SUPPORTING REPORT H

STORMWATER DRAINAGE

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Table of Contents

Page

List of Tables

List of Figures

Page

SUPPORTING REPORT H: STORMWATER DRAINAGE

1. General

The study area of approximately 850 km^2 has suffered by both external and internal floods, the main causes of which are overflow of river flood water and insufficient capacity of drainage facilities respectively.

Based on the internal flood survey, it is found that the built-up areas of about 2,000 ha corresponding to almost 10% of the existing one are affected in every year, and their affected population in 1990 is estimated to be 664×10^3 persons.

These flood situation will likely be worsen yearly and become serious constraint for the social and economic developments.

In order to find an optimum solution to such internal flood problems, the following discussions are made in this report.

1) Review of existing conditions

- Drainage area and system,
- Drainage facilities, and
- Drainage plans and commitments.

2) Formulation of stormwater drainage improvement master plan

- Planning policy and design criteria,
- Scope of measures,
- Alternative study of stormwater drainage improvement plans, and
- Recommendation of optimum plan.

2. EXISTING CONDITIONS

2.1 Drainage Area and Drainage System

The study area of approximately 850 km^2 is divided into five drainage areas, namely Greater Dhaka, Tongi, Savar, Narayanganj and Keraniganj in consideration of the existing topography, khal and river systems, and road networks. These are illustrated in Fig. H.1 and described below:

2.1.1 Greater Dhaka Area

This area is surrounded by four rivers: the Balu River to the east, the Turag River to the west, the Buriganga River to the south and the Tongi Khal to the north. The overall area is approximately 275 km^2 including low - lands around Kamrangir Char. Almost a half of the area is high land above 6.0 m PWD and mostly the built-up area. The remaining area of approximately 150 km^2 is the flood plain with a maximum depth of over 3.5 m in flood season and is mostly paddy field in dry season.

The area is divided into three drainage zones, namely, the Buriganga River Left Bank, the Turag River Left Bank and the Balu River Right Bank zones as shown in Fig. H.1.

1) Buriganga River Left Bank Zone : (DA)

This zone covers the Old Dhaka and Kallyanpur area. Total drainage area is about 42 km^2. The existing built-up area of 31.1 km^2 is projected to be 40.5 km^2 in 2010. The population is estimated to be 1,850 x 10^3 in 1990 and 2,990 x 10^3 in 2010. This zone is protected from the Buriganga River flood by the concrete wall and embankment in Phase I program of GDFCD project.

The Old Dhaka is drained through a drainage pipe collection system into the Dholai Khal and the Buriganga River. There is one pump station at Narinda. Other areas are directly drained into the Buriganga River through the drainage pipes, open ditch and the Kallyanpur Khal.

The following two projects are on-going in order to improve the drainage conditions of the Old Dhaka and Kallyanpur areas.

- Dholai Khal Rehabilitation and Area Development Project by World Bank and DCC.

- Storm Water Drainage System Improvement Project in Dhaka City by JICA and DWASA.

2) Turag River Left Bank Zone : (DB)

This zone covers the north-west part of the Greater Dhaka including Mirpur, Cantonment and Zia International Airport. Total drainage area is about 64 km^2, which is enclosed by the flood embankment along the Turag River in Phase I program of GDFCD project. The existing built-up area of 22.3 km^2 will be expanded to 43.4 km^2 in 2010. The population is estimated to be 442 x 10^3 in 1990 and 1,096 x 10^3 in 2010.

Stormwater is mainly drained through the Ibrahimpur Khal into the Turag River by gravity flow. There are no pumping station and drainage pipes. In Phase-II program of GDFCD project, construction of one pumping station at the confluence of the Turag River and the Ibrahimpur Khal is proposed.

3) Balu River Right Bank Zone : (DC)

This zone covers most parts of Dhaka city and the eastern part of the Greater Dhaka. The total drainage area is about 170 km^2. The build-up area covers an area of 68.7 km^2 in 1990 and is projected to be 131.4 km^2 in 2010. The population is estimated to be 2,181 x 10^3 in 1990 and 4,503 x 10^3 in 2010.

Stormwater collected by drainage pipes and open ditches is drained through the khals : Segunbagicha, Gerani, Begunbari and Behanali khals into the Balu River by gravity flow. In Phase II program of GDFCD project, construction of about 29 km embankment and two pumping stations along the Balu River are proposed.

2.1.2 Tongi Area

This area located at north part of the study area is surrounded by three rivers, namely, Haiderabad Khal to the east, Turag River to the west and Tongi Khal to the south. Total area is about 37 km^2. Almost half of the area is high land above 7.0 m PWD. East and west parts of the area are the flood plain of the Balu and Turag rivers with a maximum flood depth of 3.0 m in flood season. This area is divided into two drainage zones i.e. Tongi East and West zones.

1) Tongi East Zone : (TB)

This zone covers the eastern part of the Tongi area which consists of residential and industrial areas. The total area is about 15 km^2. The existing built-up area of 4.2 km^2 is projected to be 8.5 km^2 in the year 2010. The population is estimated to be 43 x 10^3 in 1990 and 263 x 10^3 in 2010.

Stormwater is collected by ditches and channels, and drained directly into the Haiderabad Khal and the Tongi Khal during the conditions of surface drainage. No drainage pipes and pumping station are existing.

2) Tongi West Zone : (TA)

This zone covers the western part of the Tongi area of about 22 km^2, which mainly consists of residential area, paddy field and swampy area. The built-up areas in 1990 and 2010 are estimated to be 6.3 km^2 and 12.8 km^2 respectively. The existing population of 100 x 10^3 is projected to become 395 x 10^3 in 2010.

There are no drainage facilities. This zone is drained directly into the tributaries of the Turag River and the Tongi Khal by surface drain system.

2.1.3 Savar Area

This area is surrounded by three rivers, the Turag River to the east, the Bansi River to the west and the Buriganga River to the south and existing road to the north. Total area is approximately 243 km^2.

The area is urbanized only at the vicinity of Savar town and along Dhaka - Aricha road as residential and institutional areas including cantonments. The other areas are developed as agriculture and grass lands. The existing built-up area of 41.8 km^2 is projected to increase to 75.1 km^2 in 2010. The population is estimated to be 366 x 10^3 in 1990 and 812 x 10^3 in 2010.

This area is divided into three drainage zones, such as, the Savar East (approx. 152 km^2), the Savar West (approx. 37 km^2) and the Savar South (approx. 54 km^2) zones. Each zone is drained directly through ditches, channels or khal into surrounding rivers as shown in Fig. H.1.

2.1.4 Narayanganj Area

This area is located at south-east part of the study area covering the DND project area in low land and Narayanganj town on the high land above 6.0 m PWD. The area is surrounded by the Buriganga and Dhaleswari rivers and two existing roads, Dhaka to Chittagong Old Road and Old railway road. The Lakhya River flows in the central part of Narayanganj town. The total area is about 101 km^2.

This area is divided into three drainage zones, namely, the DND Project (NA), the Narayanganj East (NC) and West zones (NB).

1) The DND Project Zone (NA, approx. 57 km^2)

The area was developed as an irrigation project by BWDB in 1968 and protected by polder dikes from floods. The area has reversible pumping facilities both for irrigation and drainage purposes.

Stormwater is drained through the drainage channels into the Lakhya river by the pump station with a capacity of 14.5m^3/s.

Currently the area is changing rapidly from irrigation area to an urban area. The existing built-up area of 21.7 km^2 is projected to become 42.7 km^2 in 2010. The population is estimated to be 449 x 10^3 in 1990 and 1,314 x 10^3 in 2010.

2) Narayanganj West Zone (NB, approx. 30 km^2)

The area is a narrow strip between the DND project and the Lakhya River, and covers the western part of Narayanganj town situated on the relatively high land above 6.0 m PWD. Almost 55% of the area (16 km^2) is urbanized. The built-up area in 2010 is projected to be 21 km^2. The population is estimate to be 529 x 10^3 in 1990 and 978 x 10^3 in 2010.

Stormwater is drained directly into the Lakhya River by primitive drainage channels. During heavy rains, some areas have been inundated due to insufficient drainage facilities.

3) Narayanganj East Zone (NC, approx. 14 km^2)

This area, covering the eastern part of Narayanganj town, drains into Lakhya River. The existing built-up area of 7.9 km^2 is 55 % of the whole area. The built-up area in 2010 is projected to be only 11.8 km^2. The population is estimated to be 133 x 10^3 in 1990 and 266 x 10^3 in 2010.

There is primitive surface drain facilities of ditches, channels or khal. No drainage pipes and pumping station are existing.

2.1.5 Keraniganj Area

This area is surrounded by the Dhaleswari River and the Buriganga River. Total area is approximately 170 km^2.

This area is mostly low-lying and the elevation is less than 4.0 m PWD except Keraniganj town at opposite site to the Old Dhaka area. The land use of this area is mostly paddy field. The existing built-up area of 22.3 km^2 is projected to become 38.1 km^2 in 2010. The population is estimated to be 442 x 10^3 in 1990 and 813 x 10^3 in 2010.

The area is divided into two drainage zones, the Keraniganj North Zone (approx. 30 km^2) and Keraniganj South Zone (approx. 140 km^2). Each zone has no drainage pipes and no pumping station, and drained directly through ditches, channels or khals into the Buriganga River and the Dhaleswari River.

The area has no flood protection and drainage improvement plan.

The built-up area and population in 1990 and 2010 by each drainage zone are shown in Table H.1.

2.2 Existing Drainage Facilities

2.2.1 Inventory

The existing major drainage facilities are classified into drainage pipes, khals, pumping stations and related structures.

1) Drainage Pipe

The central part of Dhaka City (approximately 60 km^2) is provided with drainage pipes of a total length of more than 110 km, ranging from 0.3 m to 3.0 m in diameter. Pipe length by diameter is shown on Table H.2.

The drainage pipe density installed is estimated as 2.4 km/km^2. The diameter of drainage pipes of brick is from 1.2 m to 4.0 m and of reinforced concrete pipes is below 1.2m.

The location map of the trunk drainage pipes is shown on Fig. H.2.

2) Khal

There are a number of khals in Dhaka City totaling approx. 437 km in length, as listed in table H.3.

Khals in urbanized areas have the function to drain stormwater, but in paddy fields or cultivated areas they function both to drain stormwater and to supply irrigation water.

The existing khal system is presented in Fig. H.3.

3) Pumping Station

There are two pumping stations : Narinda in the Old Dhaka and Demra in the DND project area.

Narinda pumping station drains almost entire old Dhaka area of 4.23 km^2. Total design discharge capacity is 9.6 m^3/s.

Demra pumping station services both as a stormwater drainage and as a irrigation facility for the DND project area of approximately 57 km^2. Total design discharge capacity is 14.52 m^3/sec.

Locations of both pumping stations are shown in Fig. H.1. Details of both pumping stations are discussed latter.

4) Other Related Structures

As other related structures, a number of concrete box culverts and bridges are existing at places where roads and railways are crossing khals.

2.2.2 Discharge Capacity of Major Khals

Existing major drainage pipes and khals located in the central Dhaka city were hydraulically evaluated in JICA previous study, the Storm Water Drainage System Improvement Project in Dhaka City.

In this study, discharge capacity of 36 major khals situated out of Dhaka city of 137 km^2 (Figs. H.4.(1) and H.4.(2)) are calculated based on the longitudinal and cross sectional survey results of the existing khals. Calculation results are shown in Table H.4 and summarized below.

Drainage Zone	Khal Width (m)	Discharge Capacity (m^3/s)	Specific Discharge Capacity ($m^3/s/km^2$)
Turag River Left Bank (DB)	5.0 ~ 47	1 ~ 32	0.1 ~ 2.4
Balu River Right Bank (DC_1)	10 ~ 40	2 ~ 60	0.3 ~ 12.8
Balu River Right Bank (DC_2)	12 ~ 44	4 ~ 62	0.2 ~ 11.9
Balu River Right Bank (DC_3)	9 ~ 58	2 ~ 93	0.3 ~ 2.6
DND Project (NA)	6 ~ 44	3 ~ 93	0.2 ~ 3.8
Narayanganj West (NB)	5 ~ 46	3 ~ 127	0.2 ~ 30.6
Narayanganj East (NC)	10 ~ 23	3 ~ 17	0.7 ~ 12.7
Keraniganj (K)	14 ~ 32	5 ~ 59	1.1 ~ 10.8

On the above table, khal sections having a required specific discharge capacity of more than 8 $m^3/s/km^2$ are very few. These are mostly less than 3 $m^3/s/km^2$ and shall be improved to have an adequate discharge capacity.

2.2.3 Narinda and Demra Pumping Station

1) Narinda Pumping Station

This pumping station was constructed in 1975 by DPHE. It drains almost entire old Dhaka area of 4.23 km^2 into the Dholai Khal. It is equipped with four pumps, one reservoir tank, one gravity channel, one emergency channel, and three gates. The main features of the pumping station are as follows :

- Total design discharge : 2.4 m^3/s X 4 units=9.6m^3/s.
- Design L.W.L. (Suction side) : 0.236m GTS
- Design H.W.L. (Discharge side) : 8.64 m GTS
- Pump head : 6.5 m for 2 pumps, 8.4 m for 2 pumps
- Pump type : Vertical axial flow pump
- Pump diameter : 1000 mm
- Number of pump : 4 units
- Reservoir tank : 4,6000 m^2 in area, 18,850 m^3 in volume.

The plan and cross-section of the pump station are illustrated in Fig. H.5.

The pump station is operated from late May through early December every year. Annual operating hours are estimated to be approximately 1000 - 1500 hours per pump station.

The existing pump station had not produced satisfactory drainage effects because of the following problems :

(1) The suction water level must be kept lower than originally designed in order to support a required hydraulic gradient of the drainage pipes and to secure smooth collection of storm water to the pump station. This operation, however, requires excessive pumping power, causing overheating of the motors. As a result, continuous operating time of the pumps is limited to several hours.

(2) A hydraulic head loss of 0.3 - 0.6 m is caused by collected trash at the screen although they are removed by manual labour. Efficient removal of the trash is required.

The DCC is implementing the construction of a new pumping station with a total capacity of 22.2 m^3/s at the mouth of the Dholai Khal including the khal improvement work with financial assistance from the World Bank. Removal of the Narinda pumping station is included in the above project.

2) Demra Pumping Station

This pumping station was constructed by BWDB in 1968 in connection with DND irrigation project. It serves both as an stormwater drainage and as a irrigation facility for the DND project area of 58.6 km^2. The specifications of the pumping station are as follows:

- Total design discharge : $3.63 m^3/s$ X 4 unit = $14.52 m^3/s$
- Design H.W.L. (suction side) : 1.8 m PWD.
- Design L.W.L. (suction side) : 1.0 m PWD
- Design H.W.L. (discharge side) : 5.94 m PWD
- Pump head : 4.9 m
- Pump type : Vertical axial flow pump
- Pump diameter : 1300 mm
- Number of pump : 4 units

The plan and cross section of the pumping station are illustrated in Fig. H.6.

Based on the operation records between 1970 and 1989, annual operating hours per one pump for irrigation and storm drainage work are as follows:

- For irrigation : Max = 1280 hr, Min = 570 hr, Average = 900 hr.
- for storm drainage : Max = 1980 hr, Min = 540 hr, Average = 1200 hr

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

2.3 Existing Plans and Commitments (See Fig. H.7)

2.3.1 Dhaka City

The first master plan study on flood protection and internal drainage of Dhaka city covering an area of 75 km^2 was undertaken by DPHE in 1968. The WAPDA was assigned to construct the flood embankment and pumping station, and DPHE was appointed to construct the internal drainage system. This plan was, however, not accepted by the Government.

As a follow up to the above study, BWDB prepared a separate plan for the internal drainage system in 1976. However these plans were not accepted by the Government due to mainly financial constrains.

Afterwards, DPHE prepared a drainage plan, namely, "Internal Scheme for Removing Water Logging within Dhaka City" with an estimated cost of Tk. 66 million in 1976 that was implemented up to June, 1980.

In 1981, another drainage plan, namely, "Internal Scheme for Removing Water Logging within Dhaka Metropolis" was proposed by DPHE and approved at Tk 190 million. This project was implemented in June 1983.

In 1985, the "Revised Crash Program for Construction of Storm Water Drainage in Water Logging Area of Dhaka Metropolis" was prepared by DPHE. This project was executed up to 1989.

In 1987, the "Study on Storm Water Drainage System Improvement Project in Dhaka City" was conducted by Japan International Cooperation Agency (JICA) in collaboration with DPHE. Study area covers the city of Dhaka with an area of about 137 km^2 which will be urbanized in the year 2000.

At the same time, UNDP/UNCHS conducted a feasibility study on the improvement of Dholai Khal as an Old Dhaka area development project (Dholai Khal Rehabilitation and Area Development Project). This project is now on going.

During August to September 1988, Bangladesh was devastated by the worst flood in its flood history. Dhaka city suffered very serious flood damage. To solve this problem, the Government of Bangladesh decided to implement the "Greater Dhaka Flood Control and Drainage Scheme" proposed by the Committee. The project consists of Phase-I and-II, with several components. Phase-I Project was started in 1989 and still on-going. Phase-II is under preparation stage as mentioned in the Supporting Report G.

Moreover, JICA conducted a re-evaluation and updating of the previous JICA study, taking into account the results of related projects, which began after the 1988 floods as well as the information gained from the flood itself, and proposed an urgent program for improvement of the stormwater drainage system in Dhaka City in March 1990.

The drainage zones and the required drainage facilities with a phased program proposed by JICA are shown in Fig. H.8. The proposed urgent program is composed of the works of Phase-I and Phase-II as shown in Fig. H.9.

After the 1988 floods, also DWASA made an improvement plan for cleaning khals as shown in Fig. H.10, according to the proposal by the Committee.

There are two commitments for the improvement of the stromwater drainage system, one by the Government of Japan, and the other by the World Bank.

They are explained as follows :

1) The Government of Japan has committed itself to an urgent project for the improvement of the stormwater drainage as a JICA grant Project.

   The Project Consists of :
   - one pumping station ($Q=10m^3/s$) for the drainage zone H.
   - sluice gates (W2.5m X H2.5 X 2) at the pump station above.
   - khal improvement (4.1 km) for the drainage zones (F and H)

The project is shown in Fig. H.9.

2) Dholai Khal Rehabilitation and Area Development Project will be implemented by the World Bank (Fig.H.11).

The Project consists of :

- khal improvement with a total length of about 4.2 km
- pumping station with gates (7.4 m^3/s X 3 units)
- retention basin : 2 sites (Narinda site, Dayaganj/Jatrabari)

2.3.2 DND Project Area

Regarding the DND Project area, RAJUK has a town planning for the area. If a large part of the agriculture area is to be changed to urban use, its drainage facilities such as drainage channels and drainage pumps, will be reviewed according to the new land use. The existing irrigation and drainage system is illustrated in Fig. H.12.

2.3.3 Other Towns

For the town areas of Savar, Tongi and Narayanganj, there are some drainage plans proposed by the Institute of Diploma Engineers in 1989, however, no detailed study is existing.

- Savar Town: two pump stations, 16 regulators
- Tongi Town: two pump stations, 10 regulators
- Narayanganj Town: 8 regulators

3. Stormwater Drainage Improvement Plan

3.1 Planning Policy and Hydraulic Design Criteria

3.1.1 Planning Policy

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

1) Plans are to be prepared to meet the population and land use in the target year 2010. The whole area to be planned is approximately 456 km^2, a location of which is illustrated in Fig. H.13. The population and built-up area in 1990 and 2010 by drainage zone of Master Plan area are shown in Table H.5.

2) For the existing urbanized areas of Dhaka city (approximately 137 km^2), the plans shall meet the requirements of Storm Water Drainage System Improvement Project in Dhaka City and Dholai Khal Rehabilitation and Area Development Project committed by JICA and World Bank respectively.

3) The plans are to consist of structural and non-structural measures in order to limit the project cost.

4) Scope of the structural measures for the existing built-up areas are construction of pumping stations with gates, and improvements of khals and trunk drain to mitigate the existing internal flood damage. Secondary and tirtiary drainage pipes are excluded in the proposal, taking into account that the investment for project implementation must be reasonable.

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

3.1.2 Hydraulic Design Criteria

1) Design Flood Water Level

The existing built-up areas in the study area are mostly formed on the high lands over 6.0 m PWD, where are free from habitual floods. Further built-up areas are, however, mostly expected to develop on the surrounding low lands below 4.5 m PWD, where will be protected from the external floods by the polder dikes.

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

The following design flood water levels are applied for each drainage area or zone based on the calculation results of probable water level at the gauging stations as described in Supporting Report D.

(1)	Greater Dhaka		
	- Buriganga River Left Bank Zone	:	5.80 to 6.45 PWD
	- Turag River Left Bank Zone	:	6.45 m PWD
	- Balu River Right Bank Zone	:	5.90 m PWD
(2)	Tongi	:	6.45 m PWD
(3)	Savar	:	7.20 m PWD
(4)	Narayanganj	:	5.45 to 5.80 m PWD
(5)	Keraniganj	:	5.45 to 5.80 m PWD

Fig. H.14 shows the design flood water levels for demarcation of the gravity and pump drainage in the Master Plan area.

On the other hand, the pump equipment shall be designed to be able to operate during 100-year frequency external flood. Considering the water level difference of about 2 m between 2-year and 100-year frequency floods, the design flood water level at the highest pump efficiency of 100% will actually be higher than 2-year frequency flood water level.

2) Design Rainfall

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

(1) For Pumping Station and Retarding Pond

2-days consecutive rainfall with a 5 - year frequency is applied as the design rainfall for pumping station and retarding pond. The design rainfall depth and its hourly distribution are illustrated in Fig. H.15.

(2) For Khal Improvement and Trunk Drain

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

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

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

The applied rainfall intensity - duration curve is illustrated in Fig. H.15.

3) Area Reduction Factor

The above design rainfalls are made based on the point rainfall data at Dhaka station (B.M.D.). For the calculation of the design discharge, the areal reduction factor is to be considered. The areal reduction curves are illustrated in Fig. D.15 of the Supporting Report D.

4) Run off Coefficient and Run off Ratio

The runoff coefficients by land use shown below are proposed for the calculation of design peak discharge by the Rational Formula.

Land Use	Proposed Runoff Coefficient
Commercial Area	0.65
Industrial Area	0.55
High Class Residential Area	0.3
Middle & Low Class Residential Area	0.5
Green Zone and Others	0.2
Water Bodies	1.0

The runoff ratio (total runoff/total rainfall) of 0.8 is employed for the estimation of required pump and retarding pond capacities.

5) Drainage Criteria

As described in planning policy, short duration internal flooding with a low flood damage will be allowable. For pump drainage areas, 2-days discharge period by pumps is proposed in view of technical and economical reasons.

6) Specific Peak Run-off

Specific peak run-off is estimated by Rational formula as described below;

$$Q = \frac{1}{3.6} \times C \times I$$

in which Q : specific peak run-off ($m^3/s/km^2$)

C : run-off coefficient

I : average rainfall intensity during time of concentration (mm/hr)

Time of concentration (Tc) expressed in minutes is;

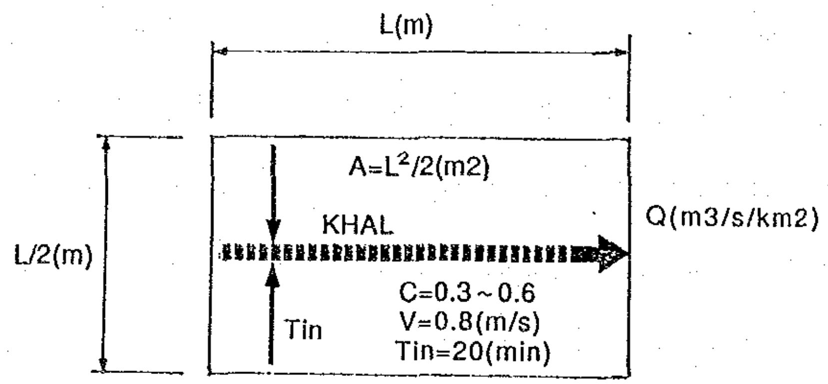
$$Tc = T\,in + \frac{L}{V}$$

Where Tin: inflow time of rain water (min)

L : length of khal (m)

V : average velocity of khal (m/s)

In this study, the value of Tin, V for the khal are adopted 20 minutes and 0.8 m/s respectively. Drainage area model for calculation of specific peak run-off is as follows.



As calculation results, specific peak run-off by drainage area is shown in Table H.6 and Fig. H.16.

7) Specific Requirements of Pump and Retarding Pond

Specific pump capacity and storage requirements of the retarding pond in the pump drainage area are estimated by Storage Basin Model as shown below:

$$I - 0 = \frac{DS}{dt} \quad \text{.................. (1)}$$

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

$$0 = Qp \times dt \quad \text{................. (3)}$$

Where, I : Inflow volume due to rainfall during dt (m^3)

0 : Outflow volume due to pumping during dt (m^3)

dt : Calculation time interval

S : Storage volume of retarding pond (m^3)

f : Runoff rate (0.8)

A : Catchment area (ha)

Rt : Rainfall during dt (mm)

Qp : Pump discharge volume during dt (m^3)

As the calculation results, specific requirements of both facilities are to be 1.14 $m^3/s/km^2$ and 0.120 x 10^6 m^3/km^2 respectively as shown in Fig. H.16.

3.2 Scope of Structural and Non-structural Measures

As described in the previous section, the plans are to consist of structural and non-structural measures to control the project cost and to facilitate smooth implementation of the project.

The structural measures to be included are as follows :

1) for the existing built-up area :

   (1) All the required pumping station with retarding pond and sluice gate
   (2) Khal improvement and installation of trunk drain

2) for the future built-up area :

   (1) All the required pumping station with retarding pond and sluice gate
   (2) Trunk khal improvement

Lateral drains and tertiary drainage pipes are excluded from the master plan. Because a beneficial effects of lateral drains and tertiary drainage pipes will be expected only after completion of the connected major drainage works.

The non-structural measures are to be proposed for the future urbanized areas. Non-structural measures to be included are :

1) Land use regulation for the proposed pump, retarding pond and trunk khal areas.

2) Recommendation of minimum ground elevation by filling up in future development areas.

Fig. H.17 shows the scope of the structural and non-structural measures.

3.3 Demarcation of Gravity and Pump Drainage Areas

Ground elevation and area curves were made for the following twelve drainage zones to demarcate gravity and pump drainage areas.

1) Greater Dhaka Area

(1) DA (Buriganga River Left Bank Zone : A = 34.33 km^2)
(2) DB (Turag River left bank Zone : A = 60.84 km^2)
(3) DC1 (Northern Area of Balu River Right Bank Zone : A = 45.86km^2)
(4) DC2 (Central Area of Balu River Right Bank Zone : A = 30.65 km^2)
(5) DC2 (Southern Area of Balu River Right Bank Zone : A = 90.74 km^2)

2) Tongi Area

(1) TA (Tongi West Zone : A = 13.24 km^2)
(2) TB(Tongi East Zone : A = 11.06 km^2)

3) Savar Area

(1) S (Savar Whole Area : A= 56.52 km^2)

4) Narayanganj Area

(1) NA (DND Project Zone : A = 56.79 km^2)
(2) NB (Narayanganj West Zone : A = 18.63 km^2)
(3) NC (Narayanganj East Zone : A = 12.80 km^2)

5) Keraniganj Area

(1) K (Keraniganj Whole Area : A = 24.27 km^2)

Ground elevation and area curves including design flood water levels are shown in Fig. H.18.

Demarcation criteria of gravity and pump drainage system corresponding to ground elevation in each zone is as follows :

1) The area above the design flood water level plus 0.5 to 1.0 m can drain stormwater by gravity, assuming that :

(1) outlet water levels of drainage pipes or khals are at the frequent flood water levels of 2-years return period.

(2) head difference required for gravity drainage of 5 - year frequency discharge through drain pipes or khals is to be considered in the range of 0.5 to 1.0 m.

2) The area below the design flood water level plus 0.5 to 1.0 m can not be drained by gravity flow. Pump drainage system is required.

3) Future urbanized areas in the existing low-lands will be built-up by land filling of minimum 2.0 m.

Based on the above criteria, the following conclusions are reached for each drainage zone:

1) DA Zone (A = 34.33 km^2)

This zone was investigated in JICA previous study in 1987 and 1990 and concluded as follows:

(1) Old Dhaka area (Drainage zone B in JICA previous study) is required to adopt a pump drainage system. Improvements of Dholai Khal including a construction of pumping station with some storage basins are on-going as a World Bank Project (refer to Section 2.3.1).

(2) Narrow strip area along the Buriganga River (Drainage zone A in JICA previous study) is mostly higher than 6.8 m PWD. Stormwaters can be drained by gravity. However, a central part of this area (2.71 km^2) will be combined with Kamrangir Char area where is lower than 6.8 m PWD and is required to adopt a pump drainage system.

(3) Almost 40% of the Kallyanpur area (Drainage zone H in JICA previous study) is lower than 6.95 m PWD. Pump drainage is required. Construction of Kallyanpur pumping station with a capacity of 10 m3/s and improvements of Kallyanpur Khal are on-going as JICA Grant Aid Project (refer to Section 2.3.1).

2) DB Zone (A = 60.84 km^2)

Almost 75% of the area is below 6.95 m PWD. Pump drainage is mostly required.

3) DC1 Zone (A = 45.86 km^2)

Almost 80% of the area is below 6.85 m PWD. Pump drainage is mostly required.

4) DC2 Zone (A = 30.65 km^2)

Almost 90% of the area is below 6.70 m PWD.Pump drainage is required.

5) DC3 Zone (A = 90.74 km^2)

Almost 70% of the area is below 6.55 m PWD.Pump drainage is required.

6) TA Zone (A = 13.24 km^2)

Almost 72% of the area is below 6.95 m PWD.Pump drainage is required. However, existing urbanized areas along the Tongi Khal and Tongi-Joydebpur Road are higher than 6.95 m PWD. These areas can be drained stormwater by gravity flow.

7) TB Zone (A = 11.06 km^2)

Almost 80% of the area is below 6.95 m PWD.Pump drainage is required. Tongi industrial area is, however, higher than 6.95 m. Gravity drainage is sufficient.

8) S Zone (A = 56.52 km^2)

Only 12% of the area is below 7.70 m PWD. Gravity drainage is adequate.

9) NA Zone (56.79 km^2)

Whole areas are below 6.30 m PWD.Pump drainage is required

10) NB Zone (18.63 km^2)

Almost 80% of the area is below 5.95 m PWD.Pump drainage is required. Existing Narayanganj town is, however, higher than 5.95 m, so gravity drainage is adequate.

11) NC Zone (12.80 km^2)

Almost 78% of the area is below 5.95 m PWD.Pump drainage is required. However, existing built-up areas are mostly higher than 5.95 m PWD. These areas can be drained by gravity flow.

12) K Zone (24.27 km^2)

Almost whole area is below 6.30 m PWD. Pump drainage is required.

3.4 Alternative Study of Drainage Improvement Plan

In order to identify the optimum drainage improvement plan, drainage alternative studies are conducted for the following three drainage zones:

- Turag River Left Bank Zone (DB)
- Balu River Right Bank Zone (DC)
- DND Project Zone (NA)

3.4.1 Options of Drainage Improvement Plan

Considering the existing topographic condition, drainage network and stage implementation coordinating with future urban development, drainage improvement options are proposed for the above zones as described below:

1) Turag River Left Bank Zone (DB, A = 60.84 km^2)

Two options are prepared.

(1) Alternative I: Two independent drainage system

- southern part (DB_1, A=3.63 km^2) : gravity drainage
- northern part (DB_2, A=57.21 km^2) : pump drainage

(2) Alternative II: Three independent drainage system

- southern part (DB_1, A=3.63 km^2) : gravity drainage
- central part (DB_2, A=43.40 km^2) : pump drainage
- northern part (DB_3, A=13.81 km^2) : pump drainage

2) Balu River Right Bank Zone (DC, A = 167.25 km^2)

Three options are prepared.

(1) Alternative I: Single drainage system

- whole area (DC, A=167.25 km^2) : pump drainage

(2) Alternative II: Two independent drainage system

- northern part (DC_1, A=76.51 km^2) : pump drainage
- southern part (DC_2, A=90.74 km^2) : pump drainage

(3) Alternative III: Three independent drainage system

- northern part (DC_1, A=45.86 km^2) : pump drainage
- central part (DC_2, A=30.65 km^2) : pump drainage
- southern part (DC_3, A=90.74 km^2) : pump drainage

3) DND Project Zone (NA, A = 56.79 km^2)

Two options are prepared.

(1) Alternative I: One pump drainage system

- whole area (NA, A=56.79 km^2) : pump drainage by new pumping station

(2) Alternative II: Two pump drainage system

- northern part (NA_1, A=34.08 km^2) : pump drainage by existing pumping station
- southern part (NA_2, A=22.71 km^2) : pump drainage by additional pumping station

The above drainage system alternatives are illustrated in Figs. H.19 to H.21.

3.4.2 Main Features of Alternative Plans

Alternative plans are designed under the following conditions:

1) Since the plans in the existing built-up areas of both zones, DB and DC, shall meet the requirements of the previous JICA study, consideration of these requirements will be omitted in this alternative study.

2) Drainage major facilities, such as a pumping station with a retarding pond, sluice gate and khal, in future developed areas are to be designed based on the design criteria given in section 3.1.2.

Main features of each alternative plan are shown in Tables H.7 to H.10.

3.4.3 Identification of Optimum Option

Comparative items for the identification of an optimum option are selected as below:

1) Cost	:	construction, operation and maintenance, and land acquisition costs
2) Implementation	:	easiness of stage construction coordinating with future urbanization
3) Others	:	easiness of construction, operation and maintenance, and land acquisition

Cost of alternative plans are estimated under the following conditions:

1) Estimated cost items are consisted of construction cost, operation and maintenance (O/M) cost, and land acquisition cost.

2) Construction costs are estimated in unit cost bases shown in Supporting Report J.

3) Yearly O/M costs of pumping station with sluice gate and khal are assumed to be respectively 1.5% and 0.2% of their construction costs. O/M costs are estimated in the period of 20 years.

4) Land acquisition costs for low land in DB, DC and NA areas are assumed to be respectively 3.0, 3.0 and 5.0 million Tk./ha in market price based on the field interview survey.

Comparison of alternatives are summarized below:

Comparison of Alternatives

Item \ Zone / Alternative	DB I	DB II	DC I	DC II	DC III	NA I	NA II
1. Cost (million Tk)							
(1) Construction Cost	2,313	2,453	5,992	5,782	5,767	2,247	1,986
(2) O/M Cost	570	614	1,386	1,440	1,485	528	466
(3) L/A Cost	2,286	2,287	6,267	6,158	6,104	3,883	3,863
Total	5,169	5,354	13,665	13,380	13,355	6,658	6,314
2. Stage Construction	Easy	Easy	Difficult	Moderate	Easy	Moderate	Easy
3. Water Conveyance Distance	Medium	Short	Long	Medium	Short	Long	Short
4. Others	—	L/A Problem	—	—	—	Complicated Construction	—

Note: 1. L/A means land acquisition.
2. Breakdown of costs are shown in Tables H.11 to H.13.

1) Turag River Left Bank Zone

Alternative I is recommended because of low cost. In case of alternative II, it may be difficult for land acquisition of DB_2 retarding pond, because this area is now developing.

2) Balu River Right Bank Zone

Alternative III is recommended. However, costs of alternative II and III are almost same, so more deep study will be required to conduct in the feasibility stage.

3) DND Project Zone

Alternative II is recommended. It will, however, be required to conduct a more deep study for alternative I whether the proposed pumping station can be constructed without demolishing the existing one.

3.5 Proposed Pump Drainage Plan

As concluded in section 3.3, all drainage zones except Savar area are recommended to adopt partly or wholly a pump drainage system. In this section, the proposed pump drainage plan is discussed in detail.

3.5.1 Pump Operation Period

The climate of the study area is classified into the following three distinct seasons;

- monsoon season:	May to October,	R = 1,825 mm
- cool season:	November to February,	R = 60 mm
- warm season:	March to April,	R = 175 mm

Almost 90% of the annual rainfall (R = 2,060 mm) occurs during the monsoon season from May to October. Maximum annual monthly rainfall occurs in June, the value of which is approximately 400 mm based on the rainfall series from 1953 to 1990. Variation of annual monthly rainfall is illustrated in Fig. H.20.

On the other hand, flood water levels of the surrounding rivers start to rise in April, reach to a peak in mid. August, and then fall down to December. Considering the relation between an average ground elevation of low lands (3.0 ~ 3.5 m PWD) and variation of annual monthly flood water levels, it is found that the required pump drainage period in Dhaka, Narayanganj and Keraniganj will be five (5) months from June to October in every year, as shown in Fig. H.20.

According to the O/M data of the existing Narinda and Demra pumping station, average pump operation hour during flood season from June to October are recorded about 1,200 hr corresponding to almost 60% of rainy days of 88 days (2,112 hr). It means that in flood season the pumps shall be operated during rain.

3.5.2 Zoning of Pump Drainage

Zoning of pump drainage are conducted based on the results of the demarcation and alternative studies described in sections 3.3 and 3.4. The number and area of pump drainage by each zone are as follows:

1) Greater Dhaka

(1) DA zone: 3 (PD_1 = 6.96 km^2, PD_2 = 7.24 km^2, PD_3 = 17.6 km^2)
(2) DB zone: 1 (PD_4 = 57.2 km^2)
(3) DC zone: 3 (PD_5 = 35.6 km^2, PD_6 = 30.7 km^2, PD_7 = 90.7 km^2)

2) Tongi

(1) TA zone: 1 (PD_8 = 11.8 km^2)
(2) TB zone: 1 (PD_9 = 10.3 km^2)

3) Narayanganj

(1) NA: 1 ($PD_{10,11}$ = 56.8 km^2)
(2) NB: 3 (PD_{12} = 2.5 km^2, PD_{13} = 5.5 km^2, PD_{14} = 6.3 km^2,)
(3) NC: 4 (PD_{15}=1.0 km^2, PD_{16}=3.9 km^2, PD_{17}=2.3 km^2, PD_{18}=3.7 km^2)

4) Keraniganj

(1) K zone: 1 (PD_{19} = 24.3 km^2)

Pump drainage zones are illustrated in Fig. H.21.

3.5.3 Required Pump and Retarding Pond Capacities

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

Specific requirements of pump and retarding pond capacities are estimated to be $p = 1.14\ m^3/s/km^2$ and $v = 0.120 \times 10^6\ m^3/km^2$ respectively by storage basin model under the following conditions:

1) Design rain storm (refer to Fig. H.15)

- Two days consecutive rainfall in 5-year frequency
  $R = R_1 + R_2 = 192\ mm + 53\ mm = 245\ mm$
- Duration per one day rainfall: T = 6 hr
- Rainfall pattern: central concentration type

2) Design run-off rate: $f = 0.8$

3) Design pump discharge period: T = 2 days = 48 hr

The required pump and retarding pond capacities can be estimated by the following formulae.

$$P = p \times A \quad \cdots\cdots\cdots\cdots \quad (1)$$
$$V = v \times A \quad \cdots\cdots\cdots\cdots \quad (2)$$

where, P : required pump capacity (m^3/sec)

p : specific pump capacity ($m^3/sec/km^2$)

V : required retarding pond capacity (m^3)

v : specific retarding pond capacity (m^3/km^2)

A : pump drainage area (km^2)

Calculation results by each pump drainage area are shown in Table H.14. Location of the proposed pumping stations and retarding ponds are illustrated on Figs. H.27.(1) to H. 27.(3).

3.5.4 Design Water Level and Area of Retarding Pond

1) Low Water Level (L.W.L.)

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

(1) Average ground elevation of the low land suitable as the retarding pond

(2) River flood hydrograph and required period of pump operation as shown in Fig. H.20.

2) High Water Level (H.W.L.)

The design H.W.L. of the retarding pond is related with the design L.W.L., the required storage volume and area of the retarding pond. In this study the design H.W.L. is proposed to be 4.0 m PWD after taking into account of the following case study results.

(1) Objective of Case Study

Objective of this case study is to find out the most suitable H.W.L. of the retarding pond in low land development project based on the relation between cost (reclamation cost and land acquisition cost) and benefit (land price increased after reclamation).

(2) Main Features of Case Study (refer to Fig. H.22)

- Model area: $A = 1.0\ km^2$
- Average ground elevation of model area: 3.0 m PWD
- Required pump capacity: $P = 1.14\ m^3/s$
- Required storage volume of retarding pond: $V = 120{,}000\ m^3$

- L.W.L. of retarding pond: H = 3.0 m PWD
- Reclamation unit cost: R.C = 350 Tk./m^3
- Land acquisition unit cost: L.A.C = 300 Tk./m^2
- Developed land price after reclamation: L.P = 1,700 Tk./m^2

(3) Case Study

In four (4) cases of H.W.L. of retarding pond, 3.5, 4.0, 4.5 and 5.0 m PWD, reclamation cost of development area, land acquisition cost of retarding pond and new developed land price after reclamation are estimated as below table.

Cost-Benefit by Case Study

Case	H.W.L. of Retarding Pond (m PWD)	Retarding Pond Area A_1 (km^2)	Develop-ment Area A_2 (km^2)	Cost (million Tk.)			Benefit (million Tk.)	$B-(C_1+C_2)$ (million Tk.)
				Reclama-tion Cost C_1	Land Acquisition Cost C_2	Total (C_1+C_2)	New Land Price B	
1	3.5	0.24	0.76	266.0	72.0	338.0	1,292.0	954.0
2	4.0	0.12	0.88	462.0	36.0	498.0	1,496.0	998.0
3	4.5	0.08	0.92	644.0	24.0	668.0	1,564.0	896.0
4	5.0	0.06	0.94	822.5	18.0	840.5	1,598.0	757.5

As shown in the above table and Fig. H.22, it is noted that the most suitable H.W.L. of the retarding pond will be around 4.0 m PWD.

3) Retarding Pond Area

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

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

Where, A : required area of retarding pond (m^2)
S : required storage capacity of retarding pond (m^3)
H.W.L. : design high water level of retarding pond (m PWD)
L.W.L : design low water level of retarding pond (m PWD)

Calculation results are shown in Table H. 15.

3.5.5 Design Water Level of Pumping Station

As mentioned in section 3.1.2, 1) (Design Flood Water Level), the frequent flood water level with 2-year return period is basically employed as the design outlet flood water level (H.W.L.) of the proposed pumping station, considering a adoption of a more efficient and economical pump drainage system. However, the pump equipment shall also be operated during the design water level for flood mitigation facilities with 100-year return period (H.H.W.L.).

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

On the other hand, the inner design H.W.L. and L.W.L. of the pumping stations shall be met for the requirements of the proposed retarding ponds, which are 4.0 and 3.0 m PWD respectively.

The design static head of pump equipment is estimated on the difference of the outer H.W.L. and inner L.W.L. Considering the difference of the outer H.H.W.L. and H.W.L. , the static head at design point will actually be bigger value than the above difference (H.W.L - L.W.L)

Table H.16 shows the design water levels and static head of 19 proposed pumping stations.

3.5.6 Multipurpose Use of Retarding Pond

The proposed retarding pond areas are vast and correspond to almost 12% of each pump drainage area. Since these ponds have not only a flood water storage function but also a water space function for living environment, it is recommended to have a multipurpose use of the ponds as listed below :

(1) Drainage Facility : retarding pond
(2) Inland Fishery Facility : fish pond
(3) Recreation Facility : park, boating
(4) Water Supply Facility : reservoir for irrigation
(5) Waste Water Treatment Facility : stabilization pond

3.6 Proposed Improvement of Khal and Trunk Drain

3.6.1 Proposed Drainage Networks

As described in section 3.1.1 (Planning Policy),

- The drainage plans for the existing urbanized area of Dhaka city are to meet the requirements of the on-going projects (JICA and World Bank).
- For the other existing urbanized areas, khal improvement and trunk drains (open channel or pipe) are to be proposed as a drainage networks.
- For the future urbanized areas, only trunk khal improvements are to be proposed.

In addition, the drainage pipes are installed in only Dhaka city. Other towns are adopted a surface drain system by ditches or open channels, which is the most economical drainage system.

Taking into above consideration and the existing drainage system of each zone, the networks of the proposed khal improvement and trunk drain are illustrated in Fig. H.23.(1) to 23.(3).

3.6.2 Design Discharge

1) Division of Sub-drainage Zone

In order to estimate the design discharge for khal improvements and trunk drain, each drainage zone is divided into several sub-drainage zones based on the existing topographic conditions and the proposed drainage networks. The number of sub-drainage zones are as follows:

Number of Zone and Sub-zone by Drainage Area

Drainage Area	No. of Zone	No. of Sub-zone
- Greater Dhaka	3	41
- Tongi	2	11
- Savar	1	14
- Narayanganj	3	27
- Keraniganj	1	8
Total	8	101

Figs. H.23.(1) to H.23.(3) show the proposed drainage network and divided sub-drainage area.

2) Design Discharge

The design discharge for khal improvement and trunk drain are calculated based on the specific peak run-off with a 5-year frequency of short duration rainfall (refer to section 3.1.2) and areas of drainage sub-zones.

Calculation results are shown in Tables H.16.(1) to H.16.(2) and Figs. H.24.(1) to H.24.(3).

3.6.3 Proposed Improvement of Khal and Trunk Drain

The discharge capacities of the existing khals and trunk drains are insufficient for their design discharges as mentioned in section 2.2. This is one of the main causes of internal flood in the study area. Improvements of khal and trunk drain by widening and dredging are required for alleviation of internal flooding.

1) Hydraulic Design

Hydraulic calculations for improvements of khal and trunk drain are carried out by uniform flow model of Manning Formula as presented below ;

$$Q = \frac{1}{n} \times A \times R^{\frac{2}{3}} \times i^{\frac{1}{2}}$$

Where, Q : Design discharge (m^3/s)
n : Coefficient of roughness
A : Flow area (m^2)
R : Hydraulic radius (m)
i : Hydraulic gradient

Coefficients of roughness of khal and trunk drain are applied as follows ;

- Brick pipe drain	:	0.015
- Concrete box culvert	:	0.015
- Khal with brick slope protection	:	0.025
- Khal with sodding slope protection	:	0.035

The proposed hydraulic cross sections and bed slopes including discharge capacities by the improved stretches are shown in Tables H. 18 (1) to H. 18 (2). The proposed longitudinal and cross sections including design water levels of 7 major khals are illustrated on Figs. H.25 (1) to H.25 (7).

2) Proposed Improvement Works

The proposed typical cross sections for improvements of khal and trunk drain are,

(1) Open channel

- Type (1) : Trapezoidal shape with 1:2 slope protected by sodding
- Type (2) : Trapezoidal shape with 1:1 slope protected by brick
- Type (3) : Rectangular shape with concrete panel wall

(2) Covered channel or pipe

- Type (1) : Concrete box culvert (single or double)
- Type (2) : Brick pipe

Trapezoidal shape channel is applied for the khal sections where comparatively easy land acquisition is expected. Rectangular shape channel is proposed for the khal sections where land acquisition is difficult. Operation and maintenance roads are proposed to provide both banks of trapezoidal shape channels located in the future urbanized areas.

Concrete box culvert is applied for the khal sections crossing with roads, or trunk drain sections. Brick pipe is employed for the trunk drain sections.

The proposed typical designs of improvements of khal and trunk drain are illustrated on Fig. H. 26.

The proposed improvement lengths of khal and trunk drain by drainage zone are summarized below ;

Proposed Improvement Length by Drainage Zone

Drainage Area	Drainage Zone	Improvement Length (Km)		
		Khal	Trunk Drain	Total
Greater Dhaka	DA	20.05	8.08	28.13
	DB	29.40	-	29.40
	DC	73.15	8.92	82.07
	Sub-Total	122.60	17.00	139.60
Tongi	TA	11.00	-	11.00
	TB	16.00	-	16.00
	Sub-Total	27.00	-	27.00
Savar	S	30.00	-	30.00
Narayanganj	NA	38.00	-	38.00
	NB	6.40	-	6.40
	NC	7.35	-	7.35
	Sub-Total	51.75	-	51.75
Keraniganj	K	22.50	-	22.50
Total		253.85	17.00	270.85

Breakdown of the above table by improvement work and drainage zone is shown in table H. 19. (1) to H. 19. (3).

Location of the proposed improvement of khal and trunk drain are illustrated on Figs. H. 27. (1) to H. 27. (3).

3.7 Proposed Non-structural Measures

3.7.1 Necessity of Non-structural Measures

According to the urban planning study, the population of the master Plan area of about 455 km^2 is projected to be 5.98 million in 1990 and 12.61 million in 2010 corresponding to 2.1 times of the existing one. Then, it is forecasted that the existing built-up area of about 200 km^2 (44% of Master Plan area) will be expanded to be about 366 km^2 (80% of Master Plan area) corresponding to 1.83 times of the existing one. Even the low lands of the Greater Dhaka and DND project areas having a higher increase rate than the above rate will be rapidly urbanized.

Taking into account of the above, it is noted that the implementation of the proposed structural measures shall be met for the extension of urbanization and also takes much time and investment for its completion.

On the other hand, non-structural measures mainly consisting of land use regulation is soft measures and is not required much investment for their execution. Even if the execution of non-structural measures is found to be difficult due to insufficient government organization and lack of law system for land use control, it is recommended to execute the non-structural measures in order to sustain the full functioning of the proposed structural measures and to prepare a guideline of future land development from view point of stormwater drainage.

3.7.2 Proposed Non-structural Measures

1) Preservation of Retarding Pond Area

Swampy areas totaling 19 places and 4,529 ha shall be preserved as the proposed retarding pond. Required preserved areas by pump drainage zone are shown in Table H. 15 and their locations are illustrated on Figs. H. 28. If the retarding pond area will be reduced by an unregulated urbanization, the pump capacity shall be increased to maintain the pond's H.W.L.

Sufficient preservation of retarding pond area will be performed by the following government activities ;

- Government has full land acquisition of the proposed retarding pond areas, or

- Government pays to land owners a compensation for use of retarding pond in flood season, a cost of which is a part of full land acquisition fee. the land owners give to the government a guarantee that he will not built-up in future, but use it as an agricultural land in dry season without any filling up.

Either cases would make the financial burden too heavy for the government. So it is recommended that the government shall have the following administrative guidance or order to the private land developers;

- Land developer shall provide the retarding pond with a storage capacity of 1,200 m^3/ha or a pond area corresponding 12% of the developed area.

- In case of limited development without a retarding pond, land developer shall pay to the government a burden corresponding to the same cost as per provision of the required retarding pond.

Execution of these guidance or order will decrease the financial burden for the government

2) Preservation of Khal Area

Through the field reconnaissance, an observation was made that many khal or trunk channel sections in highly urbanized areas are occupied by encroachment without proper sanction, roads and buildings. It is clear that this is one of the major causes of internal floods in the study area.

Any reduction of the proposed minimum khal and trunk drain sections shall be under strict control in order not to block flood flows that cause adverse effects of back water on upstream areas.

3) Minimum Ground Elevation of Future Development

Future land development in the low-lying areas protected from external flood by polder dike shall be made by filling up the land higher than the proposed internal design water levels of the retarding pond, khal and trunk drain.

Minimum ground elevations of future low land developments by drainage zone vary as follows :

- Greater Dhaka	:	4.50 to 5.50 m PWD
- Tongi	:	5.00 to 5.50 m PWD
- Savar	:	6.00 m PWD
- Narayangangj	:	4.50 to 5.00 m PWD
- Keraniganj	:	4.50 to 5.00 m PWD

Details of the above are illustrated on Fig. H. 28.

Table H.1 Built-up Area and Population in 1990 and 2010 by Drainage Area

ZONE	AREA (ha)	1990 Built-up area (ha)	1990 Population	2010 Built-up area (ha)	2010 Population
Greater Dhaka					
Buriganga River Left Bank Zone (DA)	4,185	3,109	1,850,355	4,045	2,990,384
Turag River Left Bank Zone (DB)	6,408	2,226	441,609	4,341	1,095,828
Balu River Right Bank Zone (DC)	16,934	6,870	2,180,669	13,143	4,502,697
Northern Area (DC-1)	4,795	1,061	336,782	4,018	1,376,538
Central Area (DC-2)	3,065	549	174,263	1,497	512,861
Southern Area (DC-3)	9,074	5,260	1,669,624	7,628	2,613,298
Total	27,527	12,205	4,472,633	21,529	8,588,909
Tongi					
Tongi West Zone (TA)	2,261	634	100,106	1280	395,274
Tongi East Zone (TB)	1,507	423	42,903	853	263,457
Total	3,768	1,057	143,009	2,133	658,731
Savar					
Savar West Zone (SA)	3,729	1,022	89,161	1923	224,363
Savar East Zone (SB)	15,231	2,743	199,420	4943	453,134
Savar South Zone (SC)	5,358	411	77,689	645	134,383
Total	24,318	4,176	366,270	7,511	811,880
Narayanganj					
DND Project Zone (NA)	5,679	2,174	448,590	4,270	1,313,749
Narayanganj West Zone (NB)	2,992	1,643	528,875	2,099	978,483
Narayanganj East Zone (NC)	1,424	790	133,151	1,179	266,204
Total	10,095	4,607	1,110,616	7,548	2,558,436
Keraniganj					
Keraniganj North Zone (KA)	2,994	539	74,573	765	127,518
Keraniganj South Zone (KB)	14,041	1,689	367,215	3,047	685,673
Total	17,035	2,228	441,788	3,812	813,191

Table H.2 Existing Drainage Pipes in Central Dhaka City

Pipe Size	Pipe Length (ft)	Remarks
13' - 3"	430	Brick Pipe
10' - 0"	2,900	"
9' - 0"	2,124	"
8' - 6"	1,000	"
8' - 0"	1,100	"
7' - 6"	1,300	"
7' - 0"	3,800	"
6' - 0"	8,970	"
5' - 6"	9,540	"
5' - 0"	12,660	"
4' - 6"	13,950	"
4' - 0"	26,700	Concrete Pipe
3' - 6"	20,350	"
3' - 0"	44,900	"
2' - 6"	48,860	"
2' - 0"	115,100	"
1' - 6"	38,800	"
1' - 0"	1,600	"
Total	358,884	

Table H.3 Existing Khal Length by Drainage Zone

Drainage Area	Drainage Zone	Khal Length (km)
Greater Dhaka	Balu River Right Bank (DA)	105.2
	Turag River Left bank (DB)	42.4
	Buriganga River Left Bank (DC)	35.6
Tongi	Tongi East (TB)	5.2
	Tongi West (TA)	16.2
Savar	Savar East (SA)	20.3
	Savar West (SB)	21.5
	Savar South (SC)	14.3
Keraniganj	Keraniganj North (KA)	23.3
	Keraniganj South (KB)	82.3
Narayanganj	DND Project (NA)	50.2
	Narayanganj West (NB)	13.0
	Narayanganj East (NC)	7.5
Total		437.0

Note : The length of existing khals were measured from the National Base Map of Scale 1:50,000.

Table H.4 Discharge Capacity of Existing Khal

Zone	Khal No.	Drainage Area (km2)	Section Bottom Wid (m)	Section Upper Wid. (m)	Section Height (m)	Roughness Coefficient	Bed Slope i (%)	Velocity (m/s)	Discharge Capacity (m3/s)	Specific Discharge Capacity (m3/s)
DB	1	5.88	0.00	4.80	1.10	0.035	0.02	0.25	0.67	0.11
	2-1	4.23	0.00	10.00	1.00	0.035	0.02	0.25	1.26	0.30
	2-2	13.81	10.60	24.40	2.90	0.035	0.02	0.64	32.39	2.35
	3-1	13.88	0.00	0.80	0.90	0.035	0.02	0.13	0.05	0.00
	3-2	23.95	0.00	38.60	1.20	0.035	0.02	0.29	6.65	0.28
	3-3	37.51	2.80	47.00	2.60	0.035	0.02	0.50	32.25	0.86
	4	3.63	0.40	5.00	1.40	0.035	0.02	0.30	1.15	0.32
DC-1	5	5.21	3.80	8.60	0.80	0.035	0.02	0.27	1.36	0.26
	6	3.14	10.00	22.20	3.50	0.035	0.02	0.71	40.15	12.79
	7	1.94	2.00	10.00	2.00	0.035	0.02	0.43	5.16	2.66
	8-1	5.79	13.00	19.80	0.90	0.035	0.02	0.33	4.86	0.84
	8-2	25.81	21.60	40.00	2.90	0.035	0.02	0.68	60.76	2.35
DC-2	9-1	5.78	0.00	11.80	2.50	0.035	0.02	0.44	6.55	1.13
	9-2	23.96	7.00	13.80	1.10	0.035	0.02	0.35	4.01	0.17
	9-3	35.21	11.40	33.60	2.20	0.035	0.02	0.52	25.68	0.73
	10	5.18	9.20	44.40	3.50	0.035	0.02	0.66	61.76	11.92
DC-3	11-1	8.81	3.00	8.50	1.20	0.035	0.02	0.34	2.34	0.27
	11-2	11.80	6.00	12.00	1.50	0.035	0.02	0.42	5.68	0.48
	11-3	18.95	4.00	11.50	0.80	0.035	0.02	0.27	1.64	0.09
	11-4	49.25	13.00	43.80	3.30	0.035	0.02	0.66	62.22	1.26
	11-5	6.59	3.00	13.00	3.50	0.035	0.02	0.61	17.00	2.58
	11-6	13.15	6.40	20.00	2.50	0.035	0.02	0.55	18.09	1.38
	11-7	16.99	3.80	18.60	3.10	0.035	0.02	0.59	20.37	1.20
	11-8	92.05	8.40	58.40	4.00	0.035	0.02	0.70	93.05	1.01
NA	1-1	18.17	5.50	15.50	1.00	0.035	0.02	0.31	3.24	0.18
	1-2	4.54	4.20	14.50	3.10	0.035	0.02	0.59	17.25	3.80
	1-3	31.23	6.00	13.30	3.20	0.035	0.02	0.63	19.58	0.63
	1-4	6.81	0.00	6.00	0.50	0.035	0.02	0.16	0.24	0.03
	1-5	3.41	3.40	11.70	1.50	0.035	0.02	0.38	4.35	1.28
	1-6	24.42	7.00	13.00	1.50	0.035	0.02	0.43	6.44	0.26
	1-7	56.79	15.70	44.20	4.00	0.035	0.02	0.77	92.57	1.63
NB	2	2.33	0.00	5.20	0.90	0.035	0.02	0.23	0.53	0.23
	3	58.29	8.20	29.50	2.30	0.035	0.02	0.52	22.40	0.38
	4	4.14	13.20	45.60	5.00	0.035	0.02	0.86	126.84	30.64
	5	1.11	0.00	5.20	2.80	0.035	0.02	0.39	2.85	2.57
	6	3.29	0.00	25.40	4.20	0.035	0.02	0.64	34.14	10.38
	7	3.57	0.00	16.60	5.00	0.035	0.02	0.67	27.86	7.80
	8	2.69	2.80	14.80	3.20	0.035	0.02	0.58	16.32	6.07
NC	9	1.02	2.40	17.20	2.60	0.035	0.02	0.51	12.94	12.68
	10	0.60	0.00	1.60	0.20	0.035	0.02	0.09	0.01	0.02
	11	3.27	1.00	19.00	2.20	0.035	0.02	0.44	9.62	2.94
	12	2.31	0.80	15.80	2.90	0.035	0.02	0.51	12.32	5.33
	13	1.92	2.80	23.40	2.60	0.035	0.02	0.51	17.36	9.04
	14	3.68	0.80	10.20	1.40	0.035	0.02	0.33	2.51	0.68
K	1	1.81	3.80	16.20	3.00	0.035	0.02	0.58	17.31	9.57
	2	3.61	5.60	30.00	2.30	0.035	0.02	0.49	20.16	5.58
	3	5.42	9.20	32.20	3.90	0.035	0.02	0.73	58.65	10.82
	4	2.46	6.60	23.00	1.10	0.035	0.02	0.32	5.20	2.11
	5	10.97	4.20	14.20	2.50	0.035	0.02	0.53	12.15	1.11

Note: (1) Informations in DA Zone are included in previous JICA Study Report.
(2) Location of the above khals are shown in Fig H.4 (1) and (2)

Table H.5 Built-up Area and Population in 1990 and 2010 in Master Plan Area

ZONE	AREA (ha)	1990 Built-up area (ha)	1990 Population	2010 Built-up area (ha)	2010 Population
Greater Dhaka					
Buriganga River Left Bank Zone (DA)	3,433	2,855	1,829,107	3,715	2,989,701
Turag River Left Bank Zone (DB)	6,084	2,200	435,000	4,326	1,095,444
Balu River Right Bank Zone (DC)	16,725	6,859	2,177,887	13,005	4,502,091
Northern Area (DC-1)	4,586	1,050	334,000	3,880	1,375,932
Central Area (DC-2)	3,065	549	174,263	1,497	512,861
Southern Area (DC-3)	9,074	5,260	1,669,624	7,628	2,613,298
Total	26,242	11,914	4,441,994	21,046	8,587,236
Tongi					
Tongi West Zone (TA)	1,324	619	96,737	1,166	391,748
Tongi East Zone (TB)	1,106	413	41,459	778	261,166
Total	2,430	1,032	138,196	1,944	652,914
Savar	5,652	2,058	131,496	4,503	410,268
Narayanganj					
DND Project Zone (NA)	5,679	2,174	448,590	4,270	1,313,749
Narayanganj West Zone (NB)	1,863	1,312	470,449	1,720	926,820
Narayanganj East Zone (NC)	1,280	746	130,571	1,148	266,204
Total	8,821	4,232	1,049,610	7,138	2,506,773
Keraniganj	2,427	735	220,878	2,000	457,252
Grand Total	45,572	19,971	5,982,174	36,631	12,614,443

Table H.6 Specific Peak Run-off

Conditions: Velocity;0.8m/s

Drainage Area (km2)	Length (km)	Width (km)	Time of Concentration (min)	Rainfall Intensity (mm/hr)	Areal Reduction Factor	C=0.3 Run-Off (m3/s)	C=0.3 Specific Run-off (m3/s/km2)	C=0.4 Run-Off (m3/s)	C=0.4 Specific Run-off (m3/s/km2)	C=0.5 Run-Off (m3/s)	C=0.5 Specific Run-off (m3/s/km2)	C=0.6 Run-Off (m3/s)	C=0.6 Specific Run-off (m3/s/km2)
0.20	0.63	0.32	33.18	108.26	1.00	1.80	9.02	2.41	12.03	3.01	15.04	3.61	18.04
0.50	1.00	0.50	40.83	99.14	1.00	4.13	8.26	5.51	11.02	6.88	13.77	8.26	16.52
1.00	1.41	0.71	49.46	90.54	1.00	7.54	7.54	10.06	10.06	12.57	12.57	15.09	15.09
2.00	2.00	1.00	61.67	80.64	0.99	13.31	6.65	17.74	8.87	22.18	11.09	26.61	13.31
5.00	3.16	1.58	85.88	66.27	0.97	26.78	5.36	35.71	7.14	44.64	8.93	53.57	10.71
10.00	4.47	2.24	113.17	55.19	0.94	43.23	4.32	57.64	5.76	72.05	7.21	86.46	8.65
20.00	6.32	3.16	151.76	44.63	0.90	66.95	3.35	89.26	4.46	111.58	5.58	133.90	6.69
30.00	7.75	3.87	181.37	38.92	0.87	84.65	2.82	112.87	3.76	141.08	4.70	169.30	5.64
40.00	8.94	4.47	206.34	35.13	0.84	98.36	2.46	131.15	3.28	163.94	4.10	196.72	4.92
50.00	10.00	5.00	228.33	32.35	0.82	110.54	2.21	147.39	2.95	184.23	3.68	221.08	4.42
60.00	10.95	5.48	248.22	30.20	0.80	120.78	2.01	161.05	2.68	201.31	3.36	241.57	4.03
70.00	11.83	5.92	266.50	28.45	0.79	131.11	1.87	174.82	2.50	218.52	3.12	262.23	3.75
80.00	12.65	6.32	283.52	27.00	0.78	140.40	1.75	187.20	2.34	234.00	2.92	280.80	3.51
90.00	13.42	6.71	299.51	25.76	0.77	148.79	1.65	198.39	2.20	247.99	2.76	297.58	3.31
100.00	14.14	7.07	314.63	24.70	0.76	156.41	1.56	208.55	2.09	260.68	2.61	312.82	3.13

Table H.7 Main Features of Alternatives of Drainage Improvement Plan by Drainage Zone

Item (Name of Zone / Alternative)			Turag River Left Bank (DB)		Balu River Right Bank (DC)			DND Project (NA)	
			I	II	I	II	III	I	II
Number of Sub-Zone			2	3	1	2	3	1	2
Drainage Area (km^2)	Sub-Zone		$DB_1 = 3.63$ $DB_2 = 57.19$	$DB_1 = 3.63$ $DB_2 = 13.81$ $DB_3 = 43.38$	$DC = 167.25$	$DC_1 = 76.51$ $DC_2 = 90.74$	$DC_1 = 45.86$ $DC_2 = 30.65$ $DC_3 = 90.74$	$NA = 56.79$	$NA_1 = 34.08$ $NA_2 = 22.71$
	Total		60.82		167.25			56.79	
Proposed System G: Gravity Drainage P: Pump Drainage			$DB_1 = G$ $DB_2 = P$	$DB_1 = G$ $DB_2 = P$ $DB_3 = P$	$DC = P$	$DC_1 = P$ $DC_2 = P$	$DC_1 = P$ $DC_2 = P$ $DC_3 = P$	$NA = P$	$NA_1 = P$ $NA_2 = P$
Proposed Facilities	Pump Station	Number of Pump Station	1	2	1	2	3	1	2
		Pump Capacity (m^3/s)	$DB_1 = -$ $DB_2 = 65.2$	$DB_1 = -$ $DB_2 = 15.7$ $DB_3 = 49.5$	$DC = 178.9$	$DC_1 = 75.5$ $DC_2 = 103.4$	$DC_1 = 40.5$ $DC_2 = 34.9$ $DC_3 = 103.4$	$NA = 64.7$	$NA_1 = 34.4$ $NA_2 = 30.3$
	Retard-ing Pond	Number of Pond	1	2	1	2	3	1	2
		Storage Volume V ($\times 10^6 m^3$) Effective Depth: H (m) Area: A ($\times 10^6 m^3$)	DB_1: - DB_2: $V = 6.9$ $H = 1.0$ $A = 6.9$	DB_1: - DB_2: $V = 5.2$ $H = 1.0$ $A = 5.2$ DB_3: $V = 1.7$ $H = 1.0$ $A = 1.7$	DC : $V = 18.8$ $H = 1.0$ $A = 18.8$	DC_1: $V = 7.9$ $H = 1.0$ $A = 7.9$ DC_2: $V = 10.9$ $H = 1.0$ $A = 10.9$	DC_1: $V = 4.2$ $H = 1.0$ $A = 4.2$ DC_2: $V = 3.7$ $H = 1.0$ $A = 3.7$ DC_3: $V = 10.9$ $H = 1.0$ $A = 10.9$	NA : P $V = 6.8$ $H = 1.0$ $A = 6.8$	NA_1 : P $V = 3.6$ $H = 1.0$ $A = 3.6$ NA_2 : $V = 3.2$ $H = 1.0$ $A = 3.2$
	Sluice Gate	Number of Sluice Gate	DB_1: 1 DB_2: 3	DB_1: 1 DB_2: 2 DB_3: 1	DC : 6	DC_1: 5 DC_2: 1	DC_1: 4 DC_2: 1 DC_3: 1	NA : 1	NA_1: 1 NA_2: 1
	Khal	Improvement Length of Main Khal (km)	22.5	22.5	55.5	55.5	57.5	36.6	38.0

Table H.8 Main Features of Khal Improvement Alternatives (Turag River Left Bank Zone: DB)

Khal No.	Alternative I			Alternative II		
	Design Discharge Q (m^3/s)	Length L (km)	Cross Section B1 x B2 x H (m)	Design Discharge Q (m^3/s)	Length L (km)	Cross Section B1 x B2 x H (m)
DB 1-1	159	4.0	4.0 x 56 x 4.0	139	4.0	35 x 51 x 4.0
1-2	101	5.0	22 x 38 x 4.0	101	5.0	22 x 38 x 4.0
1-3	72	2.0	13 x 29 x 4.0	72	2.0	13 x 29 x 4.0
DB 2-1	98	2.2	24 x 40 x 4.0	54	2.2	19 x 35 x 4.0
2-2	40	3.3	13 x 29 x 4.0	40	3.3	7 x 23 x 4.0
DB 3	48	4.0	10 x 26 x 4.0	72	4.0	10 x 26 x 4.0
DB 4	43	1.5	5 x 21 x 4.0	43	1.5	5 x 21 x 4.0
DB 5	29	0.5	5 x 19 x 3.5	29	0.5	5 x 19 x 3.5
Total		22.5			22.5	

Table H.9 Main Features of Khal Improvement Alternatives (Balu River Right Bank Zone: DC)

Khal No.	Alternative I			Alternative II			Alternative III		
	Design Discharge Q (m^3/s)	Length L (km)	Cross Section B1 x B2 x H (m)	Design Discharge Q (m^3/s)	Length L (km)	Cross Section B1 x B2 x H (m)	Design Discharge Q (m^3/s)	Length L (km)	Cross Section B1 x B2 x H (m)
DC 1-1	47	2.0	14 x 31.2 x 4.3	47	2.0	9 x 25 x 4.0	124	2.0	34 x 48 x 3.5
1-2	-	-	-	-	-	-	64	3.5	17 x 31 x 3.5
1-3	57	2.5	10 x 27.2 x 4.3	57	2.5	10 x 27.2 x 4.3	57	2.5	14 x 28 x 3.5
1-4	40	1.0	6 x 23.2 x 4.3	40	1.0	6 x 23.2 x 4.3	40	1.0	9 x 23 x 3.5
DC 2-1	82	2.5	13 x 30.2 x 4.3	82	2.5	17 x 33 x 4.0	82	2.5	15 x 29 x 3.5
2-2	40	1.5	4 x 21.2 x 4.3	40	1.5	6 x 22 x 4.0	40	1.5	6 x 20 x 3.5
DC 3	37	1.0	7 x 19 x 3.0	37	1.0	7 x 19 x 3.0	37	1.0	7 x 19 x 3.0
DC 4	26	0.6	4 x 18 x 3.5	26	0.6	4 x 18 x 3.5	26	0.6	4 x 18 x 3.5
DC 5	18	0.4	1 x 15 x 3.5	18	0.4	1 x 15 x 3.5	18	0.4	1 x 15 x 3.5
DC 6-1	41	2.5	7 x 24.2 x 4.3	172	2.5	44 x 60 x 4.0	115	2.5	28 x 44 x 4.0
6-2	136	2.0	48 x 65.2 x 4.3	116	2.0	29 x 45 x 4.0	95	2.0	23 x 39 x 4.0
6-3	93	2.0	19 x 36.2 x 4.3	93	2.0	18 x 34 x 4.0	62	2.0	11 x 27 x 4.0
6-4	36	1.0	4 x 21.2 x 4.3	36	1.0	4 x 20 x 4.0	36	1.0	4 x 20 x 4.0
DC 7	112	4.5	39 x 56.2 x 4.3	112	4.5	27 x 43 x 4.0	25	3.0	1 x 17 x 4.0
DC 8	172	1.5	61 x 78.2 x 4.3	26	1.5	3 x 19 x 4.0	26	1.5	3 x 19 x 4.0
DC 9	72	2.0	14 x 31.2 x 4.3	72	2.0	14 x 31.2 x 4.3	30	2.0	4 x 20 x 4.0
DC 10-1	244	2.4	88 x 105.2 x 4.3	200	2.4	37 x 54.2 x 4.3	200	2.4	37 x 54.2 x 4.3
10-2	217	2.6	78 x 95.2 x 4.3	146	2.6	30 x 46 x 4.0	146	2.6	30 x 46 x 4.0
10-3	123	2.3	14 x 31.2 x 4.3	123	2.3	28 x 43 x 3.75	123	2.3	28 x 43 x 3.75
10-4	74	2.7	12 x 26 x 3.5	74	2.7	15 x 29 x 3.5	74	2.7	15 x 29 x 3.5
DC 11-1	82	2.5	15 x 32.2 x 4.3	82	2.5	18 x 34 x 4.0	82	2.5	18 x 34 x 40
11-2	47	4.5	7 x 24.2 x 4.3	47	4.5	8 x 24 x 4.0	47	4.5	8 x 24 x 4.0
DC 12	44	3.0	6 x 23.2 x 4.3	44	3.0	8 x 24 x 4.0	44	3.0	8 x 24 x 4.0
DC 13	79	5.0	12 x 28 x 4.0	79	5.0	17 x 33 x 4.0	79	5.0	17 x 33 x 4.0
DC 14	178	3.0	63 x 80.2 x 4.3	38	3.0	8 x 23 x 3.75	38	3.0	8 x 23 x 3.75
DC 15	84	0.5	18 x 32 x 3.5	84	0.5	18 x 32 x 3.5	84	0.5	18x 32 x 3.5
Total		55.5			55.5			57.5	

Table H.10 Main Features of Khal Improvement Alternatives (DND Project Zone: NA)

Khal No.	Alternative I			Alternative II		
	Design Discharge Q (m^3/s)	Length L (km)	Cross Section B1 x B2 x H (m)	Design Discharge Q (m^3/s)	Length L (km)	Cross Section B1 x B2 x H (m)
NA 1-1	158	2.0	39 x 55 x 4.0	114	2.0	28 x 44 x 4.0
1-2	102	2.0	25 x 41 x 4.0	102	2.0	25 x 41 x 4.0
1-3	84	2.5	20 x 36 x 4.0	84	2.5	20 x 36 x 4.0
1-4	45	3.5	8 x 22.4 x 3.6	45	3.5	8 x 22.4 x 3.6
NA 2	116	3.0	28 x 44 x 4.0	34	3.0	4 x 20 x 4.0
NA 3	27	3.0	3 x 17.8 x 3.7	27	3.0	3 x 17.8 x 3.7
NA 4	27	3.5	7 x 18.6 x 2.9	27	3.5	7 x 18.6 x 2.9
NA 5-1	-	-	-	106	2.0	19 x 35 x 4.0
5-2	20	3.3	1 x 15.4 x 3.6	74	3.3	12 x 28 x 4.0
5-3	49	2.0	11 x 24.2 x 3.3	49	2.7	7 x 21.8 x 4.0
NA 6-1	22	3.0	1 x 17 x 4.0	63	3.0	14 x 30 x 4.0
6-2	34	3.0	5 x 19.4 x 3.6	34	3.0	4 x 18.4 x 3.6
NA 7	82	4.3	18 x 32.4 x 3.6	23	3.0	3 x 17.8 x 3.7
NA 8	21	1.5	3 x 16.2 x 3.3	21	1.5	1 x 15.8 x 3.7
Total		36.6			38.0	

Table H.11 Cost Comparison of Drainage Alternatives
(Turag River Left Bank Zone : DB)

Item	Alternative I		Alternative II	
1. Construction Cost				
(1) Pumping Station	m^3/s × $MTk./m^3/s$	MTk.	m^3/s × $MTk./m^3/s$	MTk.
P1	65.2 x 23.2 =	1,512.6	49.5 x 24.0 =	1,188.0
P2	——		15.7 x 26.5 =	416.1
Sub-total		1,512.6		1,604.1
(2) Gate	m^2 × $MTk./m^2$	MTk.	m^2 × $MTk./m^2$	MTk.
G1	8.0 x 4.9 =	39.2	29.0 x 3.8 =	110.2
G2	8.0 x 4.9 =	39.2	8.0 x 4.9 =	39.2
G3	64.0 x 3.0 =	192.0	57.0 x 3.1 =	176.7
G4	12.0 x 4.5 =	54.0	12.0 x 4.5 =	54.0
Sub-total		324.4		380.1
(3) Khal Improvement		MTk.		MTk.
Dredging	$1.87 \times 10^6 m^3$ x 240 $Tk./m^3$ =	448.8	$1.84 \times 10^6 m^3$ x 240 $Tk./m^3$ =	441.6
Slope Protection	$452 \times 10^3 m^2$ x 60 $Tk./m^2$ =	27.1	$449 \times 10^3 m^2$ x 60 $Tk./m^2$ =	26.9
Sub-total		475.9		468.5
Total		2,312.9		2,452.7
2. O/M Cost	MTk. × %/year × Year	MTk.	MTk. × %/year × Year	MTk.
(1) Pump/Gate	1,837.0 x 1.5 x 20 =	551.1	1,984.2 x 1.5 x 20 =	595.3
(2) Khal	475.9 x 0.2 x 20 =	19.0	468.5 x 0.2 x 20 =	18.7
Total		570.1		614.0
3. Land Acquisition Cost	ha × MTk.	MTk.	ha × MTk.	MTk.
(1) Pump/Gate	2 x 3.0 =	6.0	2.5 x 3.0 =	7.5
(2) Retarding Pond	690 x 3.0 =	2,070.0	690 x 3.0 =	2,070.0
(3) Khal	70 x 3.0 =	210.0	70 x 3.0 =	210.0
Total		2,286.0		2,287.5
Grand Total		5,169.0		5,354.2

Table H.12 Cost Comparison of Drainage Alternatives (Balu River Right Bank Zone : DC)

Item	Alternative I	Alternative II	Alternative III
1. Construction Cost			
(1) Pumping Station	m^3/s x MTk./m^3/s = MTk.	m^3/s x MTk./m^3/s = MTk.	m^3/s x MTk./m^3/s = MTk.
P1	178.9 x 21.5 = 3,846.4	103.4 x 22.0 = 2,274.8	103.4 x 22.0 = 2,274.8
P2	――	75.5 x 22.7 = 1,713.9	34.9 x 24.8 = 865.5
P3	――	――	40.5 x 24.5 = 992.3
Sub-total	3,846.4	3,988.7	4,132.6
(2) Gate	m^2 x MTk./m^2 = MTk.	m^2 x MTk./m^2 = MTk.	m^2 x MTk./m^2 = MTk.
G1	8 x 4.9 = 39.2	8 x 4.9 = 39.2	8 x 4.9 = 39.2
G2	10 x 4.8 = 48.0	10 x 4.8 = 48.0	10 x 4.8 = 48.0
G3	15 x 4.5 = 67.5	15 x 4.5 = 67.5	15 x 4.5 = 67.5
G4	19 x 4.3 = 81.7	19 x 4.9 = 81.7	50 x 3.2 = 160.0
G5	16 x 4.4 = 70.4	69 x 2.9 = 200.1	46 x 3.3 = 151.8
G6	98 x 2.6 = 254.8	80 x 2.8 = 224.0	80 x 2.8 = 224.0
Sub-total	561.6	660.5	690.5
(3) Khal Improvement	MTk.	MTk.	MTk.
Dredging	6.30 x $10^6 m^3$ x 240 Tk./m^3 = 1,512.0	4.44 x $10^6 m^3$ x 240 Tk./m^3 = 1,065.6	3.67 x $10^6 m^3$ x 240 Tk./m^3 = 880.8
Slope Protection	1.20 x $10^6 m^2$ x 60 Tk./m^2 = 72.0	1.12 x $10^6 m^2$ x 60 Tk./m^2 = 67.2	1.05 x $10^6 m^2$ x 60 Tk./m^2 = 63.0
Sub-total	1,584.0	1,132.8	943.8
Total	5,992.0	5,782.0	5,766.9
2. O/M Cost	MTk. x %/year x Year = MTk.	MTk. x %/year x Year = MTk.	MTk. x %/year x Year = MTk.
(1) Pump/Gate	4,408.0 x 1.5 x 20 = 1,322.4	4,649.2 x 1.5 x 20 = 1,394.8	4,823.1 x 1.5 x 20 = 1,446.9
(2) Khal	1,584.0 x 0.2 x 20 = 63.4	1,132.8 x 0.2 x 20 = 45.3	943.8 x 0.2 x 20 = 37.8
Total	1,385.8	1,440.1	1,484.7
3. Land Acquisition Cost	ha x MTk. = MTk.	ha x MTk. = MTk.	ha x MTk. = MTk.
(1) Pump/Gate	2 x 3.0 = 6.0	2.5 x 3.0 = 7.5	3.5 x 3.0 = 10.5
(2) Retarding Pond	1,880 x 3.0 = 5,640.0	1,880 x 3.0 = 5,640.0	1,880 x 3.0 = 5,640.0
(3) Khal	207 x 3.0 = 621.0	170 x 3.0 = 510.0	151 x 3.0 = 453.0
Total	6,267.0	6,157.5	6,103.5
Grand Total	13,644.8	13,379.6	13,355.1

Table H.13 Cost Comparison of Drainage Alternatives (DND Project Zone : NA)

Item	Alternative I		Alternative II	
1. Construction Cost				
(1) Pumping Station				
P1	64.7 m³/s x 23.2 MTk./m³/s =	1,501.0 MTk.	Existing P.S. = 14.5 m³/s	
P2	—		50.2 m³/s x 24.0 MTk./m³/s =	1,204.8 MTk.
Sub-total		1,512.6		1,204.8
(2) Gate				
G1	64 m² x 2.9 MTk./m² =	185.6 MTk.	46 m² x 3.2 MTk./m² =	147.2 MTk.
G2	—		42 x 3.2 =	134.4
Sub-total		185.6		281.6
(3) Khal Improvement				
Dredging	2.17 x 10⁶ m³ x 240 Tk./m³ =	520.8 MTk.	1.90 x 10⁶ m³ x 240 Tk./m³ =	456.0 MTk.
Slope Protection	667 x 10³ m² x 60 Tk./m² =	40.0	722 x 10³ m² x 60 Tk./m² =	43.3
Sub-total		560.8		499.3
Total		2,247.4		1,985.7
2. O/M Cost	MTk. %/year Year		MTk. %/year Year	
(1) Pump/Gate	1,686.6 x 1.5 x 20 =	506.0 MTk.	1,486.4 x 1.5 x 20 =	445.9 MTk.
(2) Khal	560.8 x 0.2 x 20 =	22.4	499.3 x 0.2 x 20 =	20.0
Total		528.4		465.9
3. Land Acquisition Cost	ha MTk.		ha MTk.	
(1) Pump/Gate	1.5 x 5.0 =	7.5 MTk.	1.5 x 5.0 =	7.5 MTk.
(2) Retarding Pond	680 x 5.0 =	3,400.0	680 x 5.0 =	3,400.0
(3) Khal	95 x 5.0 =	475.0	91 x 5.0 =	455.0
Total		3,882.5		3,862.5
Grand Total		6,658.3		6,314.0

Table H. 14 Required Pump Capacity and Storage Volume of Retarding Pond

Name of Area	Drainage Zone	Sub-Zone	Area (km^2)	Required Pump Capacity		Required Storage Volume of Retarding Pond		Remarks
				Specific ($m^3/s/km^2$)	Total (m^3/s)	Specific ($x10^6$ m^3/km^2)	Total ($x10^6$ m^3)	
Greater Dhaka	Buriganga River Left Bank Zone (DA)	PD-1(Kamrangi Char)	6.96	1.14	8.0	0.12	0.84	
		PD-2 (Old Dhaka)	6.75	3.29	22.2	0.03	0.21	World Bank Project
		PD-3 (Kallyanpur)	17.60	1.14	20.0	0.12	2.08	JICA Project
	Turag River Left Bank Zone (DB)	PD-4 (Northern Part)	57.19	1.14	65.2	0.12	6.86	
	Balu River Right Bank Zone (DC)	PD-5 (Northern Part))	35.57	1.14	40.6	0.12	5.50	
		PD-6 (Central Part)	30.65	1.14	35.0	0.12	3.68	
		PD-7 (Southern Part)	90.74	1.14	103.5	0.12	10.89	
Tongi	Tongi West Zone (TA)	PD-8	11.80	1.14	13.5	0.12	1.42	
	Tongi East Zone (TB)	PD-9	10.25	1.14	11.7	0.12	1.23	
Narayanganj	DND Project Zone (NA)	PD-10 (Northern Part)	30.17	1.14	14.5	0.12	3.62	Existing P.S.
		PD-11 (Southern Part)	26.62	1.14	50.2	0.12	3.19	
	Narayanganj West Zone (NB)	PD-12	2.45	1.14	2.8	0.12	0.29	
		PD-13	5.52	1.14	6.3	0.12	0.66	
		PD-14	6.26	1.14	7.1	0.12	0.75	
	Narayanganj East Zone (NC)	PD-15	1.02	1.14	1.2	0.12	0.12	
		PD-16	3.87	1.14	4.4	0.12	0.46	
		PD-17	2.31	1.14	2.7	0.12	0.28	
		PD-18	3.68	1.14	4.2	0.12	0.44	
Keraniganj	Keraniganj Zone (K)	PD-19	24.27	1.14	27.7	0.12	2.92	
Total			383.97	—	455.5	—	45.44	

Table H. 15 Design Water Levels and Area of Retarding Pond

Name of Area	Drainage Zone	Sub-Zone	Area (km^2)	Proposed Retarding Pond				Remarks
				Storage Capacity V ($x10^6$ m^3)	H.W.L. (mPWD)	L.W.L. (mPWD)	Area A (ha)	
Greater Dhaka	Buriganga River Left Bank Zone (DA)	PD-1(Kamrangi Char)	6.96	0.84	4.00	3.00	84	
		PD-2 (Old Dhaka)	6.75	0.21	-	3.00	2	World Bank Project
		PD-3 (Kallyanpur)	17.60	2.08	4.00	3.00	208	JICA Project
	Turag River Left Bank Zone (DB)	PD-4 (Northern Part)	57.19	6.86	4.00	3.00	686	
	Balu River Right Bank Zone (DC)	PD-5 (Northern Part))	35.57	5.50	4.00	3.00	427	
		PD-6 (Central Part)	30.65	3.68	4.00	3.00	368	
		PD-7 (Southern Part)	90.74	10.89	4.00	3.00	1,089	
Tongi	Tongi West Zone (TA)	PD-8	11.80	1.42	4.00	3.00	142	
	Tongi East Zone (TB)	PD-9	10.25	1.23	4.00	3.00	123	
Narayanganj	DND Project Zone (NA)	PD-10 (Northern Part)	30.17	3.62	4.00	3.00	362	
		PD-11 (Southern Part)	26.62	3.19	4.00	3.00	319	
	Narayanganj West Zone (NB)	PD-12	2.45	0.29	4.00	3.00	29	
		PD-13	5.52	0.66	4.00	3.00	66	
		PD-14	6.26	0.75	4.00	3.00	75	
	Narayanganj East Zone (NC)	PD-15	1.02	0.12	4.00	3.00	12	
		PD-16	3.87	0.46	4.00	3.00	46	
		PD-17	2.31	0.28	4.00	3.00	28	
		PD-18	3.68	0.44	4.00	3.00	44	
Keraniganj	Keraniganj Zone (K)	PD-19	24.27	2.92	4.00	3.00	292	
Total			383.97	45.44	—	—	4,402	

Table H.16 Hydraulic Requirements of Proposed Pump Station

Name of Area	Pump Station	Drainage Area (km^2)	Capacity (m^3/s)	Design Water Level (m.PWD)					Static Head (m)		Remarks
				Outer			Inner				
				H.H.W.L.	H.W.L.	L.W.L.	H.W.L.	L.W.L.	Design	Max.	
Greater Dhaka	P1	6.96	8.0	8.00	5.95	3.00	4.00	3.00	2.95	5.00	
	P2	6.75	22.2	8.00	6.45	2.40	5.00	2.40	4.05	5.60	World Bank Project
	P3	17.60	20.0	8.35	6.00	3.00	5.45	3.95	2.05	4.40	JICA Project
	P4	57.19	65.2	8.60	6.45	3.00	4.00	3.00	3.45	5.60	
	P5	35.57	40.6	8.15	6.35	3.00	4.00	3.00	3.35	5.15	
	P6	30.65	35.0	7.90	6.20	3.00	4.00	3.00	3.20	4.90	
	P7	90.74	103.5	7.65	6.05	3.00	4.00	3.00	3.05	4.65	
Tongi	P1	11.80	13.5	8.60	6.45	3.00	4.00	3.00	3.45	5.60	
	P2	10.25	11.7	8.60	6.45	3.00	4.00	3.00	3.45	5.60	
Narayanganj	P1	30.17	14.5	7.40	5.94	3.00	1.80	1.00	4.94	6.40	Existing Pump Station
	P2	26.62	50.2	7.30	5.70	3.00	4.00	3.00	2.70	4.30	
	P3	2.45	2.8	7.40	5.80	3.00	4.00	3.00	2.80	4.40	
	P4	5.52	6.3	7.40	5.80	3.00	4.00	3.00	2.80	4.40	
	P5	6.26	7.1	7.20	5.45	3.00	4.00	3.00	2.45	4.20	
	P6	1.02	1.2	7.40	5.80	3.00	4.00	3.00	2.80	4.40	
	P7	3.87	4.4	7.30	5.70	3.00	4.00	3.00	2.70	4.30	
	P8	2.31	2.7	7.20	5.60	3.00	4.00	3.00	2.60	4.20	
	P9	3.68	4.2	7.00	5.50	3.00	4.00	3.00	2.50	4.00	
Keraniganj	P1	24.27	27.7	7.20	5.45	3.00	4.00	3.00	2.45	4.20	

Note : The values of H.H.W.L. and H.W.L. of outer design water level correspond to 100 - year and 2-year frequency flood water level respectively.

Table H.17 (1) Design Discharge..

Block No.	Drainage Area (km2)	Velocity (m/s)	Time of Concentration (min)	Rainfall Intensity (mm/hr)	Run-off Coefficient	Areal Reduction Factor	Run-Off (m3/s)
Buriganga River Left Bank Zone (DA)							
DA-1	6.96	0.80	97.73	60.96	0.40	0.96	45.25
Turag River Left Bank Zone (DB)							
DB-1	5.88	0.80	91.44	63.67	0.40	0.96	39.93
DB-2	7.48	0.80	100.58	59.80	0.40	0.95	47.22
DB-3	6.33	0.80	94.13	62.48	0.40	0.96	42.19
DB-4	22.89	0.80	160.96	42.69	0.40	0.90	97.71
DB-5	13.88	0.80	129.77	50.09	0.40	0.93	71.85
DB-6	23.95	0.80	164.19	42.04	0.40	0.90	100.69
DB-7	57.21	0.80	242.85	30.75	0.40	0.81	158.33
DB-8	3.63	0.80	76.13	71.39	0.40	0.98	28.22
Balu River Right Bank Zone (DC-1)							
DC-1-1	5.79	0.80	90.89	63.91	0.40	0.96	39.47
DC-1-2	16.84	0.80	140.91	47.17	0.40	0.92	81.20
DC-1-3	5.78	0.80	90.83	63.94	0.40	0.96	39.42
DC-1-4	9.75	0.80	112.00	55.59	0.40	0.94	56.61
DC-1-5	11.49	0.80	119.87	53.01	0.40	0.94	63.62
DC-1-6	35.57	0.80	195.72	36.65	0.40	0.85	123.11
DC-1-7	5.21	0.80	87.25	65.61	0.40	0.97	36.84
DC-1-8	3.14	0.80	72.21	73.69	0.40	0.98	25.19
DC-1-9	1.94	0.80	61.04	81.10	0.40	0.99	17.31
Balu River Right Bank Zone (DC-2)							
DC-2-1	3.97	0.80	78.70	69.97	0.40	0.97	29.94
DC-2-2	4.94	0.80	85.48	66.47	0.40	0.97	35.39
DC-2-3	10.99	0.80	117.67	53.71	0.40	0.94	61.65
DC-2-4	3.22	0.80	72.87	73.29	0.40	0.98	25.70
DC-2-5	21.54	0.80	156.74	43.56	0.40	0.91	94.86
DC-2-6	3.04	0.80	71.37	74.19	0.40	0.98	24.56
DC-2-7	30.65	0.80	183.11	38.63	0.40	0.87	114.45
Balu River Right Bank Zone (DC-3)							
DC-3-1	8.81	1.00	87.83	65.33	0.40	1.00	66.65
DC-3-2	11.80	1.00	100.97	59.65	0.40	0.94	73.51
DC-3-3	17.64	0.80	143.74	46.48	0.40	0.92	83.81
DC-3-4	35.12	0.80	194.60	36.81	0.40	0.85	122.11
DC-3-5	5.36	0.80	88.21	65.15	0.40	0.97	37.64
DC-3-6	47.94	0.80	224.00	32.87	0.40	0.83	145.30
DC-3-7	6.59	1.00	86.67	65.89	0.42	1.00	52.17
DC-3-8	13.15	1.00	105.47	57.92	0.40	0.93	78.70
DC-3-9	7.39	0.80	100.09	60.00	0.40	0.95	46.80
DC-3-10	6.64	0.80	95.92	61.71	0.40	0.96	43.71
DC-3-11	16.99	0.80	141.44	47.04	0.40	0.92	81.69
DC-3-12	90.74	0.80	300.66	25.68	0.40	0.77	199.37
Tongi West Zone (TA)							
TA-1	4.13	0.80	79.88	69.34	0.40	0.97	30.86
TA-2	5.16	0.80	86.93	65.77	0.40	0.96	36.20
TA-3	3.86	0.80	77.89	70.41	0.40	0.97	29.29
TA-4	9.52	0.80	110.91	55.96	0.40	0.94	55.65
TA-5	2.28	0.80	64.49	78.65	0.40	0.99	19.73
TA-6	1.44	0.80	55.36	85.47	0.40	0.99	13.54
Tongi East Zone (TB)							
TB-1	4.64	0.80	83.46	67.47	0.40	0.97	33.74
TB-2	2.72	0.80	68.59	75.93	0.40	0.98	22.49
TB-3	8.17	0.80	104.21	58.39	0.40	0.95	50.36
TB-4	2.08	0.80	62.49	80.05	0.40	0.99	18.32
TB-5	0.81	0.80	46.52	93.30	0.40	1.00	8.40

Table H.17 (2) Design Discharge

Block No.	Drainage Area (km2)	Velocity (m/s)	Time of Concentration (min)	Rainfall Intensity (mm/hr)	Run-off Coefficient	Areal Reduction Factor	Run-Off (m3/s)
Savar Zone (S)							
S-1	6.23	0.80	93.54	62.74	0.40	0.97	42.12
S-2	10.70	0.80	116.38	54.12	0.40	0.94	60.49
S-3	4.60	0.80	83.19	67.61	0.40	0.97	33.52
S-4	4.16	0.80	80.09	69.22	0.40	0.98	31.36
S-5	14.21	0.80	131.06	49.73	0.40	0.93	73.03
S-6	26.47	0.80	171.58	40.64	0.40	0.88	105.18
S-7	4.94	0.80	85.48	66.47	0.40	0.97	35.39
S-8	1.14	0.80	51.46	88.76	0.40	0.99	11.13
S-9	2.01	0.80	61.77	80.57	0.40	0.99	17.81
S-10	0.86	0.80	47.32	92.53	0.40	1.00	8.84
S-11	6.11	0.80	92.83	63.05	0.40	0.97	41.52
S-12	9.36	0.80	110.14	56.23	0.40	0.94	54.97
S-13	5.19	0.80	87.12	65.67	0.40	0.97	36.73
S-14	16.63	0.80	140.15	47.36	0.40	0.92	80.51
DND Project Area (NA-1)							
NA-1-1	6.81	0.80	96.89	61.31	0.40	0.96	44.53
NA-1-2	3.41	0.80	74.41	72.38	0.40	0.98	26.88
NA-1-3	17.68	0.80	143.88	46.45	0.40	0.92	83.94
NA-1-4	3.30	0.80	73.52	72.90	0.40	0.98	26.20
NA-1-5	24.42	0.80	165.60	41.77	0.40	0.90	102.00
NA-1-6	4.61	0.80	83.26	67.58	0.40	0.97	33.58
NA-1-7	30.17	0.80	181.83	38.84	0.40	0.87	113.26
DND Project Area (NA-2)							
NA-2-1	7.78	0.80	102.18	59.17	0.40	0.95	48.59
NA-2-2	2.36	0.80	65.26	78.13	0.40	0.98	20.08
NA-2-3	14.39	0.80	131.76	49.54	0.40	0.93	73.67
NA-2-4	4.54	0.80	82.78	67.82	0.40	0.97	33.19
NA-2-5	2.68	0.80	68.23	76.16	0.40	0.98	22.23
NA-2-6	11.18	0.80	118.51	53.44	0.40	0.94	62.40
NA-2-7	26.62	0.80	172.01	40.56	0.40	0.88	105.57
Narayanganj West Zone (NB)							
NB-1	2.45	0.80	66.12	77.55	0.40	0.98	20.69
NB-2	5.52	0.80	89.22	64.68	0.40	0.96	38.08
NB-3	1.11	0.80	51.04	89.12	0.40	0.99	10.88
NB-4	2.41	0.80	65.74	77.80	0.40	0.98	20.42
NB-5	0.88	0.80	47.64	92.23	0.40	1.00	9.02
NB-6	3.57	0.80	75.67	71.66	0.40	0.97	27.57
NB-7	2.69	0.80	68.32	76.11	0.40	0.98	22.29
Narayanganj East Zone (NC)							
NC-1	1.02	0.80	49.76	90.27	0.40	0.99	10.13
NC-2	0.60	0.80	42.82	97.01	0.40	1.00	6.47
NC-3	3.27	0.80	73.28	73.05	0.40	0.98	26.01
NC-4	2.31	0.80	64.78	78.45	0.40	0.99	19.94
NC-5	1.92	0.80	60.82	81.25	0.40	0.99	17.16
NC-6	3.68	0.80	76.52	71.17	0.40	0.97	28.23
Keraniganj Zone (K)							
K-1	2.19	0.80	63.60	79.27	0.40	0.98	18.90
K-2	2.70	0.80	68.41	76.05	0.40	0.98	22.36
K-3	5.57	0.80	89.53	64.54	0.40	0.96	38.34
K-4	3.55	0.80	75.51	71.75	0.40	0.97	27.45
K-5	11.40	0.80	119.48	53.13	0.40	0.94	63.26
K-6	1.86	0.80	60.18	81.73	0.40	0.99	16.72
K-7	13.99	0.80	130.20	49.97	0.40	0.93	72.24
K-8	10.28	0.80	114.46	54.75	0.40	0.94	58.79

Table H.18 (1) Hydraulic Design of Khal Improvement and Trunk Drain

Khal No.	Design Discharge (m3/s)	Section Bottom Wid. (m)	Section Upper Wid. (m)	Section Height (m)	Roughness Coefficient	Bed Slope i (%)	Velocity (m/s)	Discharge Capacity (m3/s)
Buriganga River Left Bank Zone (DA)								
DA-1	45.25	7.00	23.00	4.00	0.035	0.025	0.81	48.73
Turag River Left Bank Zone (DB)								
DB.1-1	158.33	40.00	56.00	4.00	0.035	0.017	0.83	159.07
DB.1-2	100.69	22.00	38.00	4.00	0.035	0.020	0.84	101.05
DB.1-3	71.85	13.00	29.00	4.00	0.035	0.025	0.88	73.93
DB.2-1	97.71	24.00	40.00	4.00	0.035	0.017	0.78	100.41
DB.2-2	39.93	7.00	23.00	4.00	0.035	0.017	0.67	40.19
DB.3	47.22	10.00	26.00	4.00	0.035	0.015	0.66	47.41
DB.4	42.19	5.00	21.00	4.00	0.035	0.033	0.90	46.64
DB.5	28.22	5.00	19.00	3.50	0.035	0.025	0.73	30.46
Balu River Right Bank Zone (DC-1)								
DC.1-1	123.11	34.00	48.00	3.50	0.035	0.022	0.86	123.39
DC.1-2	63.62	17.00	31.00	3.50	0.035	0.022	0.80	66.83
DC.1-3	56.61	14.00	28.00	3.50	0.035	0.022	0.78	57.05
DC.1-4	39.42	9.00	23.00	3.50	0.035	0.022	0.73	41.01
DC.2-1	81.20	15.00	29.00	3.50	0.035	0.040	1.06	81.31
DC.2-2	39.47	6.00	20.00	3.50	0.035	0.040	0.94	42.66
DC.3	36.84	7.00	19.00	3.00	0.035	0.050	0.98	38.36
DC.4	25.19	4.00	18.00	3.50	0.035	0.025	0.71	27.23
DC.5	17.31	1.00	15.00	3.50	0.035	0.025	0.64	17.89
Balu River Right Bank Zone (DC-2)								
DC.6-1	114.45	28.00	44.00	4.00	0.035	0.017	0.80	114.98
DC.6-2	94.86	23.00	39.00	4.00	0.035	0.017	0.78	96.78
DC.6-3	61.65	11.00	27.00	4.00	0.035	0.025	0.86	65.43
DC.6-4	35.39	4.00	20.00	4.00	0.035	0.025	0.76	36.60
DC.7	24.56	1.00	17.00	4.00	0.035	0.033	0.80	28.72
DC.8	25.70	3.00	19.00	4.00	0.035	0.017	0.61	26.93
DC.9	29.94	4.00	20.00	4.00	0.035	0.017	0.63	30.18
Balu River Right Bank Zone (DC-3)								
DC.10-1	199.37	37.00	54.20	4.30	0.035	0.025	1.04	203.69
DC.10-2	145.30	30.00	46.00	4.00	0.035	0.025	0.98	148.30
DC.10-3	122.11	28.00	43.00	3.75	0.035	0.025	0.93	124.36
DC.10-4	73.51	15.00	29.00	3.50	0.035	0.033	0.96	73.85
DC.11-1	81.69	18.00	34.00	4.00	0.035	0.020	0.82	85.41
DC.11-2	46.80	8.00	24.00	4.00	0.035	0.020	0.74	47.28
DC.12	43.71	8.00	24.00	4.00	0.035	0.020	0.74	47.28
DC.13	78.70	17.00	33.00	4.00	0.035	0.020	0.82	81.53
DC.14	37.64	8.00	23.00	3.75	0.035	0.017	0.66	38.24
DC.15	83.81	18.00	32.00	3.50	0.035	0.033	0.98	85.87
Tongi West Zone (TA)								
TA.1-1	55.65	10.00	24.00	3.50	0.035	0.040	1.00	59.58
TA.1-2	36.20	5.00	19.00	3.50	0.035	0.040	0.92	38.52
TA.1-3	30.86	4.00	18.00	3.50	0.035	0.040	0.89	34.44
TA.2	29.29	3.00	15.00	3.00	0.035	0.100	1.26	33.99
TA.3	19.73	3.00	15.00	3.00	0.035	0.040	0.80	21.50
TA.4	13.54	6.00	14.00	2.00	0.035	0.040	0.69	13.88
Tongi East Zone (TB)								
TB.1-1	50.36	8.00	24.00	4.00	0.035	0.025	0.83	52.86
TB.1-2	33.74	4.00	20.00	4.00	0.035	0.025	0.76	36.60
TB.2	22.49	3.00	13.00	2.50	0.035	0.100	1.14	22.73
TB.3	18.32	4.00	16.00	3.00	0.035	0.025	0.65	19.47
TB.4	8.40	1.00	9.00	2.00	0.035	0.100	0.91	9.07

Table H.18 (2) Hydraulic Design of Khal Improvement and Trunk Drain

Khal No.	Design Discharge (m3/s)	Section Bottom Wid. (m)	Section Upper Wid. (m)	Section Height (m)	Roughness Coefficient	Bed Slope i (%)	Velocity (m/s)	Discharge Capacity (m3/s)
Savar Zone (S)								
S.1-1	105.18	21.00	37.00	4.00	0.035	0.025	0.94	108.59
S.1-2	60.49	3.00	19.00	4.00	0.035	0.100	1.48	65.33
S.1-3	42.12	6.00	22.00	4.00	0.035	0.025	0.80	44.64
S.2-1	73.03	18.00	32.00	3.50	0.035	0.025	0.85	74.74
S.2-2	33.52	3.00	17.00	3.50	0.035	0.050	0.97	34.02
S.3	31.36	3.00	17.00	3.50	0.035	0.050	0.97	34.02
S.4	35.39	7.00	19.00	3.00	0.035	0.050	0.98	38.36
S.5	11.13	4.00	12.00	2.00	0.035	0.050	0.74	11.77
S.6	17.81	4.00	16.00	3.00	0.035	0.025	0.65	19.47
S.7	8.84	2.00	12.00	2.50	0.035	0.025	0.55	9.55
S.8-1	80.51	20.00	34.00	3.50	0.035	0.025	0.87	81.76
S.8-2	54.97	13.00	27.00	3.50	0.035	0.025	0.82	57.36
S.8-3	41.52	5.00	19.00	3.50	0.035	0.050	1.03	43.07
S.9	36.73	4.00	16.00	3.00	0.035	0.100	1.30	38.95
DND Project Area (NA-1)								
NA.1-1	113.28	28.00	44.00	4.00	0.035	0.017	0.80	114.98
NA.1-2	102.00	25.00	41.00	4.00	0.035	0.017	0.79	104.04
NA.1-3	83.94	20.00	36.00	4.00	0.035	0.017	0.77	85.94
NA.1-4	44.53	8.00	22.40	3.60	0.035	0.029	0.84	45.99
NA.2	33.58	4.00	20.00	4.00	0.035	0.022	0.72	34.33
NA.3	26.20	3.00	17.80	3.70	0.035	0.029	0.76	29.41
NA.4	26.88	7.00	18.60	2.90	0.035	0.029	0.74	27.30
DND Project Area (NA-2)								
NA.5-1	105.57	19.00	35.00	4.00	0.035	0.029	1.00	107.54
NA.5-2	73.67	12.00	28.00	4.00	0.035	0.029	0.94	75.04
NA.5-3	48.59	7.00	21.80	3.70	0.035	0.040	0.98	52.47
NA.6-1	62.40	14.00	30.00	4.00	0.035	0.017	0.73	64.50
NA.6-2	33.19	4.00	18.40	3.60	0.035	0.033	0.83	33.29
NA.7	22.23	3.00	17.80	3.70	0.035	0.017	0.59	22.52
NA.8	20.08	1.00	15.80	3.70	0.035	0.025	0.66	20.55
Narayanganj West Zone (NB)								
NB.1	20.69	2.00	16.00	3.50	0.035	0.025	0.66	20.94
NB.2	38.08	5.00	21.00	4.00	0.035	0.025	0.78	40.60
NB.3	10.88	1.00	13.00	3.00	0.035	0.025	0.58	12.19
NB.4	20.42	2.00	16.00	3.50	0.035	0.025	0.66	20.94
NB.5	9.02	0.00	12.00	3.00	0.035	0.025	0.55	9.89
NB.6	27.57	5.00	17.00	3.00	0.035	0.040	0.84	27.82
NB.7	22.29	4.00	16.00	3.00	0.035	0.040	0.82	24.63
Narayanganj East Zone (NC)								
NC.1	10.13	1.00	13.00	3.00	0.035	0.025	0.58	12.19
NC.2	6.47	3.00	11.00	2.00	0.035	0.025	0.50	7.03
NC.3	26.01	7.00	19.00	3.00	0.035	0.025	0.70	27.12
NC.4	19.94	5.00	17.00	3.00	0.035	0.025	0.67	21.99
NC.5	17.16	4.00	16.00	3.00	0.035	0.025	0.65	19.47
NC.6	28.23	8.00	20.00	3.00	0.035	0.025	0.71	29.73
Keraniganj Zone (k)								
K.1-1	72.24	14.00	32.00	4.50	0.035	0.015	0.73	75.89
K.1-2	63.26	11.00	29.00	4.50	0.035	0.015	0.71	63.92
K.1-3	38.34	5.00	23.00	4.50	0.035	0.015	0.65	40.69
K.1-4	18.90	0.00	18.00	4.50	0.035	0.022	0.68	27.36
K.2	16.72	2.00	15.60	3.40	0.035	0.022	0.61	18.34
K.3	27.45	3.00	18.40	3.85	0.035	0.022	0.68	28.06
K.4	22.36	1.00	17.00	4.00	0.035	0.022	0.65	23.45
K.5	58.79	5.00	23.00	4.50	0.035	0.033	0.96	60.35

Table H.19 (1) Proposed Improvement Works of Khal and Trunk Drain

[1] Proposed Khal Improvement

ZONE	KHAL No.	KHAL LENGTH (km)	REQUIRED HYDRAULIC SECTION Wb x Wu x H (m x m x m)	RECTANGULAR CHANNEL BOX CULVERT (km)	RECTANGULAR CHANNEL RETAINING WALL (km)	TRAPEZOIDAL CHANNEL BRICK PROTECTION (km)	TRAPEZOIDAL CHANNEL SODDING (km)	BRIDGE/BOX CULVERT PLACES	BRIDGE/BOX CULVERT LENGTH (m)	DREDGING (1000m3)	MAINTENANCE ROAD (km)	LAND ACQUISITION (ha)	REMARKS
DA	K1	0.30	3.0 9.0 2.0	-	-	-	0.30	1.00	5.00	2.70	-	0.10	J.P.
	K2/K3	3.75	*	*	*	*	*	*	*	*	*	*	W.B.P.
	K14-1	3.00	9.0 24.6 3.9	-	-	-	3.00	1.00	47.00	37.50	-	3.20	J.P.
	K14-2	0.30	5.0 19.8 3.7	-	-	-	0.30	-	-	12.00	-	1.10	J.P.
	K15-1	1.10	6.0 19.6 3.4	-	-	-	1.10	-	-	8.40	-	0.40	J.P.
	K15-2	1.10	2.0 14.4 3.1	-	-	-	1.10	-	-	21.10	-	0.80	J.P.
	K16	0.90	1.0 7.0 3.0	-	-	0.90	-	1.00	7.00	6.30	-	0.20	J.P.
	K17-1	0.60	2.5 13.0 2.6	-	-	-	0.60	-	-	4.20	-	0.40	J.P.
	K17-2	1.60	1.0 7.0 3.0	-	-	1.60	-	2.00	14.00	12.80	-	0.40	J.P.
	K18-1	0.80	1.0 7.0 3.0	-	-	0.80	-	1.00	7.00	6.40	-	0.20	J.P.
	K19	1.40	1.0 8.0 3.5	-	-	1.40	-	1.00	24.00	12.60	-	0.40	J.P.
	K20	1.20	1.0 7.0 3.0	-	-	1.20	-	1.00	24.00	8.40	-	0.30	J.P.
	DA.1	4.00	7.0 23.0 4.0	-	-	-	4.00	-	-	192.00	8.00	9.33	
	Subtotal	20.05		0.00	0.00	5.90	10.40	8.00	128.00	324.40	8.00	16.83	
DB	K21	1.80	5.0 17.0 4.0	-	0.30	-	1.40	6.00	90.00	30.60	-	0.80	J.P.
	K22	1.30	4.0 12.0 3.0	-	0.50	-	0.80	1.00	10.00	16.90	-	0.50	J.P.
	K23	1.00	3.0 12.0 3.0	-	-	-	1.00	1.00	10.00	12.00	-	0.30	J.P.
	K24	1.40	3.0 9.0 2.0	-	-	-	1.30	5.00	95.00	12.60	-	0.40	J.P.
	K25	1.40	2.0 9.5 2.5	-	-	-	1.40	5.00	50.00	15.40	-	0.40	J.P.
	BD.1-1	4.00	40.0 56.0 4.0	-	-	-	4.00	-	-	588.00	8.00	18.13	
	DB.1-2	5.00	22.0 38.0 4.0	-	-	-	5.00	-	-	465.00	10.00	16.67	
	DB.1-3	2.00	13.0 29.0 4.0	-	-	-	2.00	-	-	132.00	4.00	5.47	
	DB.2-1	2.20	24.0 40.0 4.0	-	-	-	2.20	-	-	217.80	4.40	7.63	
	DB.2-2	3.30	7.0 23.0 4.0	-	-	-	3.30	-	-	158.40	6.60	7.70	
	DB.3	4.00	10.0 26.0 4.0	-	-	-	4.00	-	-	228.00	8.00	10.13	
	DB.4	1.50	5.0 21.0 4.0	-	-	-	1.50	-	-	63.00	3.00	3.30	
	DB.5	0.50	5.0 19.0 3.5	-	-	-	0.50	-	-	17.33	1.00	1.03	
	Subtotal	29.40		0.00	0.80	0.00	28.40	18.00	255.00	1,957.03	45.00	72.46	
DC	K4	1.80	6.0 19.5 4.5	-	-	1.00	0.80	1.00	10.00	54.00	-	1.10	J.P.
	K5-1	0.70	6.0 19.5 4.5	-	-	-	0.70	-	-	25.90	-	0.30	J.P.
	K5-2	0.50	6.0 19.5 4.5	-	-	-	0.50	2.00	36.00	20.00	-	0.40	J.P.
	K5-3	0.50	5.5 x 4.3	0.50	-	-	-		-	30.00	-	0.20	J.P.
	K5-4	1.40	5.0 x 4.3	1.40	-	-	-		-	39.00	-	0.40	J.P.
	K5-5	0.40	4.0 x 4.3	0.40	-	-	-		-	19.20	-	0.20	J.P.
	K6	1.00	1.5 10.5 3.0	-	-	0.50	0.50		-	10.00	-	0.30	J.P.
	K7-1	1.00	1.0 10.0 3.0	-	-	-	1.00	1.00	10.00	8.00	-	0.20	J.P.
	K7-2	0.40	1.0 7.0 3.0	-	-	0.40	-	2.00	20.00	3.20	-	0.10	J.P.
	K8-1	1.05	1.0 13.0 4.0	-	-	-	1.05	1.00	10.00	11.60	-	0.30	J.P.
	K8-2	1.00	1.0 13.0 4.0	-	-	-	1.00	6.00	60.00	11.00	-	0.30	J.P.
	K8-3	0.65	1.0 8.0 3.5	-	-	0.65	-	2.00	20.00	5.90	-	0.20	J.P.
	K8-4	0.35	1.0 7.0 3.0	-	-	0.35	-	-	-	2.50	-	0.10	J.P.
	K9-1	0.40	5.0 x 3.8 x 2	0.40	-	-	-	-	-	7.20	-	0.20	J.P.
	K9-2	0.60	4.5 x 3.8 x 2	0.60	-	-	-	-	-	9.60	-	0.30	J.P.
	K10-1	0.80	5.0 x 3.8	0.80	-	-	-	-	-	8.00	-	0.20	J.P.
	K10-2	1.00	4.5 x 3.8	1.00	-	-	-	-	-	8.00	-	0.20	J.P.
	K11	0.70	4.0 x 3.9	0.70	-	-	-	-	-	24.00	-	0.20	J.P.
	K12	1.50	5.0 14.0 3.0	-	-	-	1.50	-	-	21.00	-	0.60	J.P.
	K13	1.40	3.0 15.0 4.0	-	-	-	1.40	-	-	22.40	-	0.60	J.P.
	DC.1-1	2.00	34.0 48.0 3.5	-	-	-	2.00	-	-	224.00	4.00	8.00	
	DC.1-2	3.50	17.0 31.0 3.5	-	-	-	3.50	-	-	233.33	7.00	10.03	
	DC.1-3	2.50	14.0 28.0 3.5	-	-	-	2.50	-	-	146.67	5.00	6.67	
	DC.1-4	1.00	9.0 23.0 3.5	-	-	-	1.00	-	-	45.33	2.00	2.33	
	DC.2-1	2.50	15.0 29.0 3.5	-	-	-	2.50	-	-	153.33	5.00	6.83	
	DC.2-2	1.50	6.0 20.0 3.5	-	-	-	1.50	2.00	20.00	56.00	3.00	3.20	
	DC.3	1.00	7.0 19.0 3.0	-	-	-	1.00	-	-	32.67	2.00	2.07	
	DC.4	0.60	4.0 18.0 3.5	-	-	-	0.60	1.00	10.00	19.20	1.20	1.20	
	DC.5	0.40	1.0 15.0 3.5	-	-	-	0.40	-	-	9.60	0.80	0.72	
	DC.6-1	2.50	28.0 44.0 4.0	-	-	-	2.50	-	-	277.50	5.00	9.33	
	DC.6-2	2.00	23.0 39.0 4.0	-	-	-	2.00	-	-	192.00	4.00	6.80	
	DC.6-3	2.00	11.0 27.0 4.0	-	-	-	2.00	-	-	120.00	4.00	5.20	
	DC.6-4	1.00	4.0 20.0 4.0	-	-	-	1.00	-	-	39.00	2.00	2.13	
	DC.7	1.50	1.0 17.0 4.0	-	-	-	1.50	-	-	45.00	3.00	2.90	
	DC.8	1.50	3.0 19.0 4.0	-	-	-	1.50	-	-	54.00	3.00	3.10	
	DC.9	2.00	4.0 20.0 4.0	-	-	-	2.00	-	-	78.00	4.00	4.27	
	DC.10-1	2.40	37.0 54.2 4.3	-	-	-	2.40	-	-	357.89	4.80	10.59	
	DC.10-2	2.60	30.0 46.0 4.0	-	-	-	2.60	-	-	304.20	5.20	10.05	
	DC.10-3	2.30	28.0 43.0 3.8	-	-	-	2.30	-	-	237.86	4.60	8.43	
	DC.10-4	2.70	15.0 29.0 3.5	-	-	-	2.70	-	-	165.60	5.40	7.38	
	DC.11-1	2.50	18.0 34.0 4.0	-	-	-	2.50	1.00	10.00	202.50	5.00	7.67	
	DC.11-2	4.50	8.0 24.0 4.0	-	-	-	4.50	-	-	229.50	9.00	10.80	
	DC.12	3.00	8.0 24.0 4.0	-	-	-	3.00	-	-	153.00	6.00	7.20	
	DC.13	5.00	17.0 33.0 4.0	-	-	-	5.00	1.00	10.00	390.00	10.00	15.00	
	DC.14	3.00	8.0 23.0 3.8	-	-	-	3.00	-	-	140.25	6.00	7.00	
	DC.15	0.50	18.0 32.0 3.5	-	-	-	0.50	-	-	34.67	1.00	1.47	
	Subtotal	73.15		5.80	0.00	2.90	64.45	20.00	216.00	4,281.60	112.00	166.77	

Note: (1) J.P. means JICA Project
(2) W.B.P. meams World Bank Project

Table H.19 (2) Proposed Improvement Works of Khal and Trunk Drain

[1] Proposed Khal Improvement

ZONE	KHAL No.	KHAL LENGTH (km)	REQUIRED HYDRAULIC SECTION Wb x Wu x H (m x m x m)	RECTANGULAR CHANNEL: BOX CULVERT (km)	RECTANGULAR CHANNEL: RETAINING WALL (km)	TRAPEZOIDAL CHANNEL: BRICK PROTECTION (km)	TRAPEZOIDAL CHANNEL: SODDING (km)	BRIDGE/BOX CULVERT: PLACES	BRIDGE/BOX CULVERT: LENGTH (m)	DREDGING (1000m3)	MAINTENANCE ROAD (km)	LAND ACQUISITION (ha)	REMARKS
	TA.1-1	1.00	10.0 24.0 3.5	-	-	-	1.00	-	-	48.00	2.00	2.40	
	TA.1-2	2.00	5.0 19.0 3.5	-	-	-	2.00	1.00	10.00	69.33	4.00	4.13	
TA	TA.1-3	2.00	4.0 18.0 3.5	-	-	-	2.00	1.00	10.00	64.00	4.00	4.00	
	TA.2	2.00	3.0 15.0 3.0	-	-	-	2.00	-	-	46.67	4.00	3.60	
	TA.3	2.00	3.0 15.0 3.0	-	-	-	2.00	-	-	46.67	4.00	3.60	
	TA.4	2.00	6.0 14.0 2.0	-	-	-	2.00	-	-	36.67	4.00	3.47	
	Subtotal	11.00		0.00	0.00	0.00	11.00	2.00	20.00	311.34	22.00	21.20	
	TB.1-1	1.00	8.0 24.0 4.0	-	-	-	1.00	-	-	51.00	2.00	2.40	
	TB.1-2	9.00	4.0 20.0 4.0	-	-	-	4.00	3.00	40.00	156.00	18.00	8.53	
TB	TB.2	2.00	3.0 13.0 2.5	-	-	-	2.00	1.00	20.00	36.00	4.00	3.33	
	TB.3	3.00	4.0 16.0 3.0	-	-	-	3.00	1.00	10.00	77.00	6.00	5.60	
	TB.4	1.00	1.0 9.0 2.0	-	-	-	1.00	-	-	10.00	2.00	1.40	
	Subtotal	16.00		0.00	0.00	0.00	11.00	5.00	70.00	330.00	32.00	21.26	
	S.1-1	1.00	21.0 37.0 4.0	-	-	-	1.00	-	-	90.00	2.00	3.27	
	S.1-2	3.00	3.0 19.0 4.0	-	-	-	3.00	-	-	108.00	6.00	6.20	
	S.1-3	5.00	6.0 22.0 4.0	-	-	-	5.00	2.00	40.00	225.00	10.00	11.33	
	S.2-1	3.00	18.0 32.0 3.5	-	-	-	3.00	-	-	208.00	6.00	8.80	
	S.2-2	2.00	3.0 17.0 3.5	-	-	-	2.00	2.00	40.00	58.67	4.00	3.87	
	S.3	2.00	3.0 17.0 3.5	-	-	-	2.00	3.00	30.00	58.67	4.00	3.87	
S	S.4	2.00	7.0 19.0 3.0	-	-	-	2.00	-	-	65.33	4.00	4.13	
	S.5	1.00	4.0 12.0 2.0	-	-	-	1.00	-	-	15.00	2.00	1.60	
	S.6	2.00	4.0 16.0 3.0	-	-	-	2.00	-	-	51.33	4.00	3.73	
	S.7	1.00	2.0 12.0 2.5	-	-	-	1.00	-	-	16.00	2.00	1.60	
	S.8-1	0.50	20.0 34.0 3.5	-	-	-	0.50	-	-	37.33	1.00	1.53	
	S.8-2	2.50	13.0 27.0 3.5	-	-	-	2.50	-	-	140.00	5.00	6.50	
	S.8-3	2.00	5.0 19.0 3.5	-	-	-	2.00	1.00	10.00	69.33	4.00	4.13	
	S.9	3.00	4.0 16.0 3.0	-	-	-	3.00	1.00	10.00	77.00	6.00	5.60	
	Subtotal	30.00		0.00	0.00	0.00	30.00	9.00	130.00	1,219.66	60.00	66.16	
	NA.1-1	2.00	28.0 44.0 4.0	-	-	-	2.00	-	-	189.00	4.00	7.47	
	NA.1-2	2.00	25.0 41.0 4.0	-	-	-	2.00	1.00	30.00	204.00	4.00	7.07	
	NA.1-3	2.50	20.0 36.0 4.0	-	-	-	2.50	1.00	30.00	217.50	5.00	8.00	
	NA.1-4	3.50	8.0 22.4 3.6	-	-	-	3.50	1.00	10.00	154.98	7.00	8.03	
	NA.2	3.00	4.0 20.0 4.0	-	-	-	3.00	1.00	10.00	9.00	6.00	6.40	
NA	NA.3	3.00	3.0 17.8 3.7	-	-	-	3.00	2.00	20.00	95.76	6.00	5.96	
	NA.4	3.50	7.0 18.6 2.9	-	-	-	3.50	-	-	109.48	7.00	7.14	
	NA.5-1	2.00	19.0 35.0 4.0	-	-	-	2.00	-	-	168.00	4.00	6.27	
	NA.5-2	3.80	12.0 28.0 4.0	-	-	-	3.80	2.00	20.00	311.32	7.60	10.13	
	NA.5-3	2.70	7.0 21.8 3.7	-	-	-	2.70	1.00	10.00	111.02	5.40	6.08	
	NA.6-1	3.00	14.0 30.0 4.0	-	-	-	3.00	-	-	166.50	6.00	8.40	
	NA.6-2	3.00	4.0 18.4 3.6	-	-	-	3.00	1.00	10.00	95.94	6.00	6.08	
	NA.7	2.50	3.0 17.8 3.7	-	-	-	2.50	1.00	10.00	30.18	5.00	4.97	
	NA.8	1.50	1.0 15.8 3.7	-	-	-	1.50	1.00	10.00	39.08	3.00	2.78	
	Subtotal	38.00		0.00	0.00	0.00	38.00	12.00	160.00	1,901.76	76.00	94.78	
	NB.1	0.50	2.0 16.0 3.5	-	-	-	0.50	-	-	13.33	1.00	0.93	
	NB.2	1.00	5.0 21.0 4.0	-	-	-	1.00	-	-	42.00	2.00	2.20	
	NB.3	0.50	1.0 13.0 3.0	-	-	-	0.50	1.00	10.00	9.33	1.00	0.83	
NB	NB.4	0.60	2.0 16.0 3.5	-	-	-	0.60	1.00	20.00	16.00	1.20	1.12	
	NB.5	0.30	0.0 12.0 3.0	-	-	-	0.30	1.00	20.00	4.90	0.60	0.48	
	NB.6	2.00	5.0 17.0 3.0	-	-	-	2.00	1.00	10.00	56.00	4.00	3.87	
	NB.7	1.50	4.0 16.0 3.0	-	-	-	1.50	-	-	38.50	3.00	2.80	
	Subtotal	6.40		0.00	0.00	0.00	6.40	4.00	60.00	180.06	12.80	12.23	
	NC.1	0.75	1.0 13.0 3.0	-	-	-	0.75	-	-	14.00	1.50	1.25	
	NC.2	1.20	3.0 11.0 2.0	-	-	-	1.20	-	-	16.00	2.40	1.84	
NC	NC.3	2.50	7.0 19.0 3.0	-	-	-	2.50	-	-	81.67	5.00	5.17	
	NC.4	1.00	5.0 17.0 3.0	-	-	-	1.00	1.00	20.00	28.00	2.00	1.93	
	NC.5	0.60	4.0 16.0 3.0	-	-	-	0.60	1.00	20.00	15.40	1.20	1.12	
	NC.6	1.30	8.0 20.0 3.0	-	-	-	1.30	1.00	20.00	45.50	2.60	2.77	
	Subtotal	7.35		0.00	0.00	0.00	7.35	3.00	60.00	200.57	14.70	14.08	
	K.1-1	2.50	14.0 32.0 4.5	-	-	-	2.50	-	-	200.00	5.00	7.33	
	K.1-2	3.00	11.0 29.0 4.5	-	-	-	3.00	1.00	20.00	210.00	6.00	8.20	
	K.1-3	1.00	5.0 23.0 4.5	-	-	-	1.00	-	-	50.00	2.00	2.33	
K	K.1-4	3.00	0.0 18.0 4.5	-	-	-	3.00	1.00	20.00	100.00	6.00	6.00	
	K.2	3.00	2.0 15.6 3.4	-	-	-	3.00	1.00	20.00	76.44	6.00	5.52	
	K.3	3.00	3.0 18.4 3.9	-	-	-	3.00	-	-	101.79	6.00	6.08	
	K.4	3.00	1.0 17.0 4.0	-	-	-	3.00	1.00	20.00	90.00	6.00	5.80	
	K.5	4.00	5.0 23.0 4.5	-	-	-	4.00	1.00	20.00	200.00	8.00	9.33	
	Subtotal	22.50		0.00	0.00	0.00	22.50	5.00	100.00	1,028.23	45.00	50.59	
	Total	253.85		5.80	0.80	8.80	229.50	86.00	1,199.00	11,734.65	427.50	536.36	

Table H.19 (3) Proposed Improvement Works of Khal and Trunk Drain

[2] Proposed Drainage Pipe (Brick Pipe & Box Culvert)

ZONE	DRAINAGE PIPE No	SECTION No	LENGTH m	EXIST PIPE m	PROPOSED DRAIN Type	Size m	REMARKS
DA	S-1	1	1000	-	Brick Pipe	3.1	J.P.
	S-2	1	600	-	Brick Pipe	1.9	With Sluice Gate J.P.
	S-3	1	1400	-	Brick Pipe	2.5	With Sluice Gate J.P.
	S-4	1	800	-	Brick Pipe	2.1	With Sluice Gate J.P.
	S-5	1	100	3.0	R.C.Box Culvert	3.1	Additional Construction J.P.
	NARINDA	2	650	3.0	R.C.Box Culvert	2.9	Additional Construction J.P.
	(Main)	3	450	3.0	Brick Pipe	2.8	Additional Construction J.P.
		4	350	2.7	Brick Pipe	2.6	Additional Construction J.P.
		5	750	-	Brick Pipe	1.9	J.P.
	(Branch)	6	500	-	Brick Pipe	2.2	With Sluice Gate J.P.
		Subtotal	2800	-			
	S-6 NARINDA (Diversion)	1	1480	-	R.C.Box Culvert	2.2x2.86	J.P.
DC	S-7	1	700	-	R.C.Box Culvert	2.6x3.0	J.P.
	Old Railway Rd.	2	650	-	Brick Pipe	3.0	J.P.
	& Old Govt.	3	650	-	Brick Pipe	2.3	J.P.
	House Rd.	4	500	-	Brick Pipe	1.9	J.P.
		Subtotal	2500				
	S-8 Circular Rd.	1	540	1.5	Brick Pipe	1.5	Additional Construction J.P.
	S-9	1	480	-	Brick Pipe	2.7	J.P.
	DIT Av.	2	240	-	Brick Pipe	1.9	J.P.
		Subtotal	720				
	S-10 SANTINAGAR	1	530	1.2	Brick Pipe	2.7	Additional Construction J.P.
		2	520	0.8	Brick Pipe	2.2	Additional Construction J.P.
		Subtotal	1050				
	S-11	1	700	-	Brick Pipe	3.1	Reconstruction J.P.
	R-12	1	550	0.9	Brick Pipe	2.4	Reconstruction J.P.
	NAYATARA	2	550	0.6	Brick Pipe	2.8	J.P.
		Subtotal	1100				
	S-13 DHANMANDI	1	450		Brick Pipe	1.8	J.P.
	S-14	1	300	-	Brick Pipe	2.7	J.P.
	DHAKA Univ.	2	450	-	Brick Pipe	2.9	J.P.
	(Main)	3	550	-	Brick Pipe	2.4	J.P.
	(Branch)	4	560	-	Brick Pipe	2.1	J.P.
		Subtotal	1860				
	TOTAL		17000				
		Brick Pipe	[14070]				
		R.C. Box Culvert	[2930]				

Note: J.P. means JICA Project

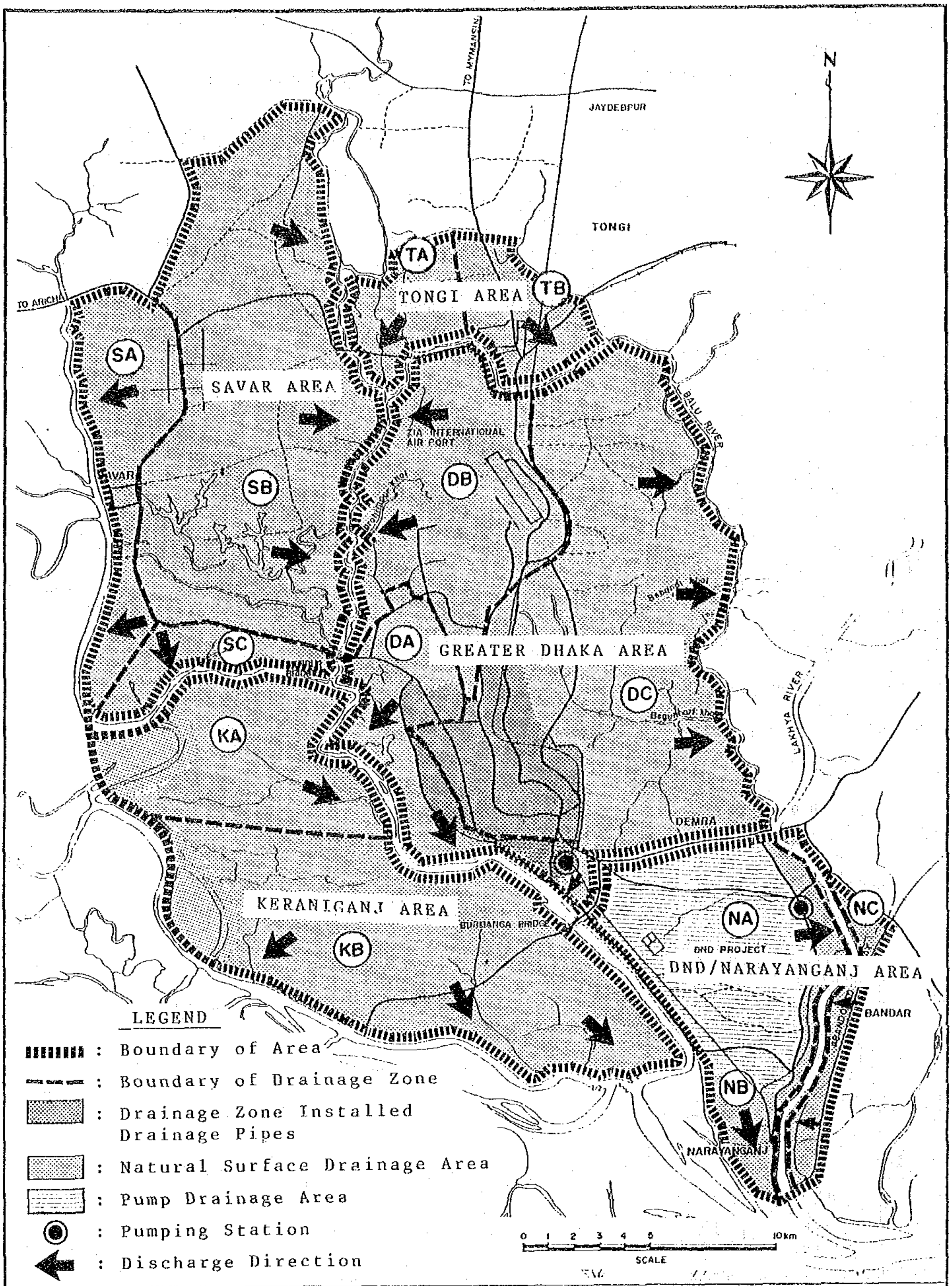


FIG. H.1	EXISTING STORM WATER DRAINAGE AREA AND SYSTEM

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

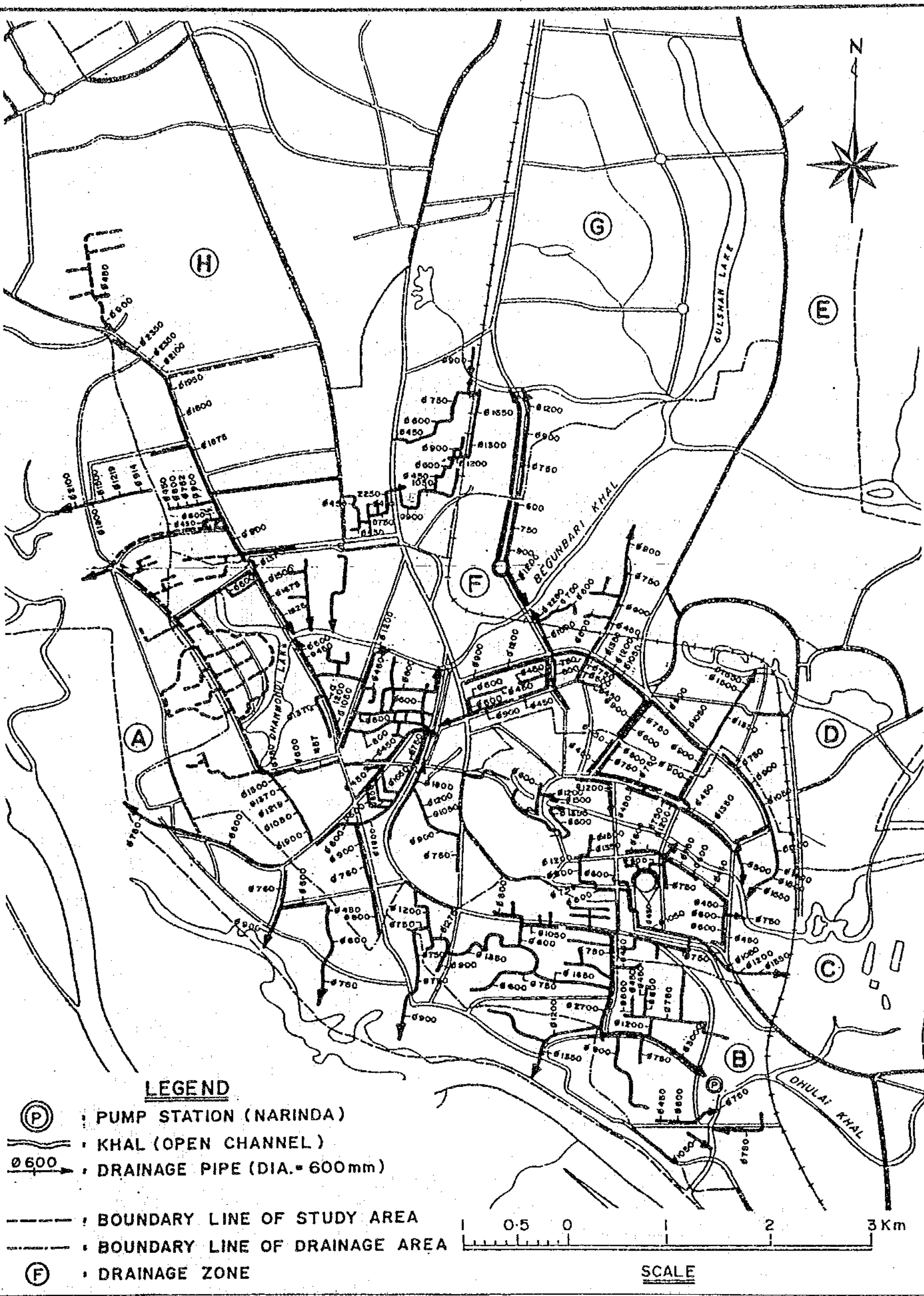


FIG. H.2 LOCATION OF TRUNK DRAINAGE PIPES IN DHAKA CITY

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

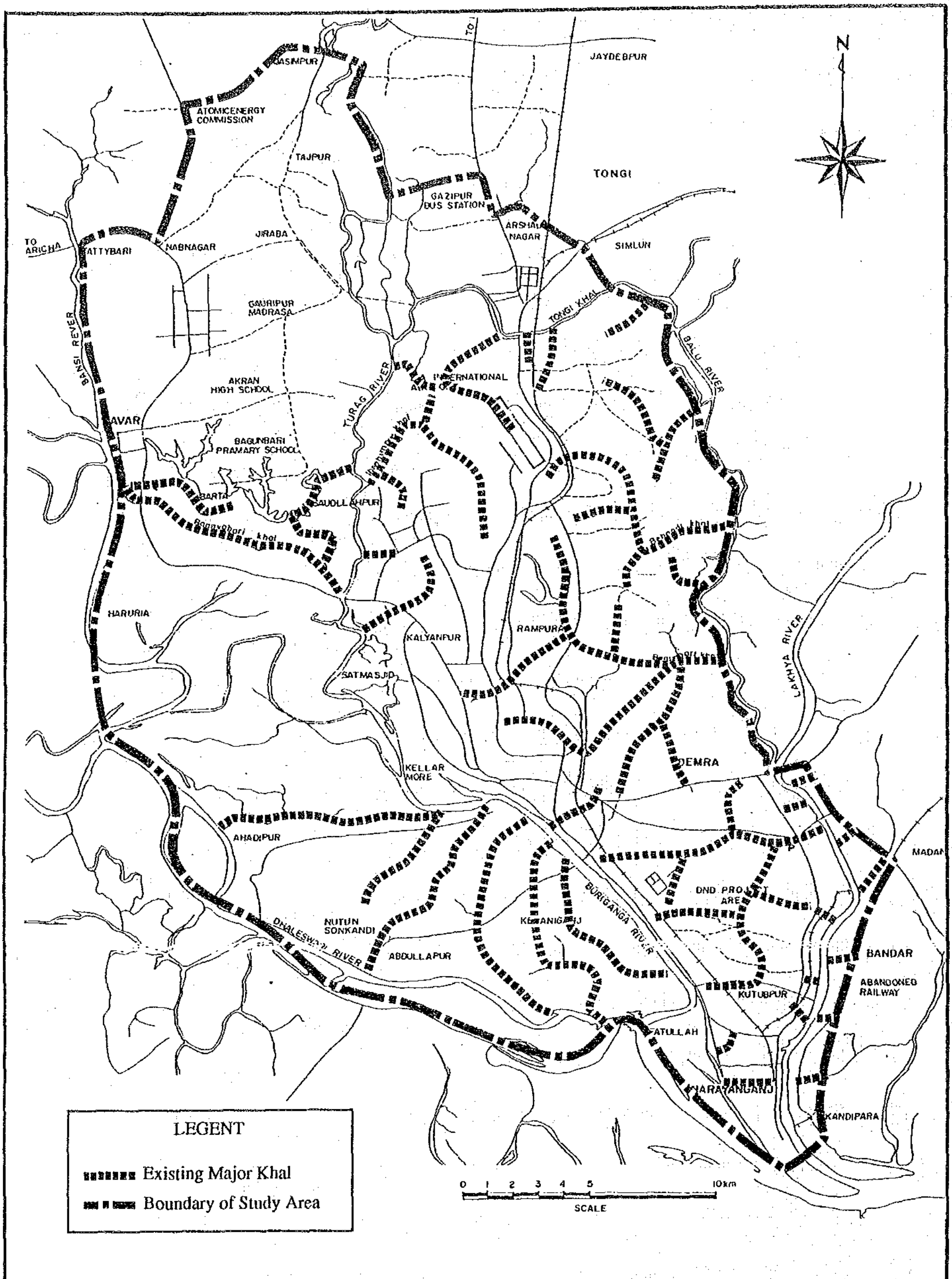
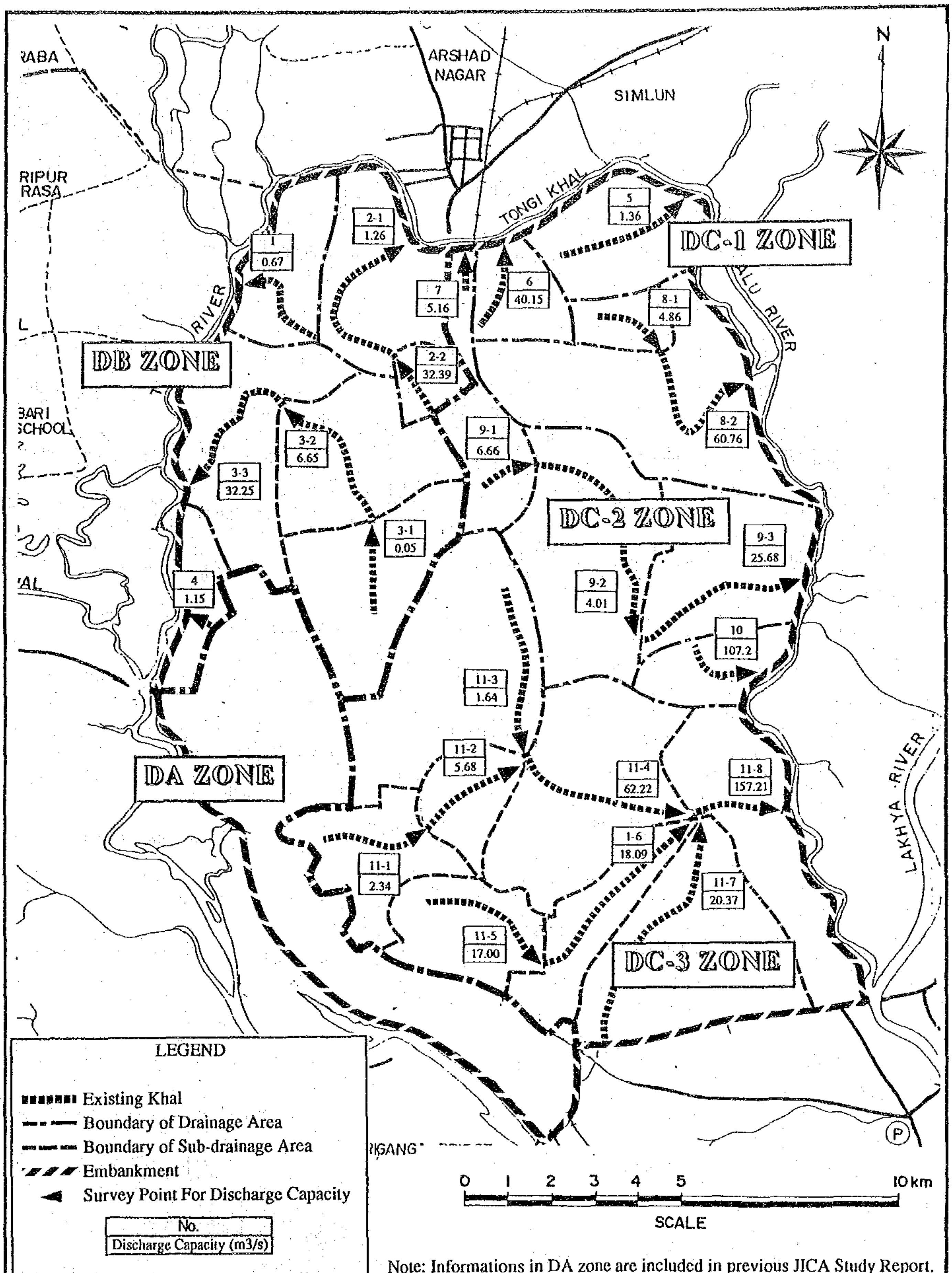


FIG. H.3 KHAL NETWORK IN DHAKA METROPOLITAN AREA

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



Note: Informations in DA zone are included in previous JICA Study Report.

FIG. H.4.1 DISCHARGE CAPACITY OF EXISTING MAJOR KHAL IN GREATER DHAKA

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

JICA

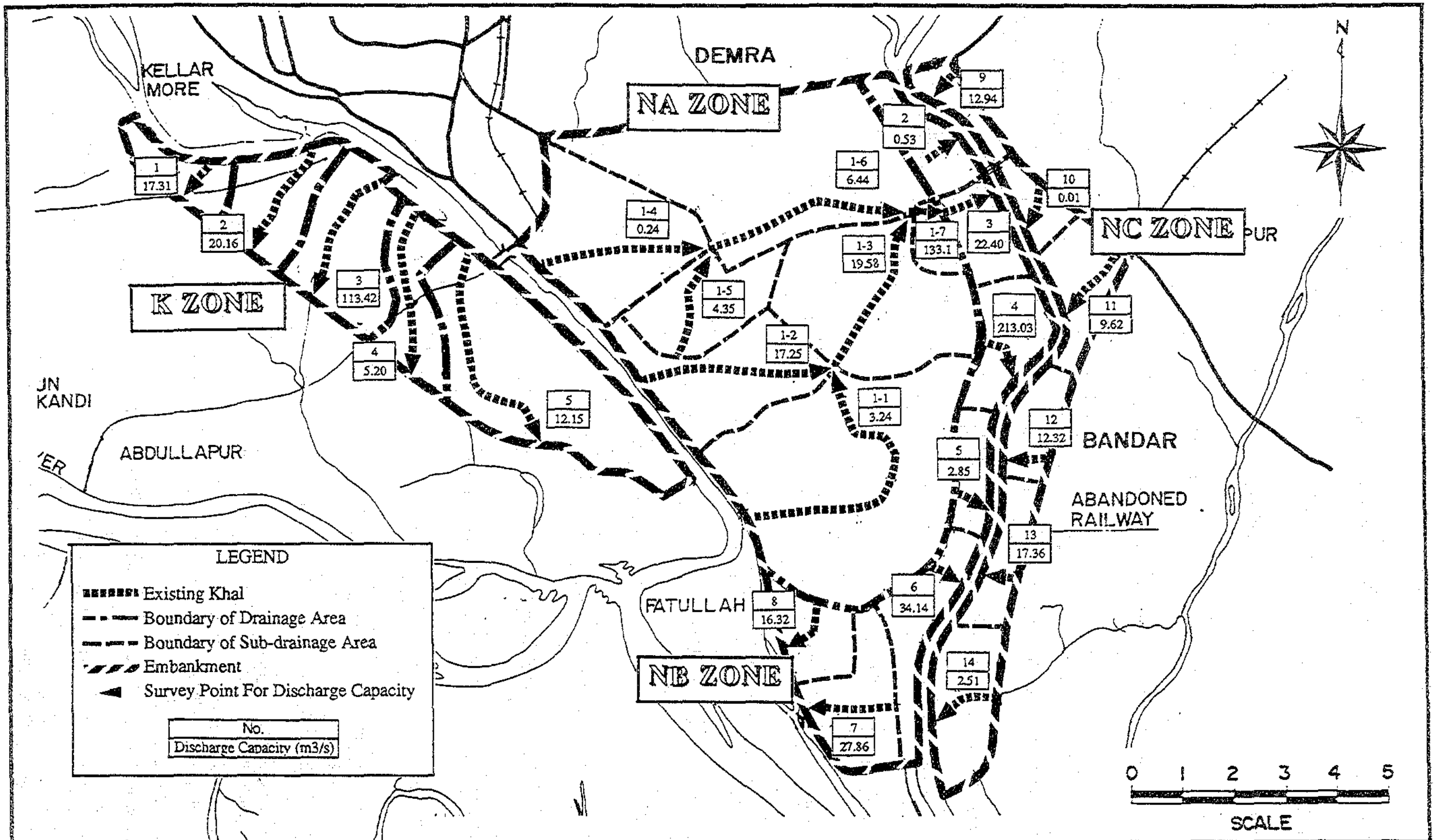


FIG. H.4.2 DISCHARGE CAPACITY OF EXISTING MAJOR KHAL IN NARAYANGANJ AND KERANIGANJ

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