.4	
		No.3	78.76	31.5	
5. Keraniganj		No.1	18.90	7.6	
		No.2	22.36	8.9	
		No.3	31.44	12.6	
		No.4	30.92	12.4	
		No.5	61.73	24.7	
		*No.6-No 10	-	1.0	For domestic water use

Note:1) S/S1-S5:Existing gates constructed by GOB

2) Design Discharges:Refer to JICA previous study report and Table G.11 (3)

3) ( ) :On-going projects are not included as Proposed Sluice Gate