## 1.2 Population of the Study Area Assumed for 1986

The base year for this Study is 1986. As it falls at the midpoint of the scheduled census taking, it will be necessary to assume the 1986 population of the Study Area.

### (a) Method Used for Assuming the 1986 Population

The flowchart used for making the population assumptions are given in Fig. D.2.

Steps 1 to 5:

From the census of 1974 and 1981, obtain the population of wards, the density, and the changes in the population of the Thanas.

Step 6:

Obtain the status of expansion of the urban areas, the speed of expansion, the characteristics of the land use of the various properties, and the classification of the land.

Step 7:

In Steps 1 thru 6, based on the accumulated density, the progress of urbanization, and the characteristics of land use, classify the population changes in the Study Area, and define the growth rate for each classification. The Classification and growth rates are as described in Table D.2 and D.3.

Step 8 and 9:

The growth rate for the period 1974 - 1981, by ward, in the Study Area will be classified according to the populational changes established in Step 7. Consideration will be given to the changes in urbanization in the ward, characteristics of the land use division, and population changes in the Thana, in meeting the classifications. When the land use occurs in several wards,

the land will be divided between the wards, and the population changes will require reclassification.
The population of each ward will be calculated from the growth rates established from the above.

Steps 10 and 11:

From the population of the wards (assumed values) obtained from Step 9, the population by Drainage Zone is obtained by reclassifying and re-totaling. The population of the entire Study Area is totaled in Step 12, and compared with the control total population of the Study Area.

Step 12:

The control total population of the Study Area is compared with the assumed "aggregate" population in Step 11. The method of assuming the control total by the Macro Indicator Method will be further explained in Paragraph (2).

(b) Characteristics of Population Trend in the Study Area

The changes in the population trend in the Study Area during the period 1974 - 1981 can be clarified by analyzing the population trend by the lowest administrative unit of the "Thana".

The Study Area includes 12 Thanas: Sutrapur, Kotwali, Lalbagh, Ramna, Dhanmondi, Motijheel, Tejgaon, Mohammadpur, part of Mirpur, Cantonment, part of Gulshan, and part of Demra.

The characteristics of land use and population changes are given in Table D.1. The results of this analysis will form the basic data for analyzing the population changes after 1981.

In summary, there is a saturation in the population in the center of Old Dhaka, and there is an exodus of the population from this area. In contrast to this, in the peripheral areas to the north and east, there is a sharp increase in the number of residences being built.

There is an uncontrolled sprawl phenomena taking place in the low-wet areas to the east. The high cost of earth fill required for building construction is a constraint for the development of residential construction. The development of residences to the north has brought about improvements to the transport facilities, and is creating new employment opportunities.

(c) Evaluation of Control Total Population for 1986

The total population of the Study Area for 1986 is estimated from the past trend of the population separately given, and this figure is used as the control total. The average annual growth rate is established as 5% - 6% and the total population of the Study Area has been assumed based on this assumption. The results are shown in Table D.4.

The average annual growth rate of 5% - 6% is based on the following:

(1) High Growth Case (6% p.a.):

- The Bangladesh Bureau of Statistics is making an estimate of the population of the Dhaka Region for the years after 1981. In this study, the annual growth rate is assumed at 2.89%. In the past trends the growth rate of Dhaka SMA has been approximately 3% more than that for the Dhaka Region.

  If this estimate is applied to the Study Area, the growth rate for the Study Area for the period 1981/86 would be 5.89%.

- As the latest and newest population study for the Dhaka SMA, which recognizes the results of the 1981 census, there is the one prepared by the National Physical Planning Project (UNDP, UNCHS, Urban Development Department, 1984).

The population of the Dhaka District (including Joydepur and Savar Areas), which is larger than the Dhaka SMA, for 1990 is estimated as 6,900,000 (as against 4,100,000 for 1981), and the growth rate is assumed at 5.8%. The open areas in the Study Area on the high lands to the north is slightly smaller, and according to the study the growth rate would not be more than 5.8%.

- The development trend for 1981/86 would be in the Model Town in the north, the area around the New Airport, the Mirpur - Senparaparbata Area to the northeast, and the low wetlands in the east (near the Railway Station), and the Demra Zone where there is considerable sprawl phenomena (unplanned) taking place. The population increase in these areas is considered to be less than that for the period 1974/81.
  Therefore, the growth rate for 1981/86 in the Study Area is considered to be less than 6.47%.

(2) Low Growth Case (5% p.a.):

In order to obtain information of the Land Use (1986) from impressions gained from the study, the growth rate of the population is much less for the Study Area for the period 1981/86 when compared with that for the period for 1974/1981 when there was a large increase in the population. However, there is very little data which can be used to substantiate the low growth.

Therefore, a natural growth rate larger than 2% can be assumed, and 5% will be established for the Low Growth Case.

- The growth rate in many of the Thanas were 4% to 5% for the Study Area in the comparatively built-up areas when there was a sharp increase in the period 1974/81.

For the Thanas which are fairly well built up in the Study Area for the period 1981/86, it will be necessary to assume a growth rate of 4% to 5%.

Assuming that there is room for development in the Study Area during the period 1981/86, a Low Growth Rate of 5% (annual) has been assumed.

There will be a big change in the growth rate by Drainage Zones for the period after 1986 extending to 2000. The average annual growth rate for Zone E in the North-East Edge in 14 years will grow by 3.60 times at an annual rate of 9.58%. The growth rate for Zone J, Turag River Bank Zone, will grow by 2.28 times at an annual rate of 6.06%, and will be next in order. There is a large-scale housing development planned for both Zones.

The Zone with the lowest growth will be Zone B, Dholai Khal Zone, which is expected to grow by 1.09 times at an annual rate of 0.59%. Next in line for the lowest growth will be Zone C, Segunbagicha Khal Zone with 1.27 times at an annual rate of 1.7%. These Zones are in the center of the city, and growth pattern will be concentric in "doughnut" shape.

## 2. PRESENT LAND USAGE

### 2.1 General

The development of Dhaka, as a city, really began after 1947 when Bangladesh gained its freedom from India. The principal transport facilities of roads, railways, and airport of the main metropolis of East Pakistan were already developed, and the city developed rapidly between the old railway (present Penetrating Road) and Briganga River from the Old Dhaka to the north.

Old Dhaka developed before the age of motorization, and there was no systematic city planning with the result that narrow and winding roads developed at will over the years. Commercial and industrial shops are concentrated on both sides of the roads; this has created a heavily populated and noisy district not to be found elsewhere. The narrow roads restrict the passage of trucks and commercial vehicles. These roads are bottlenecks in the development of commerce and industry.

The development of the areas north of Old Dhaka City has picked up with the establishment of the Dhaka Improvement Trust (DIT) in 1956. The Dhaka City Master Plan was prepared in 1958 based on the DIT.

The new commercial centre of Motijheel and the high income residential area of Dhanmond were developed based on the Master Plan. The government adminstrative centres, cultural facilities, such as universities, large scale municipal parks, apartment houses for government servants, and government agencies occupy a greater part of the Ramna, Larbag, and Motijheel areas. The areas north of the Old Dhaka City have well developed roads and public facilities.

The areas north of Dhaka were developed even further north during the 1960's. The new centre of government (new Parliament Building) was built in the western part of Tejgaon District, an industrial park was developed in East Tejgaon, a high-class residential area was developed in the Gulshan and Banani Districts, the international airport was moved to the north and a housing tract was developed in its surrounding areas, and a middle-class housing area was developed (present population 260,000) as the Uttara Model Town based on the DIT. A large-scale low-income and middle-income housing development (present population 260,000) was established in Mirpur.

Public projects have been realized as stated above, but it has not been possible to provide adequate housing facilities and job opportunities to absorb the large volumes of emigrants from the villages with the result that many colonies of squatters have sprung up in the existing city areas and in the open areas in the northern part of of Dhaka City. The low-income residents have started to set up their own homes in the low, wet areas to the east, and they have built their houses on fill and with raised floors with no plan or control whatsoever, and they have built housing areas without adequate living amenities.

## 2.2 Analysis of Present Land Use Framework

In order to gain knowledge of the present land use, the report prepared by the University of Dacca, "Generalized Land Use of Dacca City - 1975" was used for the Base Map.

The present land use map (scale: 1/30,000) prepared for this report reflects the latest up-to-date information since the Dacca Metropolitan Area Integrated Urban Development Project (DMAIUDP), 1981 was referred to, and further updated by the Field Survey information.

The information from the aerial photographs have not been reflected in the land use maps since the data was not available during the time that this study team was at the site.

The information available from the Field Work is principally as follows:

1) The built-up areas do not have major changes since a greater portion is occupied by the government except for the following areas:

   - Redeveloped areas (Motijheel, etc.)
   - Areas with developed roads (Kotwali, etc.)
   - Areas where commercial activities are developed (New Market vicinity, etc.)
   - Newly developed areas (Mirpur, etc.)

   The information for these areas have been corrected to the greatest extent possible based on the data obtained from the Field Survey.

2) A Generalized Land Use Dhaka City Map was prepared. The city areas which were expanded after 1974 (after maps had been prepared) and the general pattern of the changes, which were obtained from actual field surveys, are shown on the maps.

   For the low areas to the east of the city, where houses have been erected on individual fill or pirouettes outside the city limits that were established in 1974, the land fills are not continuous and do not represent big changes.

   In the present study, the land use data was used to analyse the present drainage zones and flooding problems together with the forecasting of future land use and for assuming the future drainage zones.

   The land use classifications have been rearranged as follows:

   A. <u>Residential Areas</u>:

   A-1. High Density: The High Density residential sector of the Old Urban Core.

| | |
|---|---|
| A-2. Middle Density: | Middle class (medium-rise apartment buildings).<br>Low class (lowest class). |
| A-3. Low Density: | Within the upper-class residential areas in the urban districts and farming areas outside the city urban areas. |
| B. Commercial: | Old and new central business district<br>Other shopping districts. |
| C. Industrial: | Old and modern industrial areas. |
| D. Open Space/Agricultural Area: | Urban open spaces, agricultural, low-lying areas. |
| E. Bodies of Water: | Rivers, khals, lakes. |

The characteristics of the various land use divisions are as follows:

A. Residential Areas:

A-1. High-density Residential Areas (Density more than 700 person/ha)

The density of the Dhaka area is especially high, and this report defines areas with densities more than 700 person/ha as high density areas. In the Old Urban Core, Old Dhaka falls into this category. There is a change presently taking place in this area toward becoming a commercial area (non-residential), and there is a tendency for a stoppage and/or a reduction in the number of people moving into this area.

A-2. Middle-density Residential Area (Density: 200~700 person/ha)

This area is comprised of middle income and low income and a combination of both classes of income. In areas where the middle income class were dominating, they resided in the middle income collective type living quarters. This includes the Government Officials' Quarters in the areas adjacent to the north side of Old Dhaka. The population in this area is on the low side.

Next is the combined income class area which extends from the east side to the northeast side of Dhaka (especially along the DIT Road). The area was developed after 1975 and is an example. Middle class collective residences, and low-class single residences are mixed in this area. There are squatter colonies in and around the planned development throughout the Mirpur Area.

A-3. Low-density Residential Area (Density: Less than 200 person/ha)

The high-class residential area includes the Old Ramna District and areas newer than the Khanmaondi-Gulshan. For the old areas there is the Eskaton Area which runs along the business area (non-residential) which has a tendency for the low-income residents (increase in population) to grow. There are pockets of squatters found which is causing an increase in the population.

Low-class Residential/Agricultural Areas can be found spread throughout the periphery of the established urban areas.

B. Commercial Areas:

The Old Urban Core in Old Dhaka, and the New Urban Core to the north in Motijheel form the Central Business District in Dhaka City.

The old central district of the city extends north and south from the port. Shopping/distribution areas, the Dhaka Municipal Corporation, college, and administration centres are found along the Buriganga River to the New Commercial Centre in the north, following the boulevard running north and southwards. In recent years a new trunk boulevard has been completed to west of the existing central axis, and redevelopment of the city is taking place.

In the New Urban Core of the Modern Central Business District, the administrative centre of the Central Government, and where central functions of private enterprises are concentrated, is now seeing commercial activities coming into the area.

Other commercial areas are the old market in Old Dhaka, and the commercial area which has formed with the expansion of the urbanization to the north. Sub-centres can be found concentrated at the New Market-New Elephant Road and the Tejturi Basar-New Airport Road.

C. Industrial Areas:

The Old Industrial Area has formed along the Buriganga River with little or no planning and is represented by the brick factories that are basically light industry.

The New Industrial Area has been established as an industrial park by the DIT at Tajgaon. The DIT is presently planning an industrial area at Postagora and Shayampur to the north of the Study Area in the direction of Tongi and Narayaganji.

D. Institutional Areas:

The centre of Dhaka City centre is occupied by governmental and defense related offices.

Some of the offices in this area are as follows:

o Administration and Public Sector Housing Area

The large expanse of land on the northern side of Old Dhaka, and the northern area with the Parliamentary Building at its centre are the main areas. The population and building density are lowest in this area.

o Defense (Cantonment) and Transport (Airport, Railway Station)

The wide expanse of land from Old Airport to the North Uttara Area is covered by defense related facilities (including military living quarters). Population density is low.

o Education and Cultural Institutional Area

The large land bordering on the north side of Old Dhaka (Ramna, etc.) has the university, laboratories, museum, and municipal parks such as Shishu Park. This area abounds in trees and greenery and has a low population density.

o Urban Open Space

As a park city, the Education and Cultural Institutional Area and Administration and Public Sector Housing Area make up most of the park areas. Other park areas are the Dhanmondi and Gulshan developed by the DIT, which have lakes and ponds formed by filling the excavated voids with water.

The areas around the khals and lakes within the city that are not used are occupied by squatters who have formed slum colonies.

o Agricultural Areas:

The areas in the periphery of the city which are low are cultivated during the dry season. Some of the low areas are occupied by squatters who have formed colonies (by filling the low lands with earth embankment mounds).

E. Bodies of Water:

Bodies of water are rivers, khals and lakes. Bodies of water are those areas that are covered with water the year round. (Many of the Agricultural Areas described in the above paragraph are inundated with water during the wet season.) These bodies of water serve to retard the flow of storm waters and also have an additional function of storing water, and are supplemental to the incomplete storm drainage facilities.

2.3 The present Status of Land Use:

In addition to the Present Usage of Land and the Analysis of Present Land Use Framework, a Land Use Map has been developed as shown in Fig. D.3.

This map breaks down the city areas into drainage zones, and this is described in Table D.9.

## 3. Future Land Use

### 3.1 The Framework for Future Land Use:

The future land use plan has been based on the plans and progress of the Present Land Use (the future Dacca Metropolitan Development Plan) and individual development projects.

#### 3.1.1. The Strategy for Future Development

The future land use plan which will determine the basic framework for the Dhaka Metropolitan Comprehensive Development Concept, was obtained from the Dhaka Metropolitan Area Integrated Urban Development Project (Government of Bangladesh, Asian Development Bank, United Nations Development Area, 1981).

The strategy laid out by the above project reports are a combination of Strategy B and Strategy C, and have been authorized by the Planning Commission (Ministry of Planning).

Strategy B: Continuing peripheral expansion of the city without comprehensive flood protection.

Strategy C: Expansion of the city to the north and west on land which does not require comprehensive flood protection.

The report for Strategy B gives the following additional explanation:

> "Emphasis should immediately be placed on the improvement of existing conditions in critically affected areas but not at a scale that would result in insufficient resources remaining for the development of new urban areas".

Therefore, this report will plan for the "short term" peripheral expansion of the city, and to absorb the pressures caused by the population increase due to the massive migration of the out of town people into this area.

For the "long term" planning after the population has exceeded a predetermined level, the total population for this area will be assumed as fixed, and any increase over this level will be distributed to the flood-free lands in the north of the city recommended by the Dhaka Metropolitan Integrated Urban Development Project. It will be planned to build housing that will bring the residences of employees close to their place of work.

The establishment of the urban areas to the periphery of the city will be studied for the status or progress of the existing residential development plan and the industrial park development plan, and to connect the various projects on the outer periphery for the target year of 2000.

3.1.2. Guidance for Development:

The dry khals have penetrated deep into the urban areas, and now cover a wide area of low areas. With the increase of the pressure from the increasing population, the construction of houses on earth fill and/or raised floor houses on stilts will continue, and if this trend is not controlled, the dry khals in the urban areas of outer periphery will disappear. The function of the dry khal, at the present time, is for controlling the storm drainage and is highly appraised in this report for its value in the rainy season to retard flood runoff, and it is planned to include the dry khals in the future land use plan.

The following criteria have been established for the planned development of the urban areas:

- It is assumed that the housing development planned by DIT, HSD, and commercial developers under the supervision of DIT will be implemented.

- The large-scale land fill planned for the lowlands in the western part (Kamrangirchar Development) has been included for development in the year 2000, and will be urbanized as described as Phase I Area in the DIT Feasibility Study Report (Nov. 1986).

The development of urban areas not covered by any proposed plan will be considered as follows:

- At the present stage, the building of houses in the lowlands in the east have been made on individually filled earth mounds or on stilts, and they are being built in consonance with the progress of road construction in their particular areas. This report will assume that the future pattern of unplanned housing will follow the present pattern and will continue to be built, and the expansion of the suburbs has been assumed strictly on the basis of the network of local road construction.

  Other development of the low areas are assumed to continue according to present plans.

## 3.2. Future Development Plans:

### 3.2.1. Housing Development Plans:

The large scale existing housing development plan undertaken by DIT, HSD, and private developers are as shown in Table D.10 and Fig. D.4.

The industrial park development within the Study Area are located at Tejgaon and Mirpur, and both areas have already been completed.

### 3.2.2. Road and Railway Planning:

The reports that give any information of long-range plans are the DMAIUDP and the HDP Report developed from the former. However, the project is delayed from its schedule, and it is assumed that the road network planned for the target year of 1990 will not be completed until 2000.

The main trunk roads planned for completion in the year 2000 are as follows:

- o Extended section of the DIT Roads.
- o The 18 meter road paralleling the main sewer line in the low areas in the east.
- o The link road from Sher-e-Banglanagar to Sec-10.

The road networks for the year 2000 are indicated by a DMAIDP as shown in Fig. D.5.

There are no new railway routes authorized for railway construction. However, there are some flyovers planned at railway crossings on the trunk highway routes planned for grade separation, and it can be assumed that future developments in the north will have improved transportation routes.

## 3.3 Future Land Use Plan:

The future land use plan has been based on the current Master Plan and the DMAIUDP Report, and is as follows:

Residential Area:

- The high-density area will be the housing areas of Old Dhaka. The population of the Central Business District is decreasing with the progress of commercialization, and if the remaining housing areas are taken into consideration, the density of this area is still very high.

- The low density areas are the Gulshan-Banani District, the districts planned for development after 1986, and the agricultural village areas in the periphery of the city.

- The medium-density areas will be all areas other than the housing areas. Even with the business district developed after 1986, the areas developed for the medium-income level and started at an early stage such as the Gulshan (East) Housing, there will be a comparatively high density.

- At the low-income housing areas of Basaba and Mohammadput, it can be expected that there will be areas with a comparatively high density which could exceed 1000 person/ha. However, the overall population will generally be in accordance with the surrounding housing areas, so the land use classification will follow that which has been generally described.

Commercial Area (Business Area)

It is expected that a part of the Old Urban Core will develop as the New Commercial Area together with the road improvements (the road to the Buriganga River Bridge). This also follows the recommendations of the DIT Master Plan.

Also, the Central Business District (CBD) within Motijheel and the commercialization of the housing area adjacent to the Government Offices is expected to progress as described in the Master Plan.

In the developed housing areas, there will be sub-centres formed for conducting commercial activities and the sub-centres will be of in the scale and location of the area.

Industrial Area:

- The new industrial park will develop between Dhaka-Narayanganji along the Buriganga River, and should be located on the plateau to the north.

- The development of the construction related industries should be assigned to the low development areas to the west (Kamrangirchar) along a part of the river (the same as the present layout).

Institutional Area:

- Only the location of facilities that could be discerned by existing reports have been shown.

Open Space/Agricultural Area:

- For the metropolitan development the earth borrow areas should be controlled beforehand, and the existing khals and lakes should be retained for the drainage of the surrounding areas to retain the waters. They should be kept to maintain the greenery and the waters.

- The low wet areas outside the development areas should be kept for farming.

Rivers, Khals, Lakes:

- Existing bodies of water will be preserved to the greatest extent possible. Even in the development areas, there will be some of the existing low wet areas (water retained only in the rainy seasons) converted to hold water the year round.

The major changes that are expected to take place during the period 1986 - 2000 are as follows:

- There will be a 37% reduction of the Open Space/Agricultural Areas, and these will be converted mainly into residential areas.

- Of the newly developed areas, of which many are residential, the newly developed areas are of low-density (not fully built at present), and many low-density areas are now medium-density areas.

- Expansion of urban areas which will lead to the increase of the city population, and expansion of the business district.

The future land use plan (year 2000) is shown in Fig. D.6.

The various land use areas are divided into drainage zones and are shown in Table. D.11.

**Table D.1 Characteristics of Land Use and Populational Change by Thana (1974 - 1981)**

| Thana (in Census) | Characteristics of Land Use (Population Change) | Population Growth Rate (annual) |
|---|---|---|
| [Old Dhaka] | | [4.02%] |
| Sutrapur | High density area (population stagnant)<br>Sprawl area (population increase) | 4.12% |
| Kotwali | High density area (population decrease due to departure of residents)<br>Slum clearance (population decrease) | -2.43% |
| Lalbagh | High-middle density area (population increase and stagnation)<br>Sprawl in low area in the west (population increase) | 10.05% |
| Ramna | Government District, Metropolitan Park, High-class residential area (population stagnant, many residents moving out)<br>Sprawl area in the north (population increase) | 4.60% |
| Dhanmondi | High-class residential area (population density low, many residents moving out)<br>Medium-class residential area (population stagnant/population increase due to moving in of low-income class)<br>Slum colonies in green belt (population increase) | -1.43% |
| Motijheel | New CBD, medium-class housing area, Govt. living quarters (population stagnant, low-income class increasing)<br>Housing progressing outside Railway Compound (population increase) | 20.48% |
| Tejgaon | Govt. Offices, Official Govt. Living Quarters (low-medium density) being developed (population increase)<br>Industrial Park<br>Slum colonies in all other areas (population increase) | 14.16% |
| Mohammadpur | Old medium-class housing area (medium density) housing construction in progress (population increase) | 7.12% |
| Mirpur | Planned Housing Development Area (mdium low-income) (population increase)<br>Partially occupied by slum camps (population increase) | 4.50% |
| Cantonment | Official living quarters and military facilities (population increase) | 4.43% |
| Gulshan | New high-class housing under construction (population increase) | -0.90% |
| Demra | Sprawl camps in the west Dhaka urban areas<br>Sprawl camps in the DND areas | 15.74% |

Table D.2 Classification of Area

| |
|---|
| Type A (Higher: AAA, Medium: AA, Lower: A): |
| Areas where the population growth rate is exceptionally high, and uncontrolled urban areas. Examples are the low areas on the outer east perimeter of Dhaka. |
| Type B (Higher: BBB, Medium: BB, Lower: B): |
| Areas where the growth rate is slightly higher than the natural growth rate. Built up areas where the growth rate in generally increasing, housing being built on open lots, high and medium income housing areas changing to low income housing, and where there is some increase in the number of slum colonies. |
| Type C (Higher: CCC, Medium: CC, Lower: C): |
| Areas where the growth is fixed to change with the degree of planned housing development. |
| Type D |
| Areas which have a growth rate commensurate with the natural growth rate. The agricultural areas are a good example. Areas where the influx of people and those leaving to seek employment in the city are about equal. |
| Type E (Higher: EEE, Medium: EE, Lower: E): |
| Built-up areas where the change in population is small. |

Table D.3 Population Growth Rate for Type of Area

| Type | Annual Growth Rate (%) | 5 Year Growth Rate (%) | Notes |
|---|---|---|---|
| | 1.0 | 0.951 | |
| EEE | 0.5 | 0.975 | |
| EE | 0.0 | 1.000 | |
| | 0.5 | 1.025 | |
| | 1.0 | 1.051 | |
| E | 1.5 | 1.078 | |
| | 2.0 | 1.104 | |
| D | 2.5 | 1.131 | Natural growth rate |
| B | 3.0 | 1.159 | |
| | 3.5 | 1.188 | |
| BB | 4.0 | 1.217 | |
| | 4.5 | 1.227 | |
| BBB | 5.0 | 1.276 | Lower estimate for |
| | 5.5 | 1.307 | total population |
| | 6.0 | 1.338 | Higher estimate for |
| | 6.5 | 1.370 | total population |
| A | 7.0 | 1.403 | |
| | 8.0 | 1.469 | |
| | 9.0 | 1.539 | |
| AA | 10.0 | 1.611 | |
| | 12.5 | 1.802 | |
| AAA | 15.0 | 2.011 | |
| | 20.0 | 2.488 | |

Table D.4 Estimate for Total Population in 1986

| Total Population in 1981 | Annual Growth Rate (%) | Total Population in 1986 | |
|---|---|---|---|
| 2,428,000 | 6.0% | 3,250,000 | High Growth Case |
| 2,428,000 | 5.0% | 3,100,000 | Low Growth Case |

**Table D.5 Present Population by Drainage Zones (in 1981/1986)**

| | Drainage Zone Within Study Area | Area (ha) | Population & [Density per ha] 1981 | Population Growth Rate 1981/1986 (5 years) | Population & [Density per ha] 1986 |
|---|---|---|---|---|---|
| A | Burhiganga R. B. Zone | 1,285 | 387,000 [301] | 1.14 | 442,300 [344] |
| B | Dholai Khal Zone | 776 | 525,000 [677] | 1.14 | 597,900 [770] |
| C | Segunbagicha Khal Zone | 904 | 226,000 [250] | 1.36 | 306,900 [339] |
| D | Basabo Zone | 832 | 213,000 [256] | 1.55 | 329,300 [396] |
| E | North-East Edge Zone | 1,393 | 39,000 [28] | 1.74 | 67,800 [49] |
| F | Begunbari Khal Zone | 1,602 | 392,000 [245] | 1.23 | 480,900 [300] |
| G | Gulshan-Banani Zone | 1,764 | 169,000 [96] | 1.35 | 227,900 [129] |
| H | Kallyampur Zone | 1,278 | 150,000 [117] | 1.54 | 230,700 [181] |
| I | North Zone | 3,142 | 238,000 [76] | 1.44 | 343,500 [109] |
| J | Turag River Bank Zone | 769 | 89,000 [116] | 1.34 | 119,300 [155] |
| | Total | 13,745 | 2,428,000 [177] | 1.29 | 3,146,500 [229] |

(Annual Rate: 5.30%)

Table D.6 Population Growth Rate for Type of Population Changes (1986 - 2000)

| Type | Annual Growth Rate (%) | 7 Year Growth Rate (%) | 14 Year Growth Rate (%) | Notes |
|---|---|---|---|---|
| | -3.0 | 0.808 | 0.653 | |
| "ee" | -2.5 | 0.838 | 0.701 | |
| | -1.5 | | 0.809 | |
| "e" | -1.0 | 0.932 | 0.869 | |
| | -0.5 | | 0.932 | |
| EE | 0.0 | 1.000 | 1.000 | |
| | 0.5 | | 1.072 | |
| | 1.0 | | 1.149 | |
| E | 1.3 | | 1.198 | |
| | 1.8 | 1.133 | 1.284 | |
| D | 2.3 | 1.173 | 1.380 | Natural growth rate |
| | 2.5 | | 1.413 | |
| B | 2.8 | 1.159 | 1.472 | |
| | 3.5 | | 1.169 | |
| BB | 3.8 | | 1.686 | |
| | 4.0 | | 1.732 | |
| | 4.5 | | 1.852 | |
| BBB | 4.8 | | 1.928 | |
| | 5.0 | | 1.980 | |
| | 5.5 | | 2.117 | |
| | 6.0 | | 2.261 | |
| A | 6.3 | | 2.352 | |
| | 6.5 | | 2.415 | |
| | 7.0 | | 2.579 | |
| | 7.5 | | 2.752 | |
| AA | 7.8 | | 2.862 | |
| | 8.0 | | 2.937 | |
| | 8.5 | | 3.133 | |
| | 9.0 | | 3.342 | |
| | 9.8 | | 3.702 | |
| | 10.0 | | 3.797 | |
| AAA | 12.3 | | 5.07 | |
| | 15.0 | | 5.075 | |
| | 20.0 | 2.488 | | |

Table D.7 Estimate of Total Population in 2000

| | Total Population in 1986 | Annual Growth Rate (%) | Total Population in 2000 |
|---|---|---|---|
| High Growth Case | 3,147,000 | 4.0% | 5,449,000 |
| Low Growth Case | 3,147,000 | 2.3% | 4,326,000 |

Table D.8 Future Population by Drainage Zones (in 2000)

| | Drainage Zone Within Study Area | Area (ha) | Population & [Density per ha] 1986 | Population Growth Rate 1986/2000 (14 years) | Population & [Density per ha] 2000 |
|---|---|---|---|---|---|
| A | Burhiganga R. B. Zone | 1,285 | 442,300 [344] | 1.29 | 570,300 [444] |
| B | Dholai Khal Zone | 776 | 597,900 [770] | 1.09 | 649,600 [837] |
| C | Segunbagicha Khal Zone | 904 | 306,900 [339] | 1.27 | 388,400 [430] |
| D | Basabo Zone | 832 | 329,300 [396] | 1.87 | 615,600 [740] |
| E | North-East Edge Zone | 1,393 | 67,800 [49] | 3.6 | 244,000 [175] |
| F | Begunbari Khal Zone | 1,602 | 480,900 [300] | 1.31 | 631,800 [394] |
| G | Gulshan-Banani Zone | 1,764 | 227,900 [129] | 1.48 | 337,000 [191] |
| H | Kallyampur Zone | 1,278 | 230,700 [181] | 1.97 | 455,600 [356] |
| I | North Zone | 3,142 | 343,500 [109] | 1.79 | 613,300 [195] |
| J | Turag River Bank Zone | 769 | 119,300 [155] | 2.28 | 271,700 [353] |
| | Total | 13,745 | 3,146,500 [299] | 1.518 | 4,777,300 [348] |

(Annual Rate: 3.03%)

Table D.9 Present Land Use (in 1986)

Unit: ha

| | Drainage Zone Within Study Area | Residential | | | Commercial | Industrial | Institutional | Open Space/ Agricultural | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | High Density | Midium Density | Low Density | | | | | |
| A | Burhiganga R. B. Zone | 159 | 254 | 22 | 29 | 150 | 61 | 610 | 1,285 |
| B | Dholai Khal Zone | 539 | 100 | - | 30 | 24 | 50 | 33 | 776 |
| C | Segunbagicha Khal Zone | - | 473 | 41 | 25 | 3 | 100 | 262 | 904 |
| D | Basabo Zone | - | 325 | 4 | 6 | - | 30 | 122 | 487 |
| E | North-East Edge Zone | - | 158 | 720 | 6 | - | - | 854 | 1,738 |
| F | Begunbari Khal Zone | 56 | 863 | 148 | 33 | 100 | 178 | 224 | 1,602 |
| G | Gulshan-Banani Zone | - | 115 | 550 | 26 | 105 | 546 | 422 | 1,764 |
| H | Kallyampur Zone | - | 250 | 255 | 6 | - | 227 | 440 | 1,178 |
| I | North Zone | - | 255 | 190 | 5 | 24 | 1,265 | 1,403 | 3,142 |
| J | Turag River Bank Zone | - | 258 | 57 | 2 | 10 | 40 | 502 | 869 |
| | Total | 754 | 3,051 | 1,987 | 168 | 416 | 2,497 | 4,872 | 13,745 |

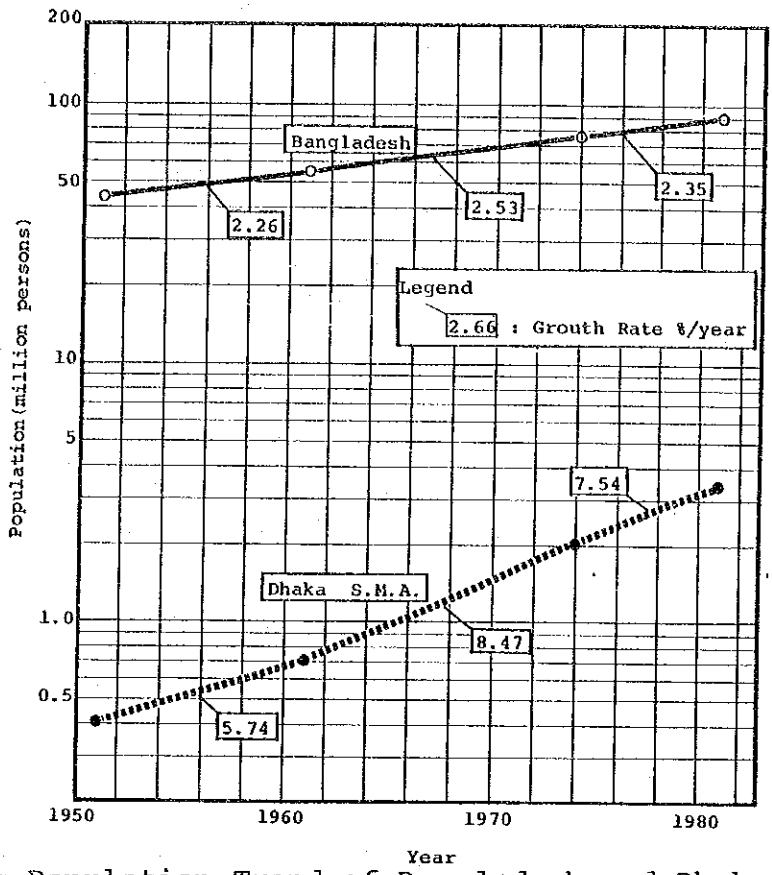
Table D.10 Housing Development Projects

| | Site of Development Project | Developer/Planning Agency | Implementation Phase |
|---|---|---|---|
| 1 | Mirpur Housing Development | HSD (land purchase and subdivision) | - developed & built up<br>- proposed and planning expansion |
| 2 | Gulshan-Banani Model Town | DIT (land purchase and subdivision) | - developed & built up<br>- developing the east side |
| 3 | Uttarra (West Model Town) | DIT (land purchase and subdivision) | - developed but built up in part |
| 4 | Joarshahara | DIT (land purchase and subdivision) | - developing |
| 5 | Senpara Parbata Redevelopment | DIT (zoning plan) | - in enforcement (built up in part) |
| 6 | Uttarra (East & Ranabhola Model Town) | DIT (land purchase and subdivision) | - planned |
| 7 | East Zone of Dhaka-Mymesngh Road | DIT (land purchase and subdivision) | - proposed by DIT |
| 8 | Kamrangirchar | DIT (land purchase and subdivision) | - proposed & purchased in part (prepared F/S report Nov. 1986) |
| 9 | East Dhaka | DIT (zoning plan) | - under study |
| 10 | Rampur Area | Private Developer (land purchase and subdivision) | - developing in part<br>- purchased in part |
| 11 | Mohammadpur Low-Lying Land | Housing Society (land purchase and subdivision) | - purchased in part |

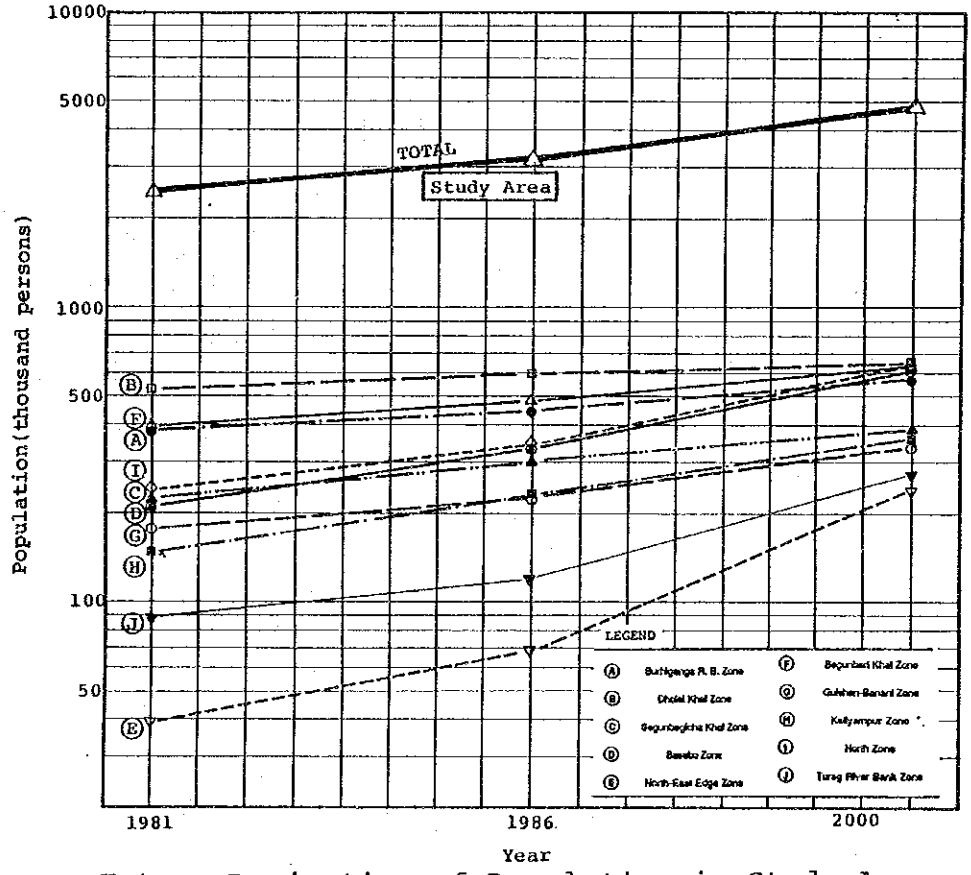
Table D.11 Future Land Use (in 2000)

Unit: ha

| | Drainage Zone Within Study Area | Residential | | | Commercial | Industrial | Institutional | Open Space/ Agricultural | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | High Density | Midium Density | Low Density | | | | | |
| A | Burhiganga R. B. Zone | 130 | 640 | 10 | 58 | 168 | 73 | 206 | 1,285 |
| B | Dholai Khal Zone | 505 | 113 | - | 60 | 30 | 52 | 16 | 776 |
| C | Segunbagicha Khal Zone | - | 471 | 41 | 45 | - | 100 | 247 | 904 |
| D | Basabo Zone | - | 520 | 30 | 11 | - | 30 | 241 | 832 |
| E | North-East Edge Zone | - | 406 | 609 | 20 | - | - | 358 | 1,393 |
| F | Begunbari Khal Zone | 56 | 885 | 148 | 83 | 142 | 178 | 110 | 1,602 |
| G | Gulshan-Banani Zone | - | 325 | 405 | 60 | 105 | 555 | 314 | 1,764 |
| H | Kallyampur Zone | - | 875 | - | 13 | - | 276 | 114 | 1,278 |
| I | North Zone | - | 560 | 10 | 10 | 24 | 1,330 | 1,208 | 3,142 |
| J | Turag River Bank Zone | - | 290 | 5 | 3 | 12 | 44 | 415 | 769 |
| | Total | 691 | 5,085 | 1,258 | 363 | 481 | 2,638 | 3,229 | 13,745 |



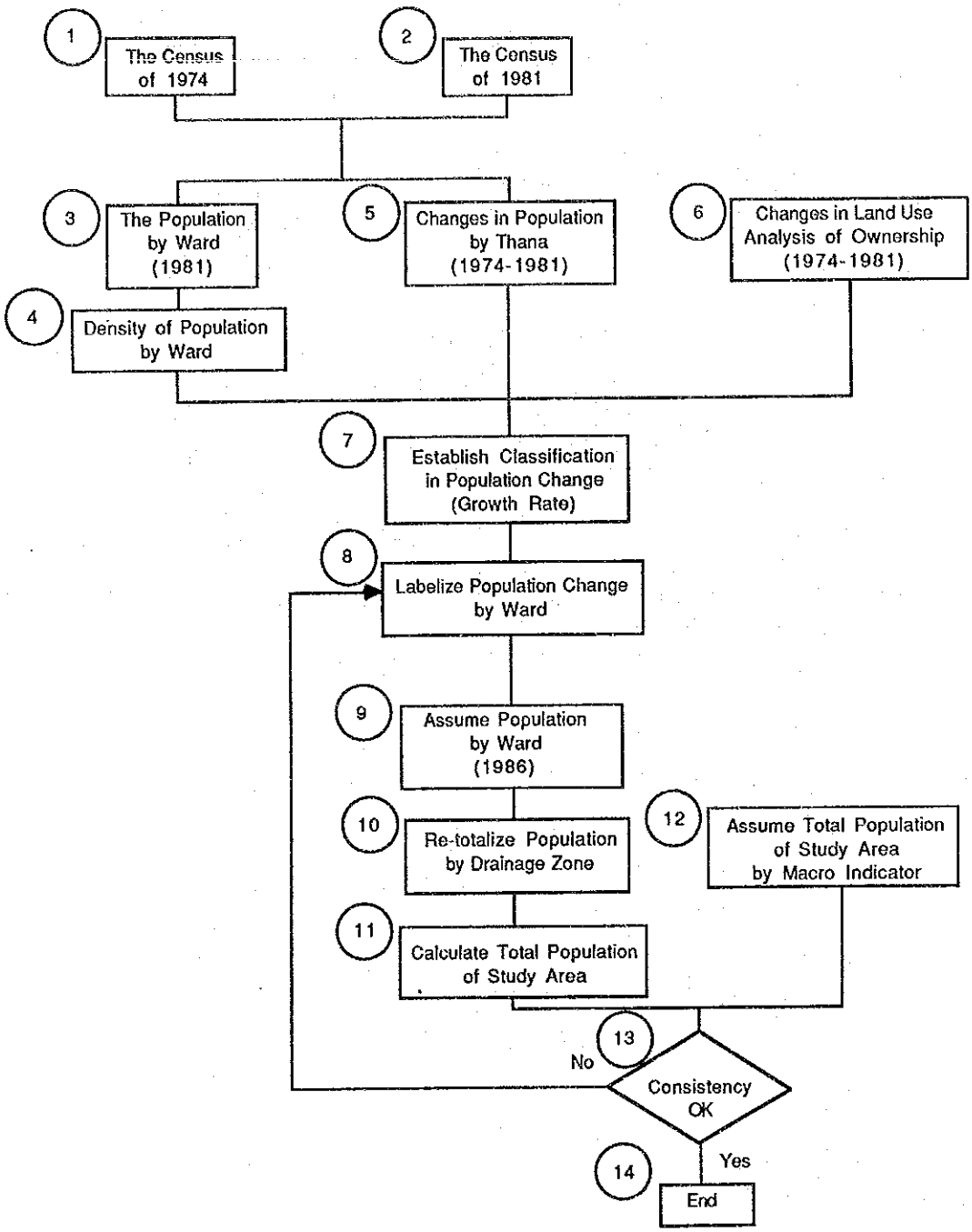

Past Population Trend of Bangladesh and Dhaka S.M.A.




Future Projection of Population in Study Area

**FIG. D.1** PAST TREND AND FUTURE PROJECTION OF POPULATION

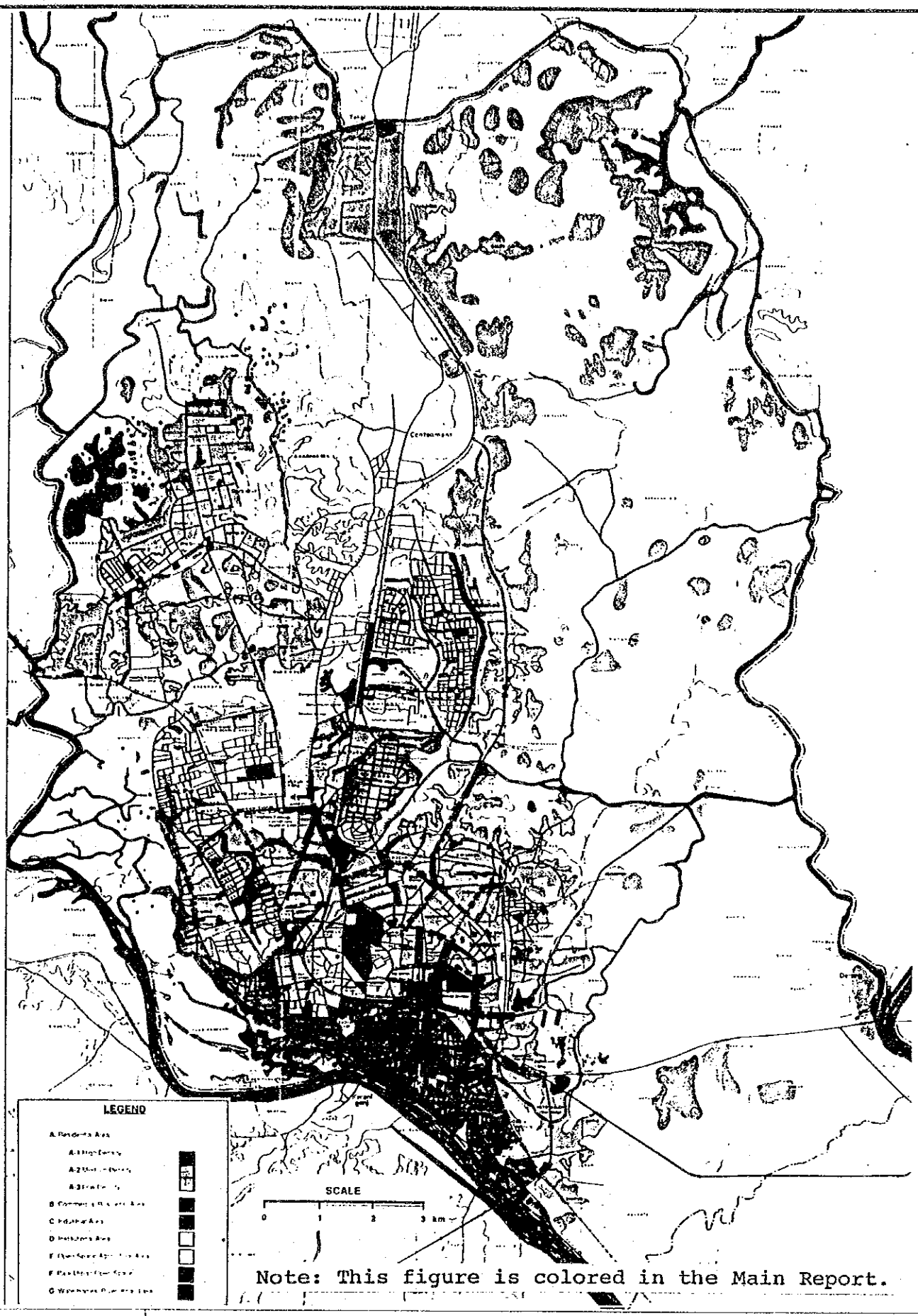
STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH




**Flowchart for Assumption of Population**

| FIG. D.2 | FLOWCHART FOR ASSUMPTION OF POPULATION |
|---|---|

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH




Note: This figure is colored in the Main Report.

**FIG. D.3** PRESENT LAND USE OF STUDY AREA IN 1986

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



JICA 1987A.D

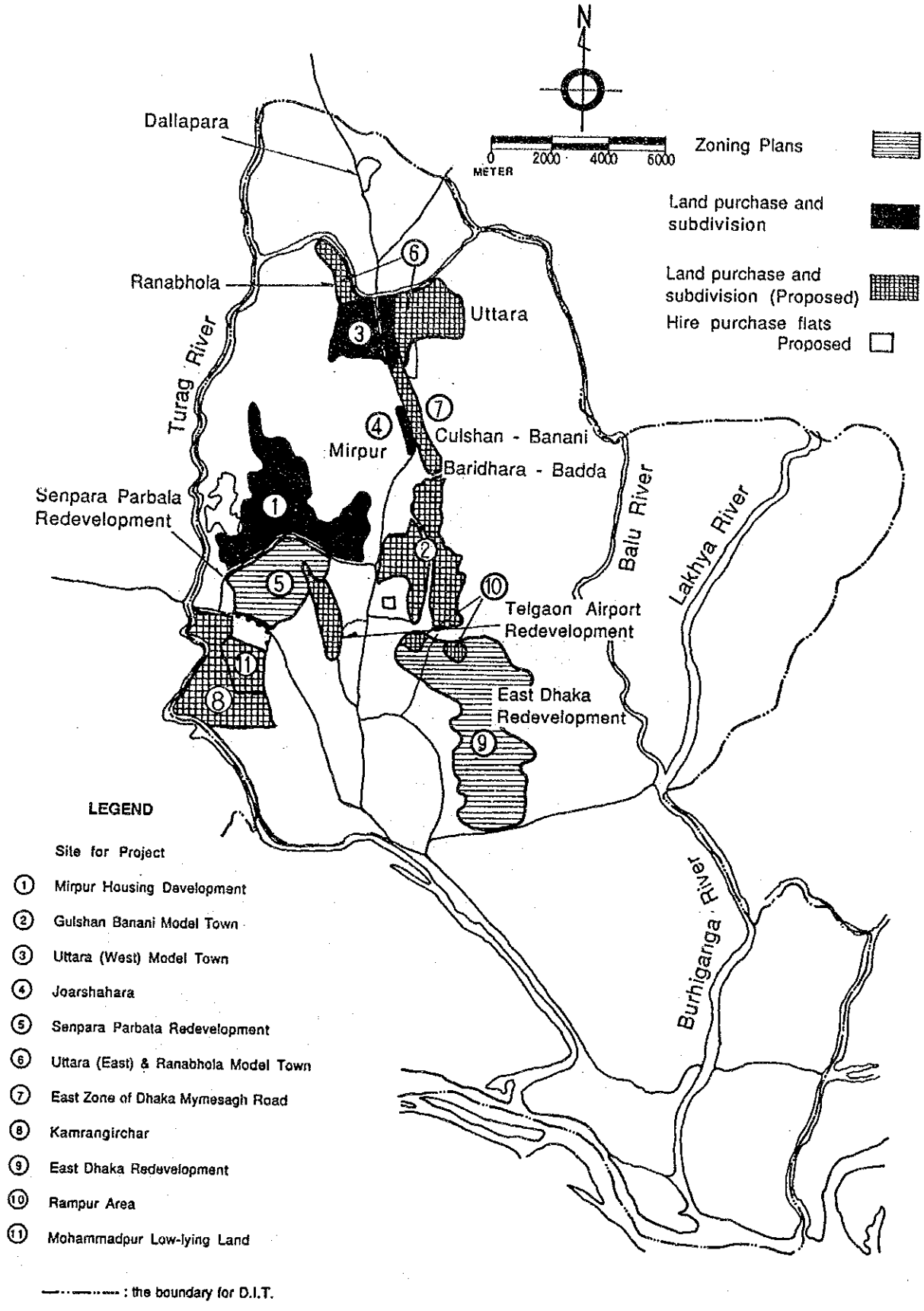



**FIG. D.4** LARGE SCALE HOUSING DEVELOPMENT PLAN

**STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH**



JICA 1987A.D

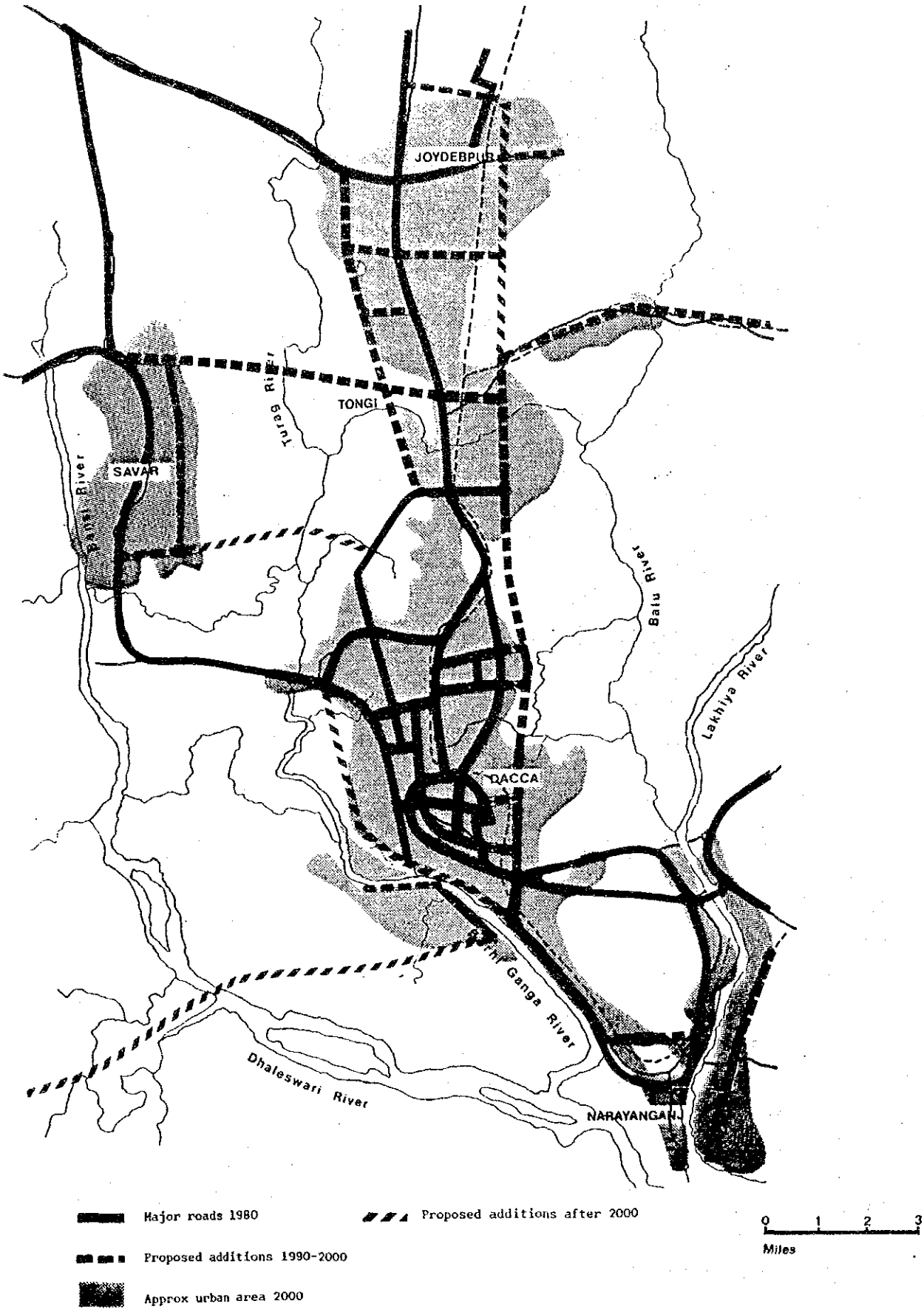
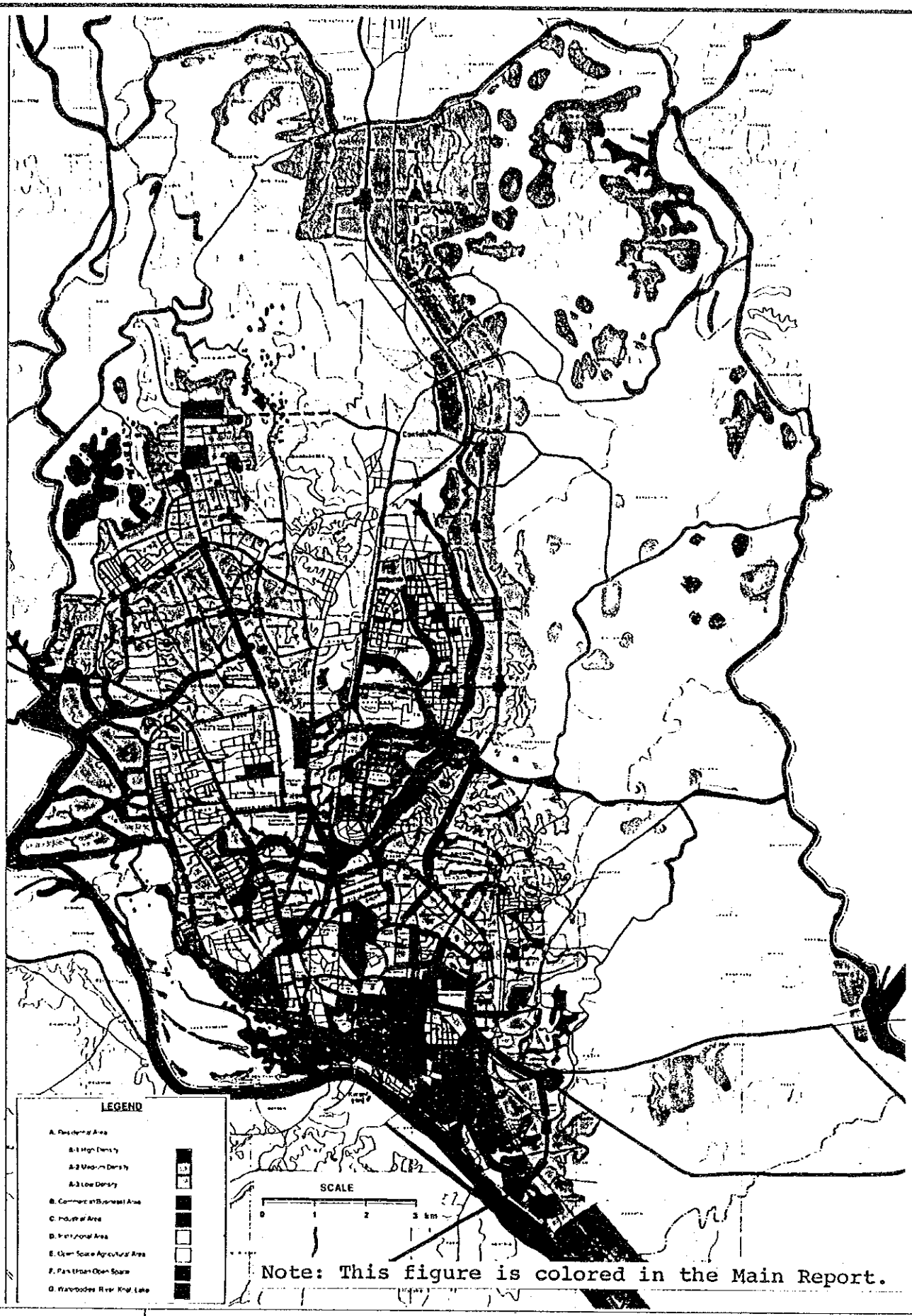



**FIG. D.5** FUTURE ROAD NETWORK PROPOSED BY DMAIDP REPORT

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



JICA 1987A.D




Note: This figure is colored in the Main Report.

**FIG. D.6** FUTURE LAND USE OF STUDY AREA IN 2000

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

# SUPPORTING REPORT E

# EXISTING DRAINAGE SYSTEM AND FACILITIES

SUPPORTING REPORT E

EXISTING DRAINAGE AND FACILITIES

## Table of Contents



## List of Tables

## List of Figures

SUPPORTING REPORT E

EXISTING DRAINAGE SYSTEM AND FACILITIES

## 1. Drainage Area and Drainage System

The Study Area is divided into 10 drainage zones. These are illustrated in Fig. E.1 and described below.

### (1) Buriganga River Bank Zone

This zone consists of a narrow strip of the built-up area at the western edge of Dhaka city and a part of the flood plain on the left side of the Buriganga River. The total area is 12.85 $km^2$. In 1986, the built-up area was 6.75 $km^2$, occupying 53% of the total area. The built-up area is projected to be 10.79 $km^2$ (84%) in 2000.

The population was estimated to be 442 x $10^3$ in 1968 and 570 x $10^3$ in 2000.

The existing built-up area is high in elevation and is not affected by the Buriganga River floods. The Buriganga River flood plain area will be developed before 2000 and its fill-up elevation is expected to be above flood water level of the river.

The area drains directly into the Buriganga River. Drainage pipes are provided in some limited areas.

### (2) Dholai Khal Zone

This zone covers the entire Old Dhaka and adjoining Gandaria areas. The total area is 7.76 $km^2$, of which 7.43 $km^2$ (96%) was already built up as of 1986.

The population is estimated to be 598 x $10^3$ in 1986 and 650 x $10^3$ in 2000.

Dholai Khal runs through the area from north to south, draining the whole area. It is 2.0 km long and approximately 30.0 m wide.

The area is divided into two (2) sub-areas according to the existing drainage system. One is the Old Dhaka area with a catchment area of 4.23 $km^2$, equivalent to 55% of the total area. Storm water is collected and conveyed through the drainage pipes to Narinda for final discharge, by pump, into Dholai Khal. The provided trunk drainage pipes are 8.8 km in total length. The pump station has design discharge capacity of 9.6 $m^3/s$.

The other system is the remaining area of 3.53 $km^2$ which drains by gravity into Dholai Khal. This sub-area is frequently affected by the flooding of the Buriganga River which backs up through Dholai Khal during flood season.

(3) Segunbagicha Khal Zone

This zone includes the most important business and Government office areas of Dhaka city.

The total area is 9.04 $km^2$, of which 6.42 $km^2$ (71%) was, in 1986, built-up area; it is expected to increase to 6.57 $km^2$ (73%) in 2000.

The population was estimated to be 307 x $10^3$ in 1986 and is expected to increase to 388 x $10^3$ in 2000.

The area consists of two (2) sub-areas: upstream high elevation area of 6.2 $km^2$ and low-lying fringe area of 2.84 $km^2$; they are distinctly separated by the Bangladesh railway. The upstream area is above 6.0 m G.T.S. in elevation and is generally free from external river floods, while the low-lying fringe area is habitually flooded.

The upstream area collects storm water by drainage pipes and drains it through Segunbagicha Khal. The low-lying fringe area drains directly to the surrounding swamp lands. Segunbagicha Khal flows a distance of 3.4 km through the center of the area. It is provided with some reserved ponds but is extremely narrow at the culverts of crossing roads and where building encroachment has taken place.

The existing drainage pipes serve a considerable part of the upstream area; the total length reaches 20.3 km.

(4) Bashabo Zone

This zone covers part of the southeast low-lying fringe area including Bashabo and Khilgaon.

The total area is 8.32 $km^2$ of which the built-up area shared 4.91 $km^2$ (59%) in 1986. This built-up area is expected to sprawl outwardly to a large extent in the future. As a result, the total built-up area will reach 5.91 $km^2$ (71%) by 2000.

The population was estimated to be 329 x $10^3$ in 1986 and is expected to increase to 616 x $10^3$ in 2000.

The elevation of the built-up area is not very high and the area frequently suffers from external river floods.

The inner part of the area is drained through tributaries of Gerani Khal, while the other parts are drained directly into the surrounding swamp lands. Drainage pipes are scarcely provided.

(5) Northeast Edge Zone

This zone consists of a narrow strip extending along the fringe of the Dhaka terrace from Begunbari Khal to Tongi Khal. The total area is 13.93 $km^2$.

Urban development is under way by fill-up in the northern part and is also expected in the other parts.

The built-up area will increase from 7.58 $km^2$ (54%) in 1986 to 10.35 $km^2$ (74%) in 2000.

The population was estimated to be 68 x $10^3$ in 1986 and is expected to be 244 x $10^3$ in 2000.

The existing built-up area is high enough to be free from external river floods and the future urban development areas are also expected to be filled up high enough.

The existing built-up area drains directly into the east low-lying areas. No drainage pipes are provided.

(6) Begunbari Knal Zone

This zone covers a large central part of Dhaka city including Dhanmondi residential and Tejgaon industrial areas.

The total area is 16.02 $km^2$ of which the built-up area was, in 1986, estimated to be 13.78 $km^2$ (86%) and will be 14.92 $km^2$ (93%) in 2000.

The population was estimated to be 481 x $10^3$ in 1986 and is expected to be 632 x $10^3$ in 2000.

Begunbari Khal flows a distance of 5.3 km from the Dhanmondi Lake to DIT Road through the center of the area. The built-up areas are comparatively high and therefore are rarely affected by external river floods, even though the flood waters back up to the inner part of the area through Begunbari Khal.

The entire area drains into Begunbari Khal from all directions, through drainage pipes in some areas and direct in other areas.

The khal is still reserved widely in the lower reaches. On the contrary, in many sections of the upper reaches, it has become narrow and shallow because of building encroachment.

(7) Gulshan-Banani Zone

This zone contains the high income residential areas of Gulshan and Banani and part of the Tajgaon industrial area.

The total area is 17.64 $km^2$ of which the built-up area was estimated to be 13.42 $km^2$ (76%) in 1986 and 14.50 $km^2$ (82%) in 2000.

The population was estimated to be 228 x $10^3$ in 1986 and is expected to be 337 x $10^3$ in 2000.

The whole area is high enough to be free from external river floods. The area is divided into many sections by the tributaries of Begunbari Khal.

The area is provided with a system of small rectangular roadside ditches. The area drains well into the tributary khals through those roadside ditches. There are no drainage pipes.

(8) Kallyanpur Zone

This zone consists of the new capital area in the southern part and medium and low density residential areas in the northern part.

The total area is 12.78 $km^2$. The built-up area is expected to increase from 7.88 $km^2$ (62%) in 1986 to 11.64 $km^2$ (91%) in 2000.

The population is estimated to be 231 x $10^3$ in 1986 and 456 x $10^3$ in 2000.

The area drains into the Turag River through natural watercourses. However, the low-lying residential areas located in the north part are vulnerable to floods of the Turag River. Drainage pipes exist only in some limited areas.

(9) North Zone

This zone contains Tongi development area, Cantonment area and Mirpur new area. The new airport is in this zone.

The total area is 31.42 $km^2$ of which 17.39 $km^2$ (55%) was the built-up area in 1986. More than 70% of the built-up area is occupied by the institutional areas including an international airport and an army base. The built-up area in 2000 is projected to be 19.34 $km^2$ (62%).

The population was estimated to be 344 x $10^3$ in 1986 and is expected to be 613 x $10^3$ in 2000.

The existing built-up areas are generally high enough to be free from external river floods except for the Katchukhet area in the southernmost part. Future urban development areas are also expected to be filled up enough except for the southernmost area.

The area drains into the Turag River through its tributaries and natural water courses. There are no drainage pipes.

(10) Turag River Bank Zone

This zone contains the western edge of Mirpur area. The total area is 7.69 $km^2$. The built-up area was estimated to be 3.17 $km^2$ (41%) in 1986 and 3.64 $km^2$ (47%) in 2000.

The population is estimated to be 119 x $10^3$ in 1986 and is expected to be 272 x $10^3$ in 2000.

The existing built-up areas are generally high and not affected by floods of the Turag River.

The area drains directly into the Turag River. There are no drainage pipes.

Land use distributions by each drainage area are as shown in Table E.1. Population by each drainage area are as shown in Table E.2.

## 2. Drainage Facilities

### 2.1 Inventory

The existing major drainage facilities are drainage pipes, khals, pump stations, and related structures of culverts and bridges.

(1) Drainage Pipe

The Study Area is provided with drainage pipes, having a total length of 109 km and a diameter ranging 0.3 m to 3.0 m. Pipe length by diameter and drainage zone are as shown in Table E.3-(1).

Begunbari Khal zone is installed with the density of 2.7 km/km$^2$, followed by Dholai Khal zone with a density of 2.5 km/km$^2$ and Segunbagicha Khal zone with a density of 2.2 km/km$^2$.

The drainage pipes are made of brick with diameters of from 1.2 to 3.0 m, and of reinforced concrete with diameters below 1.2 m. There are no drainage pipes with diameters above 3.0 m.

Location of the trunk drainage pipes is as illustrated in Fig. E.2.

(2) Khal

There are a number of khals in the Study Area totalling 53 km in length.

Major khals included are Dholai Khal, Segunbagicha Khal, Gerani Khal, and Begunbari Khal. The total length, including tributaries, and catchment areas of the above khals are as shown below:

| | Total Length (km) | Catchment Area (km2) |
|---|---|---|
| Dholai Khal | 4.0 | 16.8 |
| Segunbagicha Khal | 3.4 | 6.7 |
| Gerani Khal | 3.5 | 8.3 |
| Begunbari Khal | 6.5 | 37.7 |
| Total | 17.4 km | 69.5 $km^2$ |

Length and catchment area of the existing khals are listed by each drainage zone in Table E.3-(2).

Location of the khals is as illustrated in Fig. E.3.

(3) Pump Stations

Narinda is the only existing pump station. It drains all of Old Dhaka with a catchment area of 4.23 $km^2$. It is equipped with four (4) main pumps, each with a diameter of 1,000 mm. The total design discharge capacity is 9.6 $m^3/S$. Details are described in 2.3.

The location is as illustrated in Fig. E.3.

(4) Culverts and Bridges

Culverts and bridges are installed in the sections of the khals where roads and railways cross. Those are listed by each drainage zone in Table E.4. Their locations are as illustrated in Fig. E.3.

## 2.2 Discharge Capacity

### (1) General Drainage Pipe

Discharge capacities of major drainage pipes in the Study Area (See Fig. E.4) are estimated as shown in Table E.5-(1). The estimated capacities are also presented in terms of specific discharge. The specific discharge capacities of the existing trunk drainage pipes are mostly in the range of 1.0 $m^3/S/km^2$ to 3.0 $m^3/S/km^2$. These capacities are very small compared to the required ones of 8 $m^3/S/km^2$ to 15 $m^3/S/km^2$.

### (2) Old Dhaka Main Drainage Pipe and Other Seven (7) Major Drainage Pipes

The main drainage pipe of Old Dhaka covers a catchment area of 4.23 $km^2$ and conveys storm water a distance of 4.1 km to the Narinda pump station. The drainage pipe, with a diameter varying 1.2 to 3.0 m, is installed at an average gradient of 1/1000. The profile is as illustrated in Fig. E.6.

The estimated discharge capacity ranges from 1.0 $m^3/S$ to 12.0 $m^3/S$ according to the pipe size as shown in Table E.5-(2) and Fig. E.6. The estimated specific discharge capacities are 1.4 $m^3/S/km^2$ to 3.8 $m^3/S/km^2$, which are too small compared with the required capacities of about 7 $m^3/S/km^2$.

The seven (7) major drainage pipes shown in Fig. E.5 cover the high density area that are affected by severe floods. The discharge capacities of these pipes are to be in the range of from 0.2 $m^3/s$ to 4.5 $m^3/s$ according to the pipe sizes as shown in Table E.5-(3). The specific discharge capacities are mostly less than 3.0 $m^3/s/km^2$, which are too small compared with the required ones of 8 to 15 $m^3/s/km^2$. Figs. E.7 to E.9 show the profiles of these drainage pipes.

(3) Segunbagicha Khal

Segunbagicha Khal originating in the Ramna Lake flows a distance of 2.8 km in open channel to the Bangladesh railway crossing, where it covers a drainage area of 4.95 $km^2$.

The average gradient of stream for this stretch is estimated to be 1/5000.

The khal is crossed by roads and railways at 13 sections in this stretch. The profile is as illustrated in Fig. E.10.

The khal is provided with retarding ponds in certain places but is extremely narrow at the road and railway crossings.

The discharge capacities of these bottleneck sections are estimated as shown in Table E.5-(4) and Fig. E.10. The estimated capacities are mostly less than 5.0 $m^3/S$.

The specific discharge capacities of the sections are mostly less than 3 $m^3/S/km^2$, which are too small compared to the required ones of 6 $m^3/S/km^2$ to 8 $m^3/S/km^2$.

(4) Begunbari Khal and Paribagh Khal

The main Begunbari Khal starts from the outlet of the Dhanmondi Lake and runs through the central developed area of Dhaka city to the DIT Road crossing in the easternmost part.

The catchment area at the DIT Road crossing is 16.02 $km^2$. The total length of this stretch is 5.3 km of which 2.5 km is upstream from the New Airport Road crossing and 2.8 km downstream from the same road crossing. The khal sections are wide enough in the downstream reaches. On the other hand, those in the upstream reaches are narrowed at several places by roads and railway crossings.

The average gradient of the upstream reaches is estimated to be 1/2,500. The profile is illustrated in Fig. E.11.

Discharge capacities at the narrow sections are estimated to be mostly less than 30.0 $m^3/S$ as shown in Table E.5-(5) and Fig. E.11. The specific discharge capacities of the sections are mostly less than 5 $m^3/S/km^2$, which are small compared to the required ones of 5 $m^3/S/km^2$ to 7 $m^3/S/km^2$.

Paribagh Khal is one of the tributaries of the Begunbari Khal, which joins with the main khal between Airport road and Old Railway road crossings.

The catchment area at the confluence is 3.41 $km^2$. The total khal length is 1.0 km. The average khal width is 10 m, more or less.

The khal bed gradient is estimated to be 1/3,300 on an average. The profile is illustrated in Fig. E.12.

Discharge capacity at the narrow sections are estimated to be 1 $m^3/s$ to 3 $m^3/s$ as shown in Table E.5-(6) and Fig. E.12. The specific discharge capacities of the sections are less than 1 $m^3/s/km^2$, which are also too small compared to the required ones of 9 $m^3/s/km^2$ to 10 $m^3/s/km^2$.

(5) Dholai Khal

Dholai Khal drains an area of 16.8 $km^2$ covering B and C drainage zones. The khal stretches approximately 3.0 km from Jatrabari to the confluence with the Buriganga River. The khal is connected with Gerani Khal in the upstream, which flows in the opposite direction, ie, northerly.

The khal sections with natural trapezoidal shape are rather wide ranging (10 m to 30 m). However, the depths are shallow from 2.0 m to 4.0 m.

The average gradient of the Khal bed is estimated to be 1/10,000. The profile is illustrated in Fig. E.13.

Discharge capacities of the sections are estimated to be 3 $m^3/s$ to 50 $m^3/s$ as shown in table E.5-(7) and Fig. E.13.

## 2.3 Narinda Pump Station

### 2.3-1 General

The Narinda Pump Station drains almost the entire Old Dhaka area into the Dholai Khal. It is equipped with four (4) pumps, one (1) reservoir tank, one (1) gravity drainage channel, one (1) emergency channel, and three (3) gates.

The main features of the pump station are:

Drainage area: 4.23 $km^2$
Total design discharge capacity: 9.6 $m^3/S$
Design suction water level (L.W.L): 0.236 m G.T.S.
Target water level of suction (L.W.L): approximately 0.5 m G.T.S.
Design discharge water (H.W.L): 8.64 m G.T.S.
Required pump up head: 8.4 m for No.2 and No.3 pumps,
: 6.5 m for No.1 and No.4 pumps
Pump facilities: Vertical shaft axial flow pump, dia 1,000 mm x 4
Reservoir Tank : surface area: 4,600 $m^2$
: effective water depth: 5.636 m G.T.S.
: effective volume: 18,850 $m^3$
Gate: 2.1 m x 2.1 m, 1.9 m x 1.9 m, 3.5 m x 3.5 m
Installed year: 1975

The plan and cross section of the pump station are as illustrated in Fig. E.14 and Fig. E.15, respectively.

### 2.3-2 Operation Problems

The pump station is in operation from late May through early December every year. Daily operating hours of one (1) pump unit are limited to six (6) hours and is roughly distributed throughout each month as described below:

| Month | May | Jun. | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|
| Daily operation hour | 1 | 6 | 6 | 6 | 6 | 6 | 6 | 1 |

Annual operating hours are estimated to be approximately 1,000 - 1,500 hours per pump section.

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

(1) All the existing pumps could not be operated at the same time because the capacities of the transmission and electric board were too small in comparison to that of the motors.

This problem may have already been solved because the transmission and electric board were replaced by DPHE in late 1986.

(2) 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.

(3) 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.

(4) Gates and other equipment are damaged, impeding effective pump operation.

TABLE E.1 LAND USE OF THE STUDY AREA IN 1986 AND 2000

Unit : hectare

| Drainage Zone \ Land Use | Residential | | | Commercial | Industrial | Institutional | Open Space/ Agricultural | River, Khal Lake | Total |
|---|---|---|---|---|---|---|---|---|---|
| | High Density | Medium Density | Low Density | | | | | | |
| A. Buriganga River Bank Zone | 159 (130) | 254 (640) | 22 (10) | 29 (58) | 150 (168) | 61 (73) | 580 (161) | 30 (45) | 1,285 (1,285) |
| B. Dhulai Khal Zone | 539 (505) | 100 (113) | - (-) | 30 (60) | 24 (30) | 50 (52) | 25 (8) | 8 (8) | 776 (776) |
| C. Segunbagicha Khal Zone | - (-) | 473 (471) | 41 (41) | 25 (45) | 3 (-) | 100 (100) | 227 (207) | 35 (40) | 904 (904) |
| D. Bashabo Zone | - (-) | 425 (520) | 30 (30) | 6 (11) | - (-) | 30 (30) | 324 (220) | 17 (21) | 832 (832) |
| E. North-east Edge Zone | - (-) | 58 (406) | 694 (609) | 6 (20) | - (-) | - (-) | 630 (320) | 5 (38) | 1,393 (1,393) |
| F. Begunbari Khal Zone | 56 (56) | 863 (885) | 148 (148) | 33 (83) | 100 (142) | 178 (178) | 186 (64) | 38 (46) | 1,602 (1,602) |
| G. Gulshan-Banani Zone | - (-) | 115 (25) | 550 (405) | 26 (60) | 105 (105) | 546 (555) | 352 (244) | 70 (70) | 1,764 (1,764) |
| H. Kallyanpur Zone | - (-) | 280 (875) | 275 (-) | 6 (13) | - (-) | 227 (276) | 482 (102) | 8 (12) | 1,278 (1,278) |
| I. North Zone | - (-) | 255 (560) | 190 (10) | 5 (10) | 24 (24) | 1,265 (1,330) | 1,368 (1,168) | 35 (40) | 3,142 (3,142) |
| J. Turag River Bank Zone | - (-) | 228 (290) | 37 (5) | 2 (3) | 10 (12) | 40 (44) | 442 (403) | 10 (2) | 769 (769) |
| Total | 754 (691) | 3,051 (5,085) | 1,987 (1,258) | 168 (363) | 416 (481) | 2,497 (2,638) | 4,616 (2,897) | 256 (332) | 13,745 (13,745) |

Note : The figures in parentheses show the land use area in the year 2000.

TABLE E-2 POPULATION OF THE STUDY AREA IN 1986 AND 2000

| Drainage Zone | Area (ha) | 1986 | | 2000 | |
|---|---|---|---|---|---|
| | | Population ($x10^3$ person) | Density per hectare | Population ($x10^3$ person) | Density per hectare |
| A. Buriganga River Bank Zone | 1,285 | 442.3 | 344 | 570.3 | 444 |
| B. Dhulai Khal Zone | 776 | 597.9 | 770 | 649.6 | 837 |
| C. Segunbagicha Khal Zone | 904 | 306.9 | 339 | 388.4 | 430 |
| D. Bashabo Zone | 832 | 329.3 | 396 | 615.6 | 740 |
| E. North-East Edge Zone | 1,393 | 67.8 | 49 | 244.0 | 175 |
| F. Begunbari Khal Zone | 1,602 | 480.9 | 300 | 631.8 | 394 |
| G. Gulshan-Banani Zone | 1,764 | 227.9 | 129 | 337.0 | 191 |
| H. Kallyanpur Zone | 1,278 | 230.7 | 181 | 455.6 | 356 |
| I. North Zone | 3,142 | 343.5 | 109 | 613.3 | 195 |
| J. Turag River Bank Zone | 769 | 119.3 | 155 | 271.7 | 353 |
| Total | 13,745 | 3,146.5 | 229 | 4,777.3 | 348 |

TABLE E.3-(1) EXISTING MAJOR STRUCTURES (1)
(Drainage Pipes-DPHE)

| Zone | | Pipe Length (Km) | Remarks |
|---|---|---|---|
| A | (A=12.85 $Km^2$ ) | 8.76 | |
| B | (A= 7.76 " ) | 19.71 | |
| C | (A= 9.04 " ) | 20.28 | |
| D | (A= 8.32 " ) | 2.83 | |
| E | (A=13.93 " ) | - | |
| F | (A=16.02 " ) | 42.53 | |
| G | (A=17.64 " ) | 9.82 | |
| H | (A=12.78 " ) | 5.29 | |
| I | (A=31.42 " ) | - | |
| J | (A= 7.69 " ) | - | |
| Total | (A=137.45 $Km^2$) | 109.22 Km | |

| Pipe Size | Pipe Length | Remarks |
|---|---|---|
| 10'-0" Dia | 2,900 ft | |
| 9'-0" | 2,124 | |
| 8'-6" | 1,000 | |
| 8'-0" | 1,100 | |
| 7'-6" | 1,300 | |
| 7'-0" | 3,800 | |
| 6'-6" | 1,800 | |
| 6'-0" | 8,970 | |
| 5'-6" | 9,540 | |
| 5'-0" | 12,660 | |
| 4'-6" | 13,950 | |
| 4'-0" | 26,700 | |
| 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 | 358,454 ft. = 67.88 miles = 109.22 Km | |

TABLE E.3-(2) EXISTING MAJOR STRUCTURES (2)
(OPEN CHANNEL-KHAL)

| Zone | No. | Name of Khal | Drainage Area ($Km^2$) | Length (Km) | Remarks |
|---|---|---|---|---|---|
| A | 1 | Royer Bazar | 0.78 | 0.30 | |
| | 2 | Mahammadpur | 15.50 | 3.60 | |
| | Sub-Total | | - | 3.90 | |
| B | 3 | Dholai | 7.76 | 2.00 | |
| | 4 | Gandaria | 2.47 | 1.90 | |
| | Sub-Total | | - | 3.90 | |
| C | 5 | Segunbagicha | 6.65 | 3.40 | |
| | 6 | - | 1.25 | 0.50 | |
| | 7 | Dholai | 9.04 | 2.00 | |
| | Sub-Total | | - | 5.90 | |
| D | 8 | Khilgaon | 2.76 | 3.10 | |
| | 9 | Kamalapur | 0.94 | 1.50 | |
| | 10 | Gerani | 8.32 | 0.50 | (D zone only) |
| | Sub-Total | | - | 5.10 | |
| E | 11 | Begunbari | 37.70 | 1.20 | |
| | Sub-Total | | - | 1.20 | |
| F | 12 | Begunbari | 16.02 | 5.30 | |
| | 13 | Paribagh | 3.41 | 1.00 | |
| | 14 | Dhanmondi Lake | 3.36 | 2.90 | |
| | Sub-Total | | - | 9.20 | |
| G | 15 | Gulshan Lake | 5.26 | 4.90 | |
| | 16 | Banani-1 | 6.39 | 4.10 | |
| | 17 | Banani-2 | 1.80 | 1.50 | |
| | 18 | Mahakhali-1 | 5.99 | 3.00 | |
| | 19 | Mahakhali-2 | 0.85 | 0.80 | |
| | 20 | Mahakhali-3 | 1.96 | 1.40 | |
| | Sub-Total | | - | 15.70 | |
| H | 21 | Kallyanpur | 9.21 | 1.00 | |
| | 22 | Gabtati | 0.90 | 1.20 | |
| | 23 | Amin Bazar | 0.60 | 0.70 | |
| | Sub-Total | | - | 2.90 | |
| I | 24 | Kachukhet | 31.42 | 5.00 | |
| | Sub-Total | | - | 5.00 | |
| J | - | - | - | - | |
| | Total | - | - | 52.80 Km | |

TABLE E.4-(1) EXISTING MAJOR STRUCTURES
(BOX CULVERT/BRIDGE)

| ZONE | NO. | TYPE | OPENING | | INVERT ELEVATION | REMARKS |
|---|---|---|---|---|---|---|
| | | | WIDTH | HEIGHT | | |
| | | | m | m | m | |
| A | A1 | CULVERT | 2.20 | 2.35 | 3.16 | |
| B | B1 | BRIDGE | 37.30 | 8.80 | 0.62 | |
| | B2 | " | 18.00 | 7.81 | 1.51 | |
| | B3 | " | 16.40 | 6.91 | 1.99 | |
| | B4 | " | 2x19.0 | 7.20 | 2.29 | |
| | B5 | " | 45.00 | 8.54 | 2.26 | |
| | B6 | " | 10.30 | 6.09 | 2.71 | |
| | B7 | " | 3.70 | 1.32 | 2.75 | |
| C | C1 | BOX CULVERT | 2x4.80 | 5.22 | 1.86 | |
| | C2 | BRIDGE | 5.60 | 3.88 | 2.20 | |
| | C3 | CONDUCT PIPE | 2xØ 2.2 | Ø 2.20 | 1.70 | |
| | C4 | BRIDGE | 10.60 | 4.64 | 2.16 | |
| | C5 | CONDUCT PIPE | Ø 2.79 | Ø 2.79 | 0.81 | |
| | C6 | " | Ø 2.60 | Ø 2.60 | 2.10 | |
| | C7 | " | Ø 1.04 | Ø 1.04 | 3.47 | |
| | C8 | " | Ø 1.75 | Ø 1.75 | 2.95 | |
| | C9 | BOX CULVERT | 2.50 | 1.72 | 4.28 | |
| | C10 | " | 3.10 | 2.53 | 3.46 | |
| | C11 | CONDUIT | 2xØ .80 | - | 4.50 | |
| | C12 | BOX CULVERT | 3x1.00 | 1.13 | 4.47 | |
| | C13 | " | 1.60 | 1.94 | 4.06 | |
| | C14 | " | 2.00 | 1.05 | 4.85 | |
| | C15 | " | 2.80 | 2.10 | 3.50 | |
| | C16 | BRIDGE | 2.90 | 1.55 | 4.93 | |
| | C17 | " | 6.00 | 5.00 | 1.40 | |
| D | D1 | BOX CULVERT | 3.40 | 3.56 | 2.09 | |
| | D2 | " | 4.50 | 2.40 | 2.93 | |
| | D3 | " | 5.40 | 2.28 | 3.42 | |
| | D4 | " | 4.60 | 2.79 | 2.60 | |
| | D5 | " | 3.50 | 3.10 | 3.91 | |
| | D6 | " | 4.20 | 2.99 | 3.51 | |
| | D7 | " | 3.00 | 2.25 | 4.35 | |
| | D8 | " | 4.50 | 3.40 | 3.07 | |
| | D9 | " | 1.60 | 1.84 | 4.65 | |
| | D10 | " | 1.80 | 2.23 | 4.50 | |
| | D11 | " | 1.20 | 0.69 | 5.48 | |
| | D12 | " | 1.80 | 0.67 | 5.73 | |
| | D13 | " | 1.80 | 1.30 | 5.09 | |
| | | | 3.00 | - | 4.48 | |
| | D14 | " | 3.50 | 3.26 | 2.64 | |
| | D15 | " | 4.60 | 3.48 | 3.42 | |
| | D16 | " | 3.00 | 1.62 | 4.48 | |
| | D17 | BRIDGE | 11.40 | 4.56 | 0.88 | |

TABLE E.4-(2) EXISTING MAJOR STRUCTURES (Contd.)
(BOX CULVERT/BRIDGE)

| ZONE | NO. | TYPE | OPENING | | INVERT ELEVATION | REMARKS |
|---|---|---|---|---|---|---|
| | | | WIDTH | HEIGHT | | |
| | | | m | m | m | |
| E | - | - | - | - | - | |
| F | F1 | WOODEN BRIDGE | 35.70 | 8.5 | - 0.28 | |
| | F2 | CULVERT | 5.70 | 5.70 | 1.27 | |
| | F3 | " | 6.80 | 5.70 | 1.06 | |
| | F4 | " | 6.10 | 5.50 | 1.40 | |
| | F5 | BRIDGE | 12.20 | 4.35 | 1.27 | |
| | F6 | CULVERT | 6.00 | 3.35 | 2.53 | |
| | F7 | BRIDGE | 6.85 | 2.60 | 3.62 | |
| | F8 | " | 36.60 | 4.10 | 1.70 | |
| | F9 | CULVERT | 2.50 | 2.76 | 4.28 | |
| | F10 | " | 3.00 | 2.80 | 4.91 | |
| | F11 | BRIDGE | 3x7.60 | 3.63 | 2.37 | |
| | F12 | CONDUIT PIPE | 0.80 | 1.45 | 4.60 | |
| | F13 | BRIDGE | 2.80 | 3.60 | 4.60 | |
| | F14 | CULVERT | 2.80 | 3.34 | 5.16 | |
| | F15 | CONDUIT PIPE | 2.00 | 1.75 | 4.69 | |
| G | G1 | BOX CULVERT | 2x1.1 | 2.79 | 1.01 | |
| | G2 | " | 3x4.5 | 5.70 | 0.25 | |
| | G3 | CULVERT | 4.20 | 3.51 | 3.59 | |
| | G4 | BOX CULVERT | 3x3.50 | 4.90 | 0.44 | |
| | G5 | " | 2x3.30 | 5.24 | 0.76 | |
| | G6 | BRIDGE | 7.00 | 4.91 | 1.29 | |
| | G7 | CULVERT | 2.90 | 2.30 | 3.80 | |
| | G8 | " | 3.00 | 2.08 | 5.02 | |
| | G9 | " | 3.10 | 1.82 | 4.36 | |
| | G10 | " | 3.00 | 2.65 | 4.50 | |
| | G11 | " | 7.20 | 4.86 | 1.50 | |
| | G12 | " | 3.00 | 4.74 | 2.13 | |
| | G13 | PIPE | Ø 2.54 | | 2.94 | |
| | G14 | R.C.C. PIPE | Ø 1.50 | | 2.08 | |
| | G15 | " | Ø 1.5 | | 4.16 | |
| H | H1 | BRIDGE | 6.0 | 5.28 | 1.38 | |
| | H2 | STEEL PIPE | Ø 2.57 | | 1.00 | |
| | H3 | R.C.C. PIPE | Ø 0.80 | | 1.87 | |
| I | I1 | CULVERT | 3.30 | 2.35 | 4.30 | |
| | I2 | R.C.C. PIPE | 2x Ø 2.00 | | 3.02 | |
| J | - | - | - | - | - | |

TABLE E.5-(1) SUMMARY OF DISCHARGE CAPACITIES OF EXISTING MAJOR DRAINAGE PIPES

n = 0.015

| Zone | No. | Drainage Area | Size | Capacity | Specific Capacity | Remarks |
|---|---|---|---|---|---|---|
| | | $Km^2$ | mm DIA | $m^3/S$ | $m^3/S/Km^2$ | |
| A | S1 | 0.22 | 2,100 | 3.45 | 15.7 | |
| | S2 | 0.50 | 760 | 0.24 | 0.5 | |
| | S3 | 0.22 | 900 | 0.39 | 1.8 | |
| | S4 | 0.18 | 760 | 0.24 | 1.3 | |
| | S5 | 0.38 | 900 | 0.85 | 2.2 | |
| | S6 | 0.41 | 1,350 | 1.73 | 4.2 | |
| B | S7 | 4.12 | 3,000 | 12.30 | 3.0 | Old Dhaka |
| C | S8 | 1.50 | 1,200 | 0.95 | 0.63 | |
| | S9 | 1.40 | 1,500 | 1.95 | 0.4 | |
| | S10 | 0.54 | 1,650 | 1.82 | 3.4 | |
| | S11 | 1.50 | 1,350 | 1.73 | 1.15 | |
| D | S12 | 0.81 | 1,650 | 1.82 | 2.2 | |
| E | - | - | - | - | - | |
| F | S13 | 4.25 | 1,800 | 4.45 | 1.0 | |
| | S14 | 1.80 | 1,800 | 3.86 | 2.14 | |
| | S15 | 0.65 | 1,200 | 0.77 | 1.2 | |
| | S16 | 0.67 | 900 | 0.39 | 0.6 | |
| | S17 | 1.45 | 2,280 | 4.20 | 2.9 | |
| G | S18 | 0.73 | 760 | 0.24 | 0.3 | |
| H | S19 | 2.78 | 2,350 | 4.45 | 1.6 | |
| I | - | - | - | - | - | |
| J | - | - | - | - | - | |

TABLE E.5-(2) DETAILED DISCHARGE CAPACITIES OF EXISTING OLD DHAKA DRAINAGE PIPES

| Pipe Size mm | Drainage Area $Km^2$ | $\frac{1}{n} I^{\frac{1}{2}}$ | A | $R^{2/3}$ | $\bar{V}$ | Q | q |
|---|---|---|---|---|---|---|---|
| Ø 3,000 | 4.12 | 2.108 | 7.07 | 0.826 | 1.74 | 12.3 | 2.99 |
| Ø 2,700 | 2.43 | 2.108 | 5.73 | 0.7699 | 1.62 | 9.3 | 3.83 |
| Ø 1,650 | 1.70 | 2.108 | 2.14 | 0.554 | 1.17 | 2.5 | 1.47 |
| Ø 1,575 | 0.60 | 2.108 | 1.95 | 0.538 | 1.133 | 2.2 | 3.67 |
| Ø 1,500 | - | 2.108 | 1.77 | 0.521 | 1.10 | 1.9 | - |
| Ø 1,350 | - | 2.108 | 1.43 | 0.485 | 1.022 | 1.46 | - |
| Ø 1,275 | - | 2.108 | 1.28 | 0.467 | 0.985 | 1.26 | - |
| Ø 1,200 | - | 2.108 | 1.13 | 0.448 | 0.945 | 1.07 | - |

Note : n = 0.015

I = 1/1,000

TABLE E.5-(3) DETAILED DISCHARGE CAPACITIES OF 7 EXISTING MAJOR DRAINAGE PIPES

| Zone | No. | Drainage Area ($km^2$) | Pipe Size Dia. (mm) | $\frac{1}{n} I^{1/2}$ | A ($m^2$) | $R^{2/3}$ (m) | $\bar{V}$ (m/S) | Q ($m^3$/S) | q ($m^3$/S/$km^2$) |
|---|---|---|---|---|---|---|---|---|---|
| B | S5 | 0.38 | 900 | 3.590 | 0.64 | 0.371 | 1.33 | 0.85 | 2.24 |
| | | 0.18 | 750 | 3.590 | 0.44 | 0.327 | 1.17 | 0.51 | 2.83 |
| | S6 | 0.41 | 1,350 | 2.494 | 1.43 | 0.484 | 1.21 | 1.73 | 4.22 |
| | | 0.15 | 1,200 | 2.494 | 1.13 | 0.448 | 1.12 | 1.27 | 8.47 |
| C | S8 | 1.5 | 1,200 | 1.886 | 1.13 | 0.448 | 0.84 | 0.95 | 0.63 |
| | | 1.0 | 900 | 1.886 | 0.64 | 0.371 | 0.70 | 0.44 | 0.44 |
| | | 0.8 | 750 | 1.886 | 0.44 | 0.327 | 0.62 | 0.27 | 0.34 |
| | | 0.5 | 600 | 1.886 | 0.28 | 0.280 | 0.53 | 0.15 | 0.30 |
| | S9 | 1.4 | 1,500 | 2.108 | 1.77 | 0.521 | 1.10 | 1.95 | 1.39 |
| | | 1.1 | 1,350 | 2.108 | 1.43 | 0.484 | 1.02 | 1.49 | 1.35 |
| | | 0.6 | 1,200 | 2.108 | 1.13 | 0.448 | 0.94 | 1.06 | 1.77 |
| | | 0.3 | 900 | 2.108 | 0.64 | 0.226 | 0.48 | 0.31 | 1.03 |
| | S11 | 1.50 | 1,350 | 2.494 | 1.43 | 0.484 | 1.21 | 1.73 | 1.15 |
| | | 1.05 | 1,200 | 2.494 | 1.13 | 0.448 | 1.12 | 1.27 | 1.21 |
| | | 0.85 | 1,050 | 2.494 | 0.87 | 0.411 | 1.03 | 0.90 | 1.06 |
| | | 0.40 | 600 | 2.494 | 0.28 | 0.281 | 0.70 | 0.20 | 0.50 |
| F | S13 | 4.25 | 1,800 | 2.981 | 2.54 | 0.587 | 1.75 | 4.45 | 1.05 |
| | | 2.20 | 1,200 | 2.981 | 1.13 | 0.448 | 1.34 | 1.51 | 0.69 |
| | | 1.85 | 900 | 2.981 | 0.64 | 0.371 | 1.11 | 0.71 | 0.38 |
| | S14 | 1.80 | 1,800 | 2.582 | 2.54 | 0.587 | 1.52 | 3.86 | 2.14 |
| | | 1.65 | 1,600 | 2.582 | 2.01 | 0.543 | 1.40 | 2.81 | 1.70 |
| | | 1.45 | 1,500 | 2.582 | 1.77 | 0.521 | 1.35 | 2.39 | 1.65 |

TABLE E.5-(4) DISCHARGE CAPACITY OF EXISTING SEGUNBAGICHA KHAL

(n = 0.030)

| Distance Km | Drainage Area $Km^2$ | I | $\frac{1}{n} I^{1/2}$ | A ($m^2$) | P (m) | $R^{1/2}$ (m) | $\bar{V}$ (m/S) | Q ($m^3$/S) | q ($m^3$/S/$Km^2$) |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 4.95 | 1/5,000 | 0.471 | 12.86 | 11.60 | 1.070 | 0.50 | 6.49 | 1.3 |
| 0.06 | 4.95 | " | " | 33.60 | 23.60 | 1.266 | 0.60 | 20.03 | 4.0 |
| 0.10 | 4.95 | " | " | 16.46 | 10.50 | 1.349 | 0.64 | 10.46 | 2.1 |
| 0.16 | 4.90 | " | " | 19.10 | 12.70 | 1.313 | 0.62 | 11.81 | 2.4 |
| 0.62 | 4.55 | " | " | POND | | | | | - |
| 0.70 | 4.01 | " | " | 7.60 | 13.82 | 0.671 | 0.32 | 2.40 | 0.6 |
| 0.74 | 3.50 | " | " | POND | | | | | - |
| 0.80 | 3.43 | " | " | 34.45 | 17.10 | 1.595 | 0.75 | 25.9 | 7.6 |
| 0.85 | 3.40 | " | " | 30.93 | 17.45 | 1.465 | 0.67 | 21.3 | 6.3 |
| 1.10 | 3.20 | " | " | 6.16 | 8.80 | 0.788 | 0.37 | 2.29 | 0.7 |
| 1.32 | 3.10 | " | " | 5.31 | 8.17 | 0.750 | 0.35 | 1.88 | 0.6 |
| 1.40 | 3.10 | " | " | 19.05 | 13.55 | 1.255 | 0.59 | 11.30 | 3.6 |
| 1.55 | 3.00 | " | " | 1.80 | 6.70 | 0.416 | 0.20 | 0.35 | 0.1 |
| 1.60 | 2.90 | " | " | 5.20 | 6.70 | 0.78 | 0.37 | 1.90 | 0.7 |
| 1.69 | 2.80 | " | " | 2.27 | 5.34 | 0.565 | 0.27 | 0.60 | 0.2 |
| 1.90 | 2.75 | " | " | 4.81 | 5.90 | 0.873 | 0.41 | 1.98 | 0.7 |
| 2.10 | 2.65 | " | " | 3.50 | 5.20 | 0.768 | 0.36 | 1.27 | 0.5 |
| 2.18 | 2.60 | " | " | 4.65 | 6.10 | 0.834 | 0.39 | 1.83 | 0.7 |
| 2.28 | 2.59 | " | " | 10.12 | 13.80 | 0.813 | 0.38 | 3.88 | 1.5 |
| 2.40 | 1.82 | " | " | 0.77 | 4.40 | 0.313 | 0.15 | 0.11 | 0.1 |
| 2.51 | 1.80 | " | " | 3.30 | 9.60 | 0.490 | 0.231 | 0.76 | 0.4 |
| 2.57 | 1.50 | " | " | 8.16 | 8.10 | 1.005 | 0.473 | 3.86 | 2.6 |
| 2.81 | 1.32 | " | " | 2.96 | 5.30 | 0.678 | 0.319 | 0.95 | 0.7 |
| 3.11 | - | " | " | 2.07 | 4.00 | 0.645 | 0.30 | 0.63 | - |

TABLE E.5-(5) DISCHARGE CAPACITY OF EXISTING BEGUNBARI KHAL

(n = 0.030)

| Distance Km | Drainage Area $Km^2$ | I | $\frac{1}{n} I^{1/2}$ | A ($m^2$) | P (m) | $R^{1/2}$ (m) | $\bar{V}$ (m/S) | Q ($m^3$/S) | q ($m^3$/S/$Km^2$) |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | - | Level | - | - | - | - | - | - | - |
| 0.51 | - | " | - | - | - | - | - | - | - |
| 1.20 | - | " | - | - | - | - | - | - | - |
| 1.38 | - | " | - | - | - | - | - | - | - |
| 1.85 | - | " | - | - | - | - | - | - | - |
| 2.31 | - | " | - | - | - | - | - | - | - |
| 2.80 | - | " | - | - | - | - | - | - | - |
| 3.50 | 9.80 | 1/2,500 | 0.6667 | 23.66 | 14.0 | 1.419 | 0.95 | 22.38 | 2.3 |
| 3.71 | - | " | " | - | - | - | - | - | - |
| 3.90 | 9.50 | " | " | 29.58 | 15.50 | 1.539 | 1.03 | 30.34 | 3.2 |
| 3.99 | - | " | " | - | - | - | - | - | - |
| 4.41 | - | " | " | - | - | - | - | - | - |
| 4.49 | 8.93 | " | " | 25.62 | 14.5 | 1.462 | 0.974 | 24.96 | 2.8 |
| 4.60 | 5.54 | " | " | 53.07 | 29.6 | 1.476 | 0.984 | 52.22 | 9.4 |
| 4.95 | - | " | " | - | - | - | - | - | - |
| 5.29 | 4.44 | " | " | 20.1 | 12.7 | 1.358 | 0.905 | 18.20 | 4.1 |
| 5.35 | - | " | " | - | - | - | - | - | - |
| 6.31 | 3.36 | " | " | 18.29 | 12.20 | 1.310 | 0.87 | 16.0 | 4.8 |

TABLE E.5-(6) DISCHARGE CAPACITY OF EXISTING PARIBAGH KHAL

(n = 0.030)

| Distance Km | Drainage Area $Km^2$ | I | $\frac{1}{n} I^{1/2}$ | A ($m^2$) | P (m) | $R^{1/2}$ (m) | $\bar{V}$ (m/S) | Q ($m^3/S$) | q ($m^3/S/Km^2$) |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 3.41 | 1/3300 | 0.5803 | 6.27 | 7.2 | 0.912 | 0.529 | 3.32 | 0.97 |
| 0.14 | 3.36 | " | " | 3.36 | 5.2 | 0.747 | 0.433 | 1.45 | 0.43 |
| 0.20 | 3.11 | " | " | 1.68 | 4.0 | 0.561 | 0.326 | 0.55 | 0.18 |
| 4.32 | 2.88 | " | " | 1.90 | 4.5 | 0.563 | 0.327 | 0.62 | 0.22 |

TABLE E.5-(7) DISCHARGE CAPACITY OF EXISTING DHOLAI KHAL

(n = 0.030)

| Distance Km | Drainage Area $Km^2$ | I | $\frac{1}{n} I^{1/2}$ | A ($m^2$) | P (m) | $R^{1/2}$ (m) | $\bar{V}$ (m/S) | Q ($m^3/S$) | q ($m^3/S/Km^2$) |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 16.80 | 1/10000 | 0.3333 | 44 | 30 | 1.291 | 0.430 | 18.92 | 1.13 |
| 0.32 | 16.75 | " | " | 84 | 32 | 1.903 | 0.634 | 53.26 | 3.18 |
| 0.48 | 16.70 | " | " | 74 | 30 | 1.826 | 0.609 | 45.07 | 2.70 |
| 0.63 | 16.60 | " | " | 44 | 20 | 1.692 | 0.564 | 24.82 | 1.50 |
| 0.85 | 16.50 | " | " | 49 | 26 | 1.526 | 0.509 | 24.94 | 1.51 |
| 1.01 | | | | POND | | | | | |
| 1.20 | 12.26 | | " | 43 | 32 | 1.218 | 0.406 | 17.46 | 1.42 |
| 1.35 | 12.26 | " | " | 72 | 36 | 1.587 | 0.529 | 38.09 | 3.11 |
| 1.49 | 11.91 | " | " | 36 | 20 | 1.480 | 0.493 | 17.75 | 1.49 |
| 1.66 | 9.39 | " | " | 34 | 22 | 1.337 | 0.446 | 15.16 | 1.61 |
| 1.71 | 9.39 | " | " | 55 | 34 | 1.378 | 0.459 | 25.25 | 2.69 |
| 1.88 | 9.14 | " | " | 26 | 18 | 1.278 | 0.426 | 11.08 | 1.21 |
| 2.06 | 9.04 | " | " | 13 | 12 | 1.055 | 0.352 | 4.58 | 0.51 |
| 2.23 | 8.89 | " | " | 22 | 17 | 1.188 | 0.396 | 8.71 | 0.98 |
| 3.29 | 8.74 | " | " | 9 | 10 | 0.932 | 0.311 | 2.80 | 0.32 |

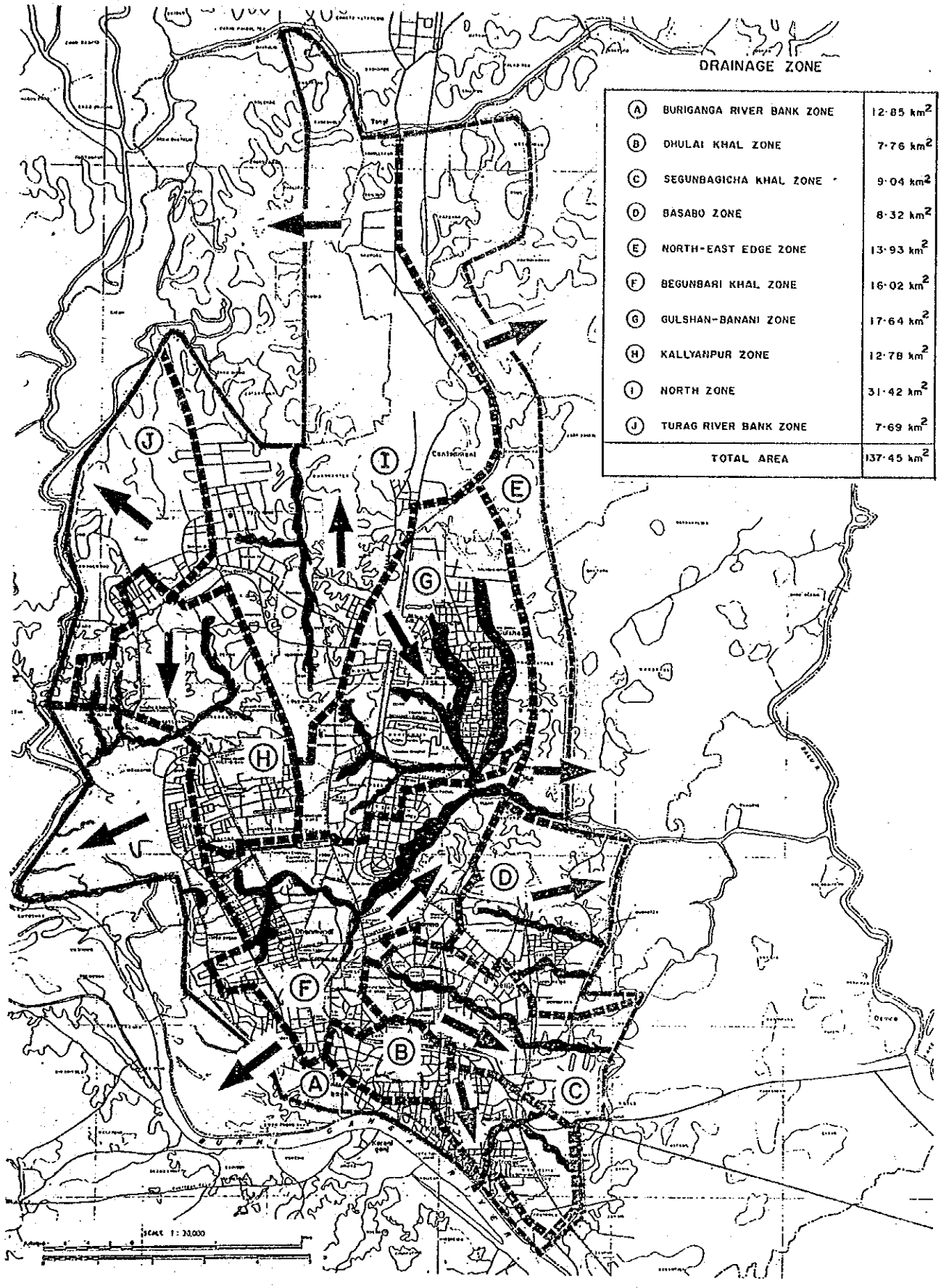



**FIG. E.1** DRAINAGE ZONES

**STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH**



JICA 1987A.D

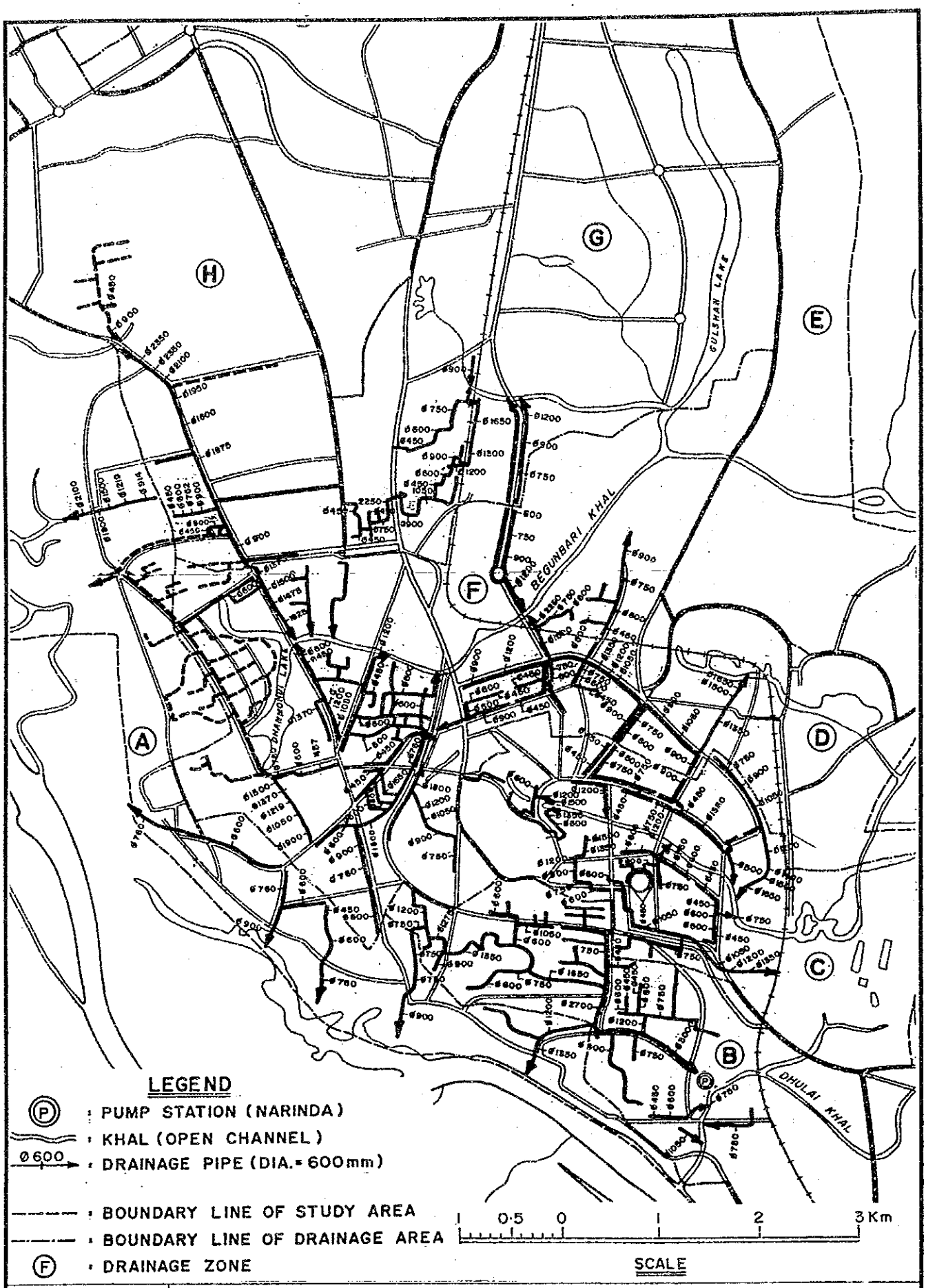



**FIG. E.2** EXISTING DRAINAGE FACILITIES (1)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



JICA 1987A.D

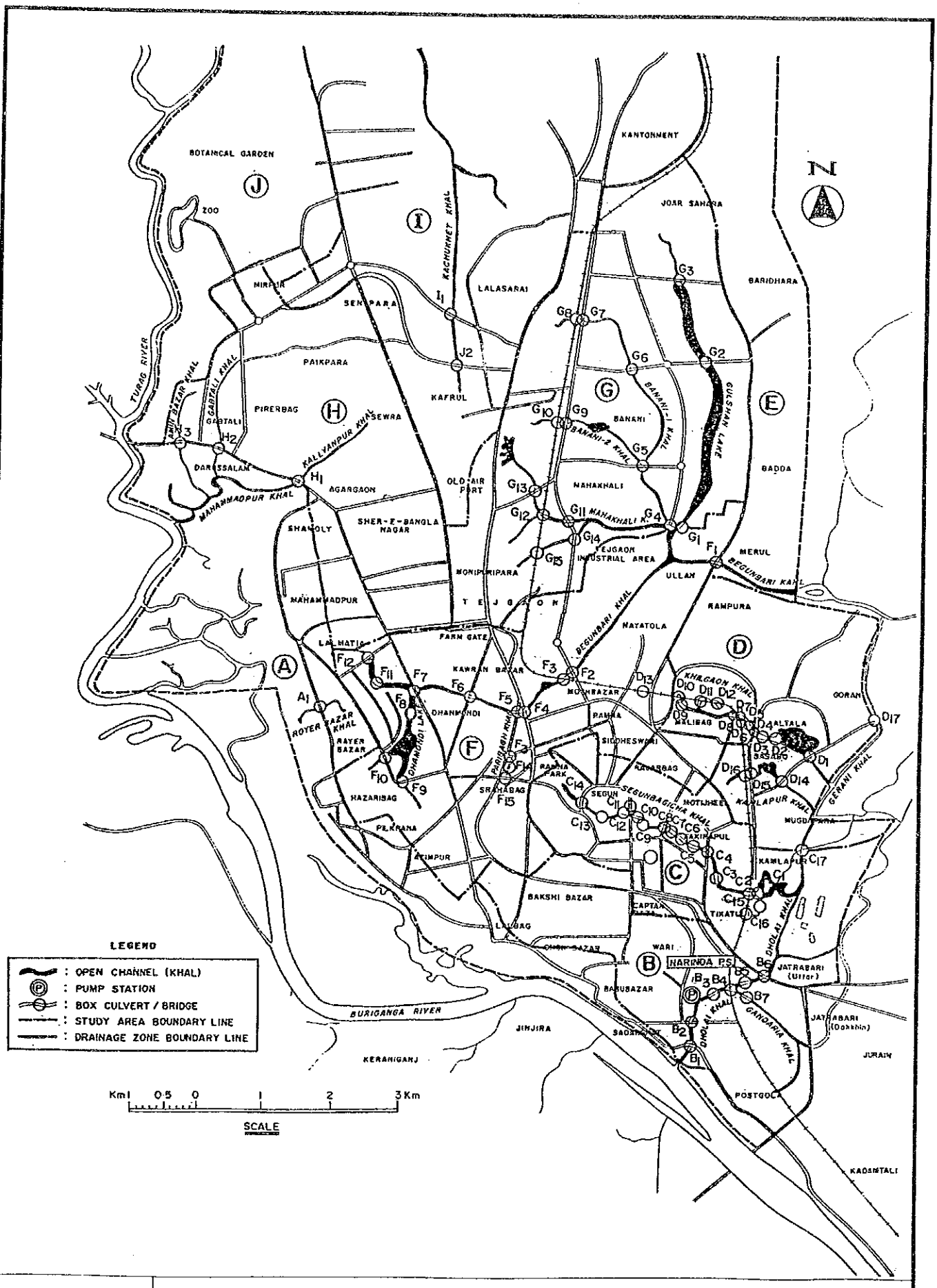



**FIG. E.3** EXISTING DRAINAGE FACILITIES (2)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



JICA 1987A.D

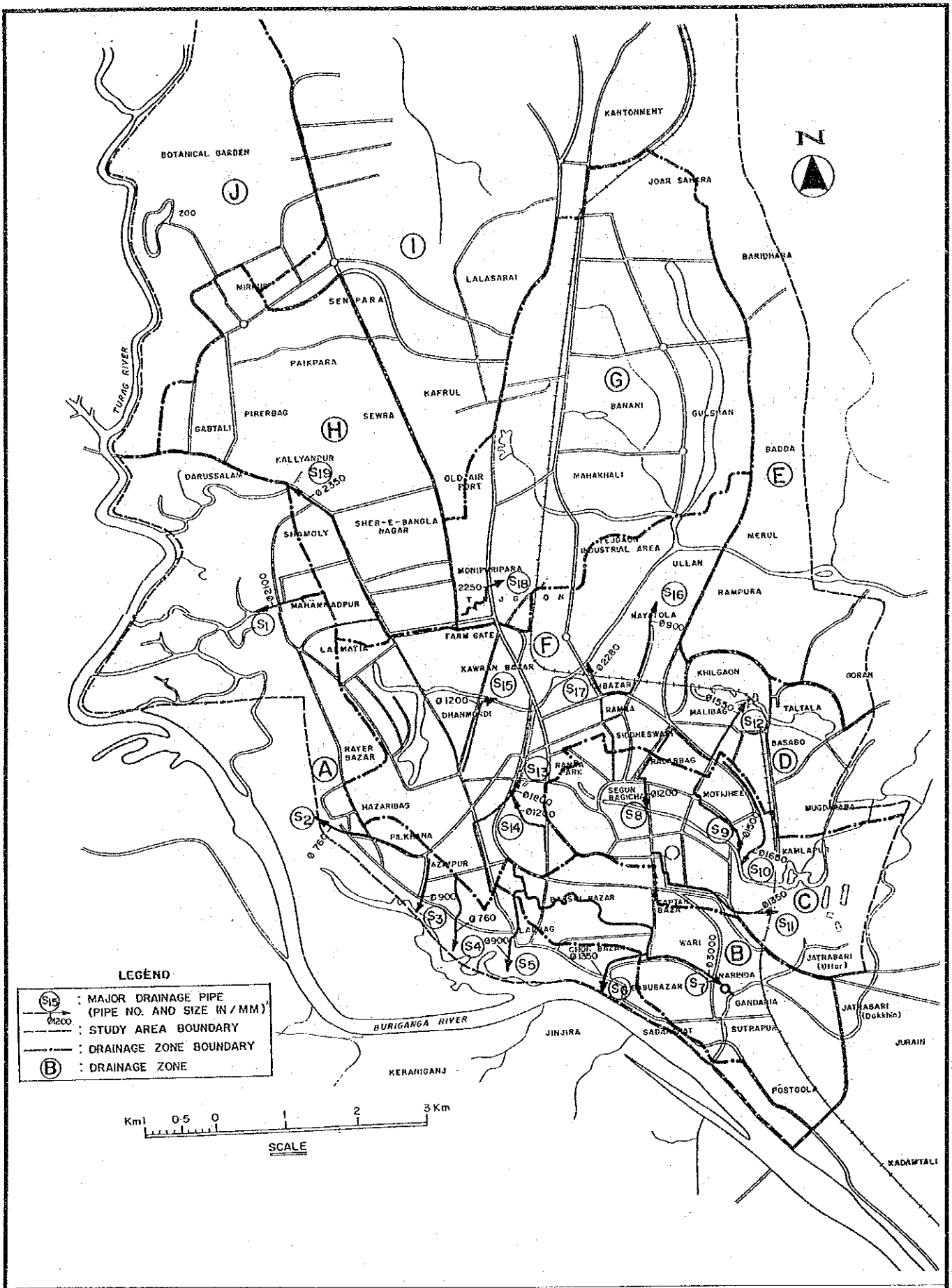



**FIG. E.4** EXISTING DRAINAGE FACILITIES (3)

**STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH**

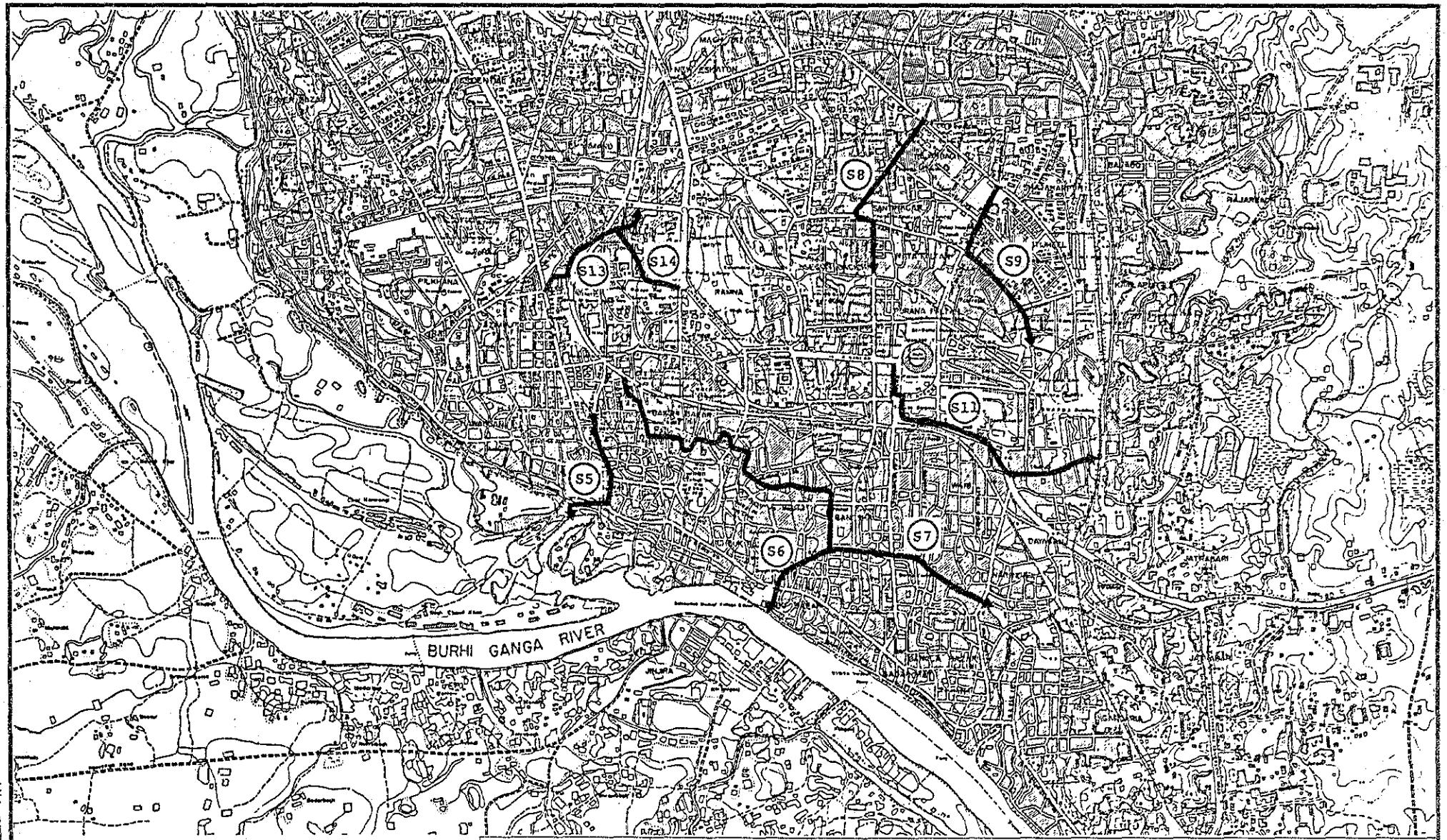



**FIG. E.5** EXISTING TRUNK DRAINAGE PIPES (1)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



JICA 1987.A.D

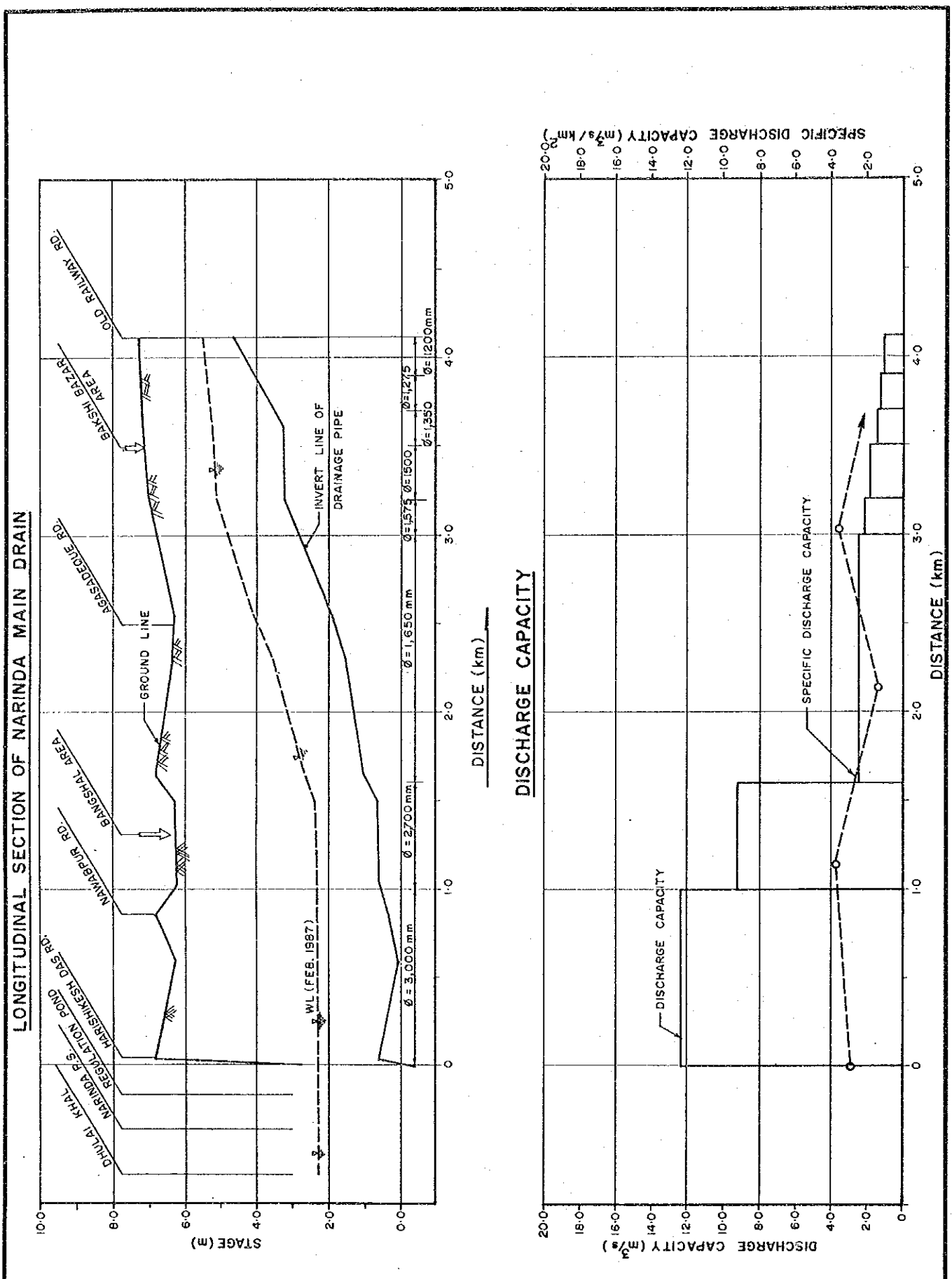
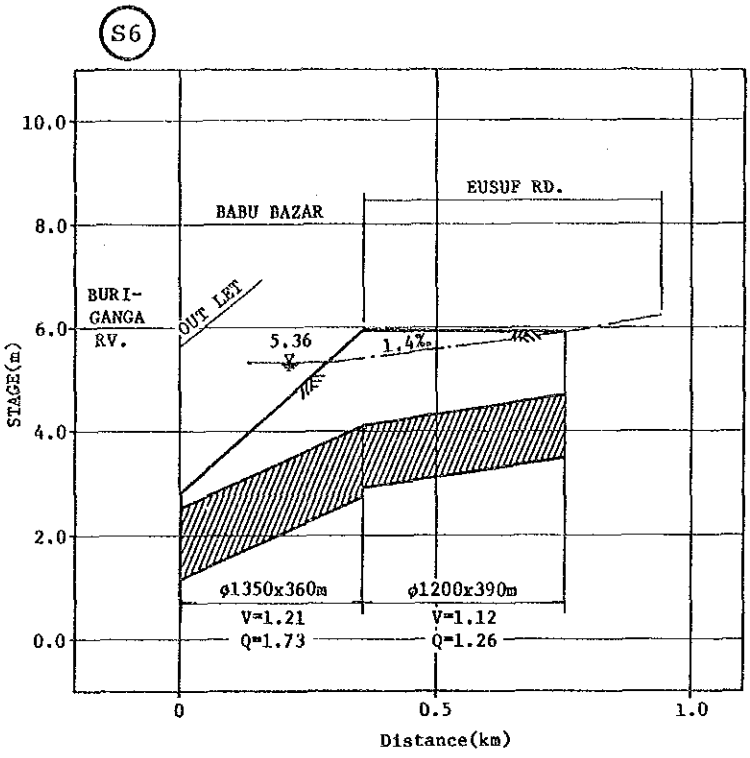



**FIG. E.6** EXISTING TRUNK DRAINAGE PIPES (2)

**STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH**




LEGEND

: Existing Drain Pipe

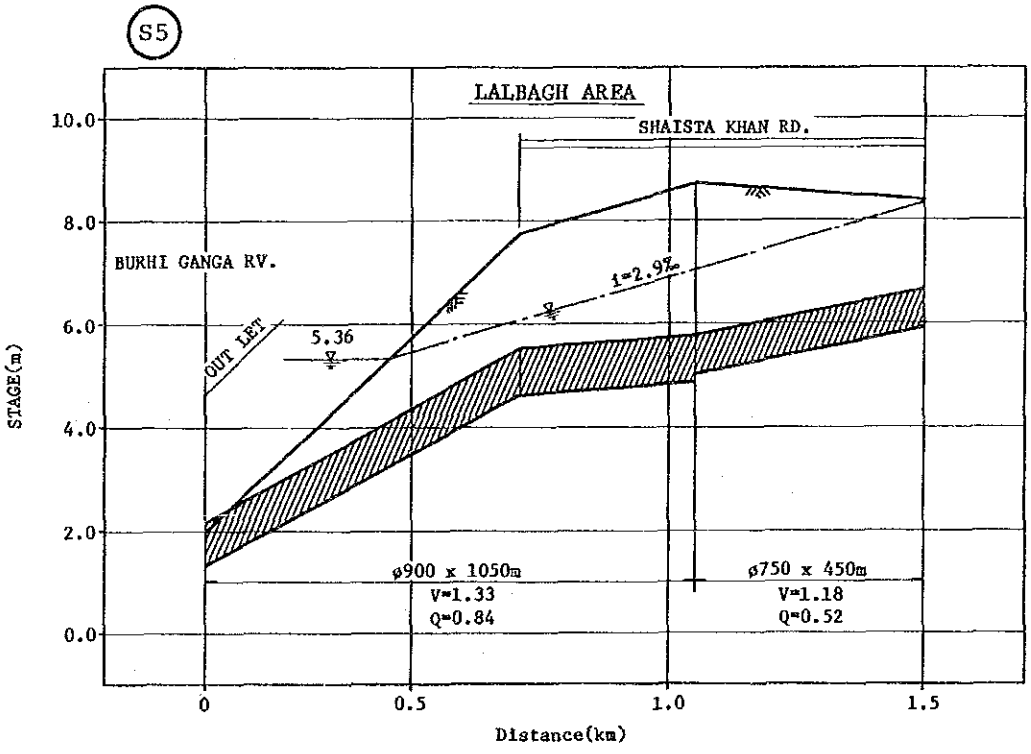
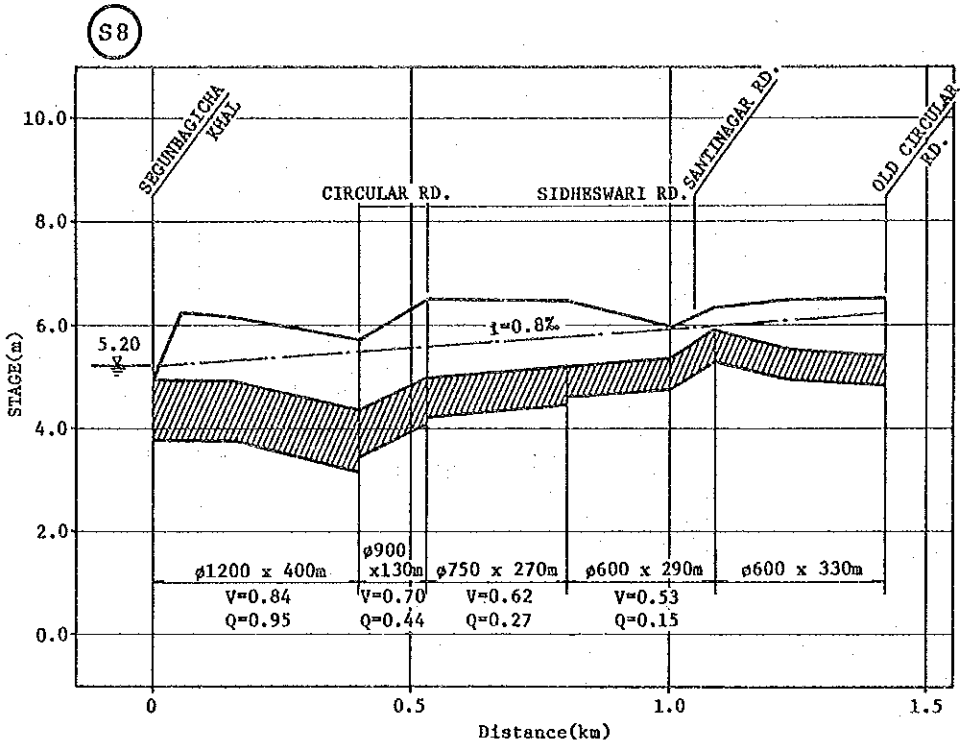



**FIG. E.7** EXISTING TRUNK DRAINAGE PIPES (3)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH




LEGEND

: Existing Drain Pipe

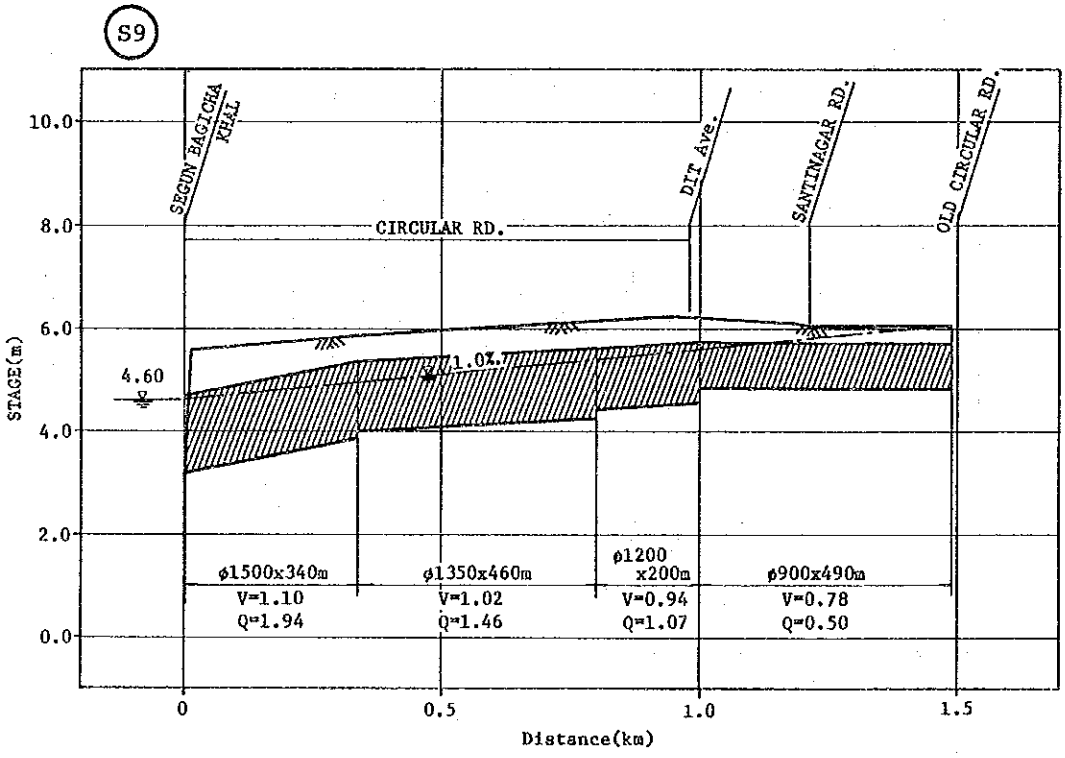



**FIG. E.8** EXISTING TRUNK DRAINAGE PIPES (4)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

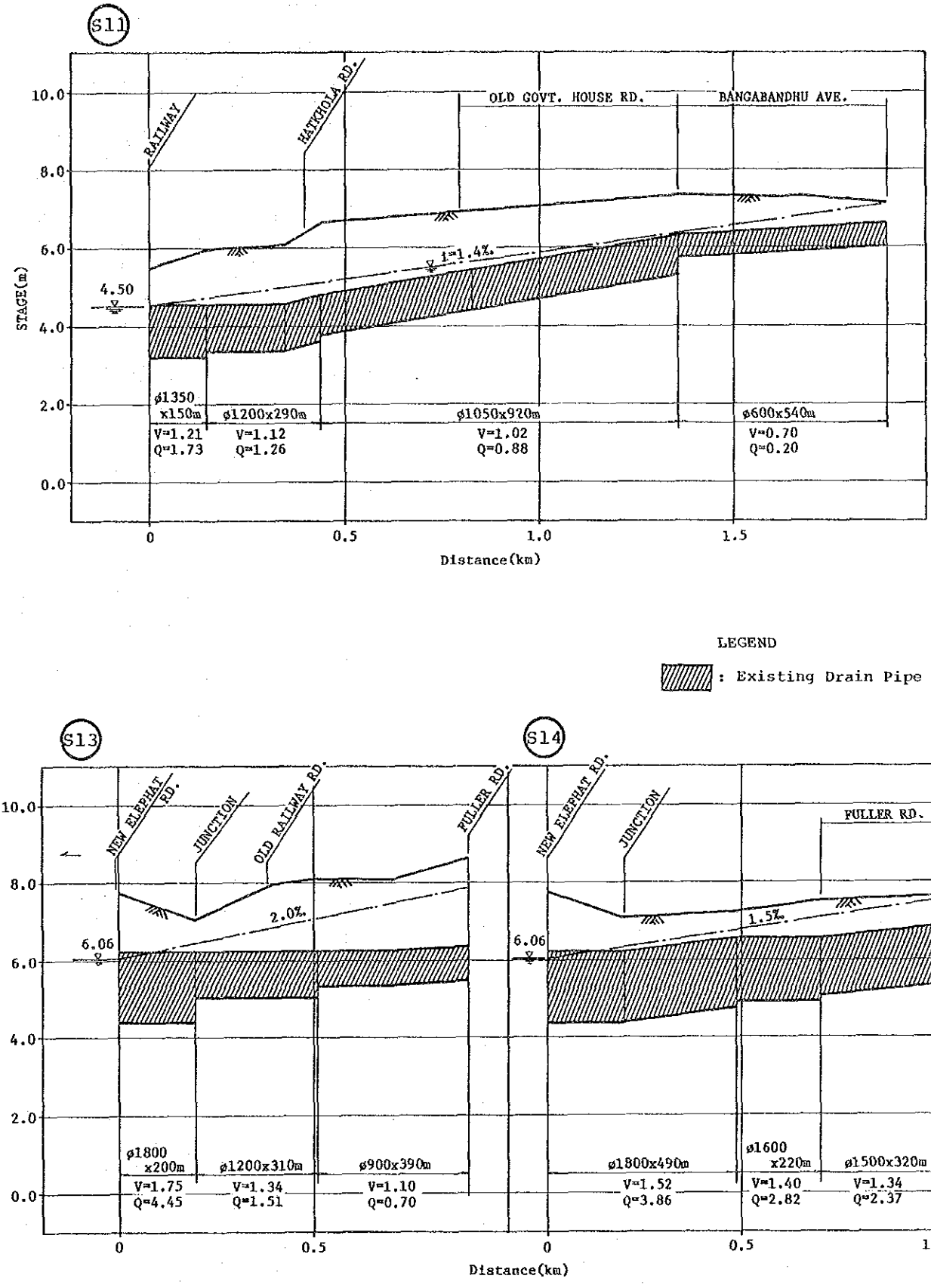



**FIG. E.9** EXISTING TRUNK DRAINAGE PIPES (5)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

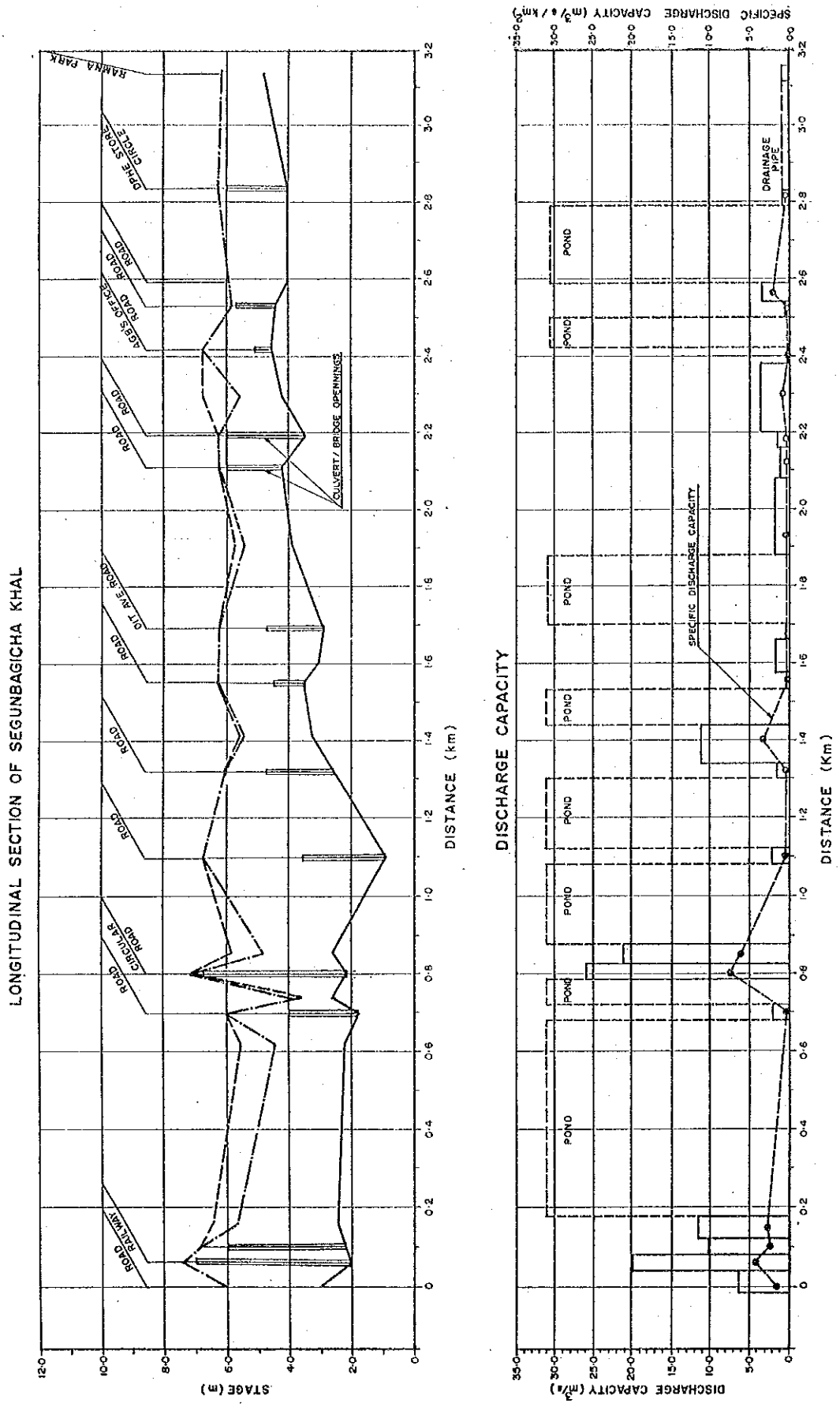



**FIG. E.10** LONGITUDINAL SECTION AND CAPACITY OF SEGUNBAGICHA KHAL

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

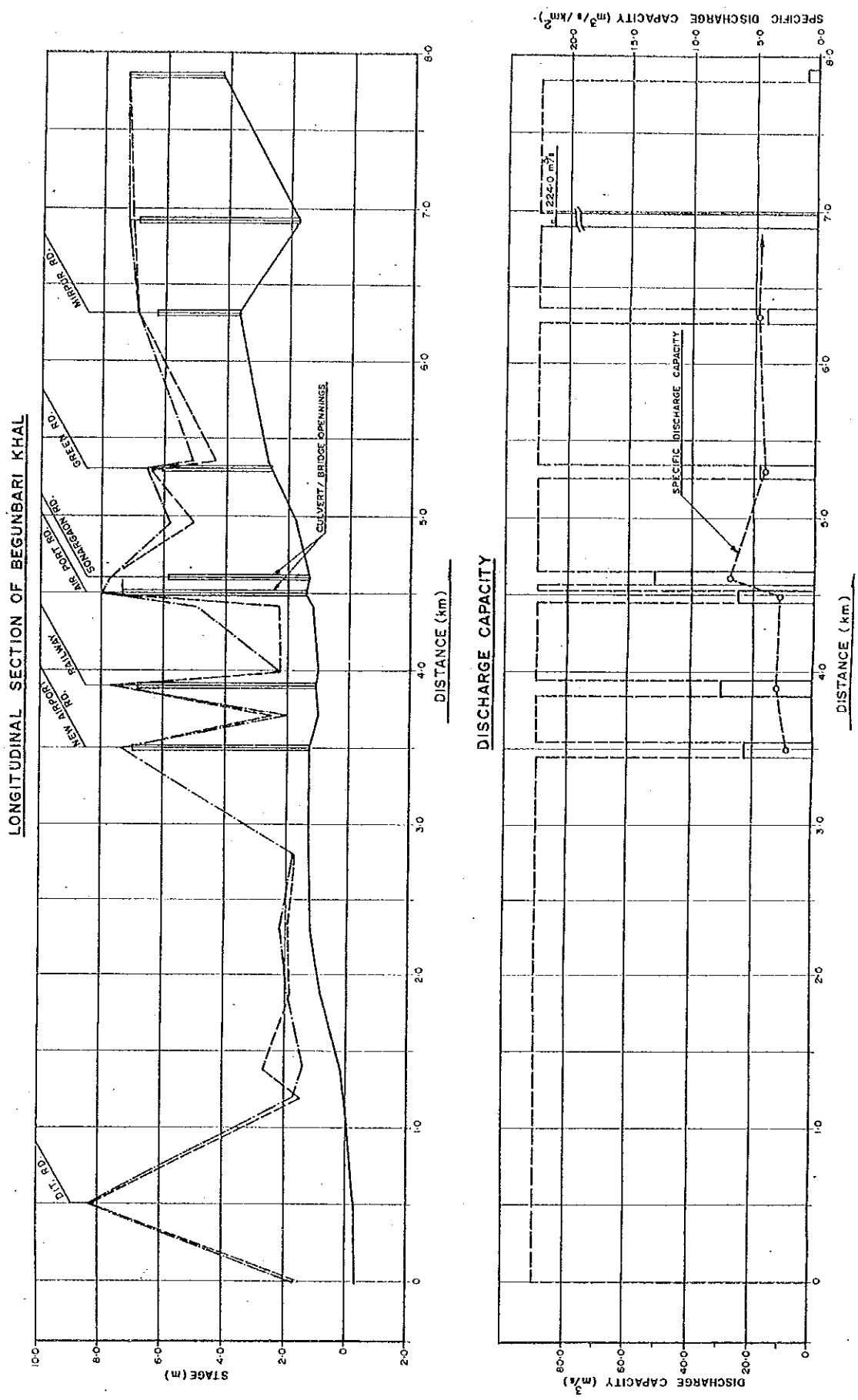
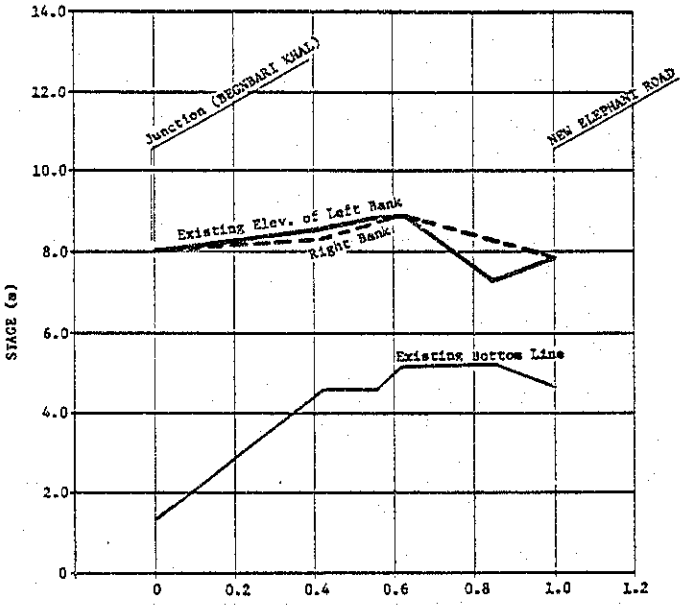



**FIG. E.11** LONGITUDINAL SECTION AND CAPACITY OF BEGUNBARI KHAL

## LONGITUDINAL SECTION OF PARIBAGH KHAL




## DISCHARGE CAPACITY

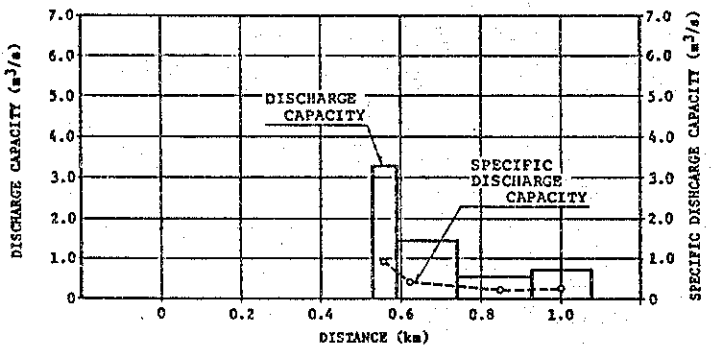


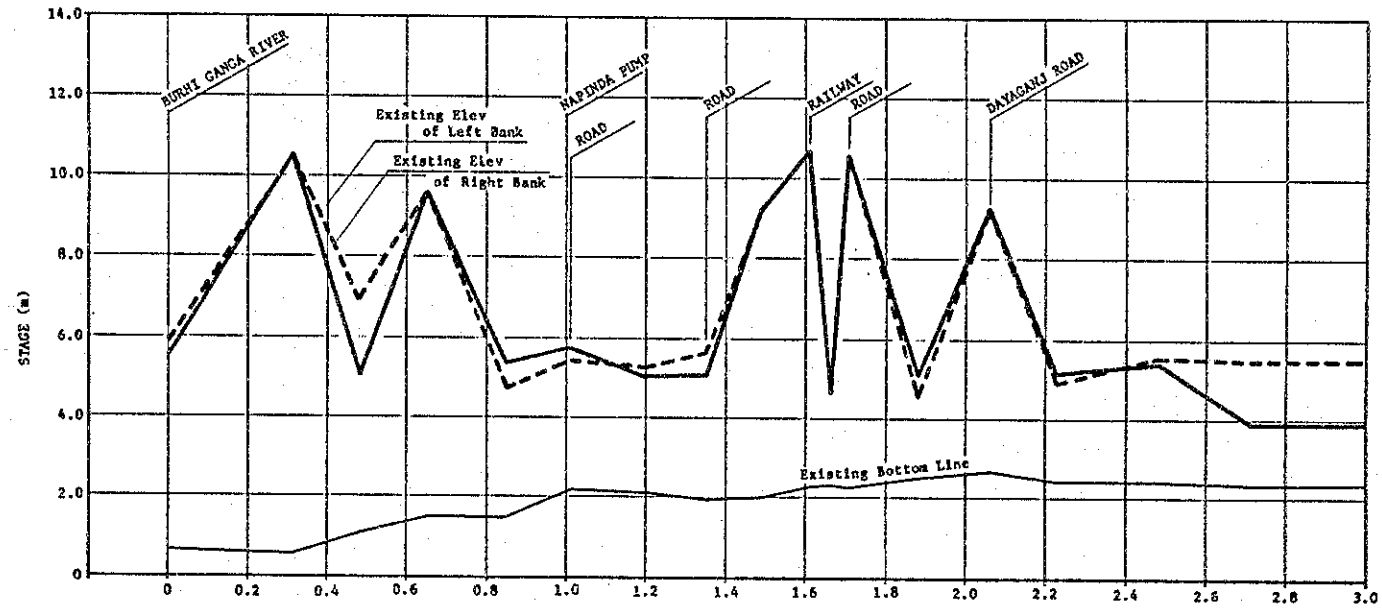

**FIG. E.12** LONGITUDINAL SECTION AND CAPACITY OF PARIBAGH KHAL

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



JICA 1987A.D

# LONGITUDINAL SECTION OF DHOLAI KHAL




## DISCHARGE CAPACITY

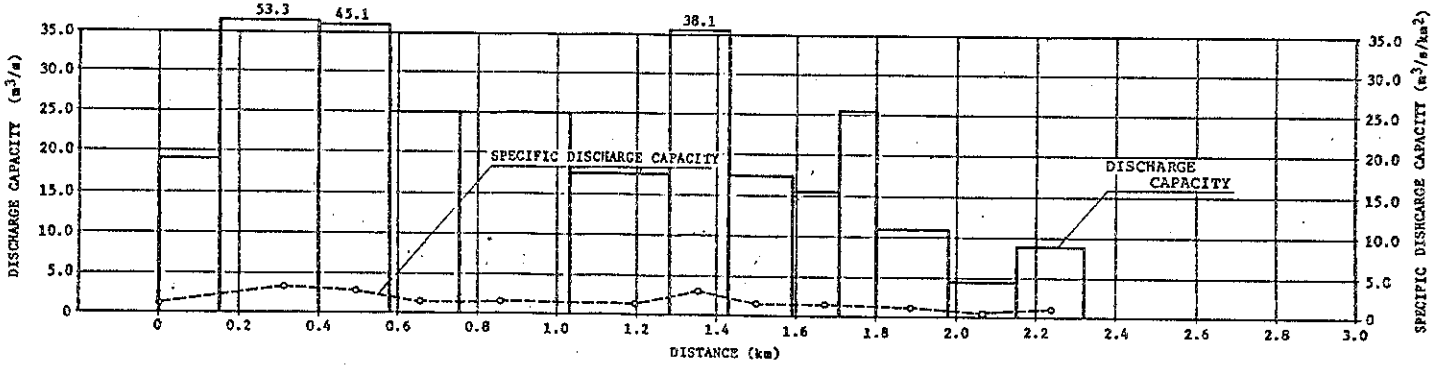
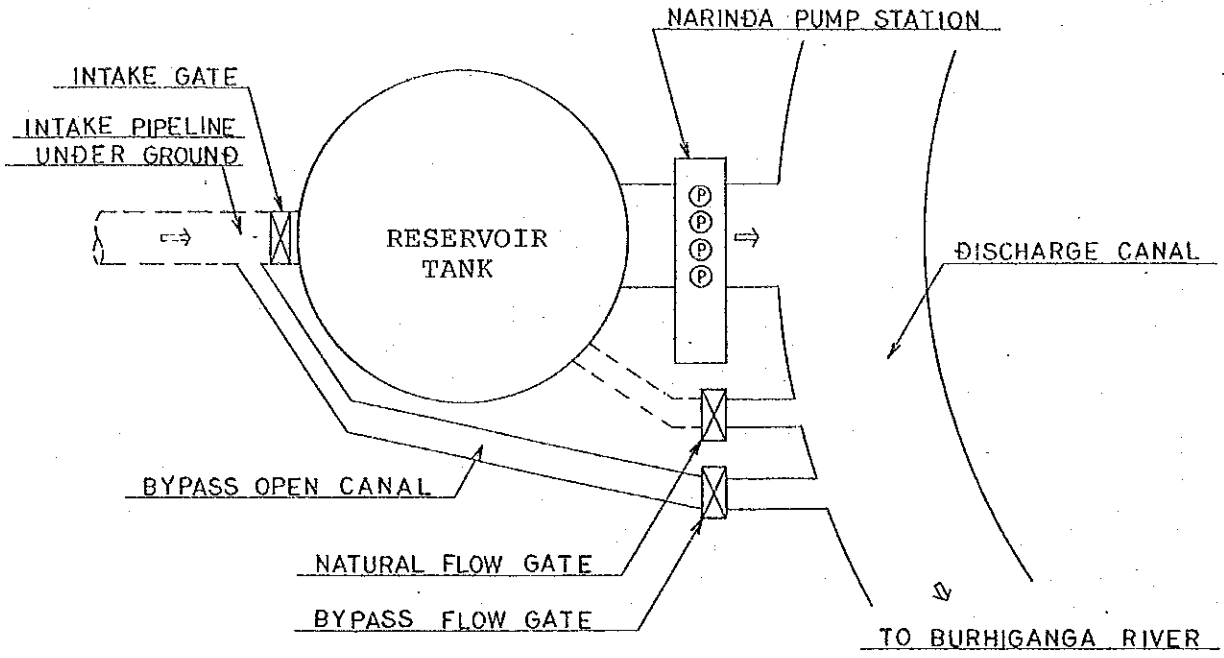



**FIG. E.13** LONGITUDINAL SECTION AND CAPACITY OF DHOLAI KHAL

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH



JICA 1987.A.D



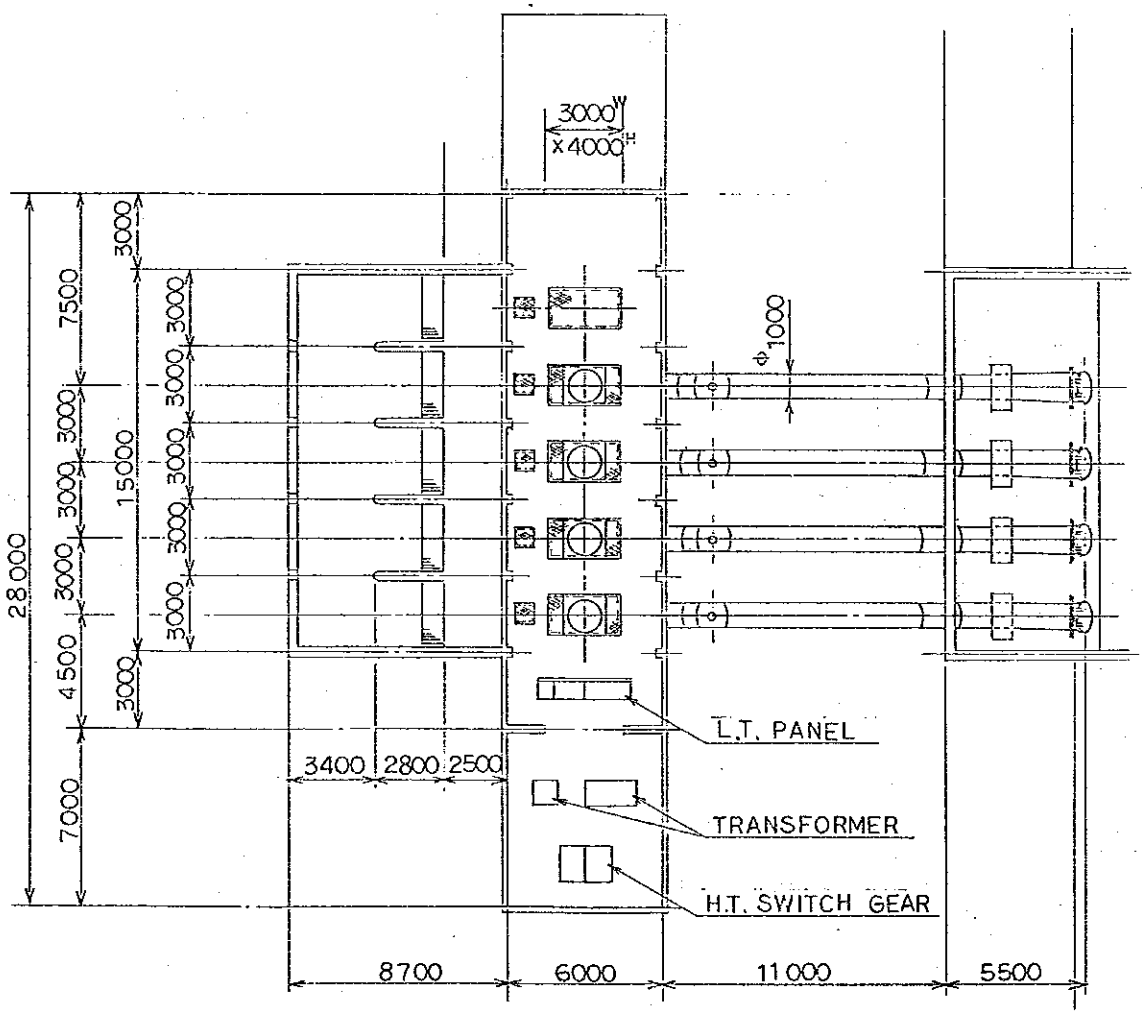
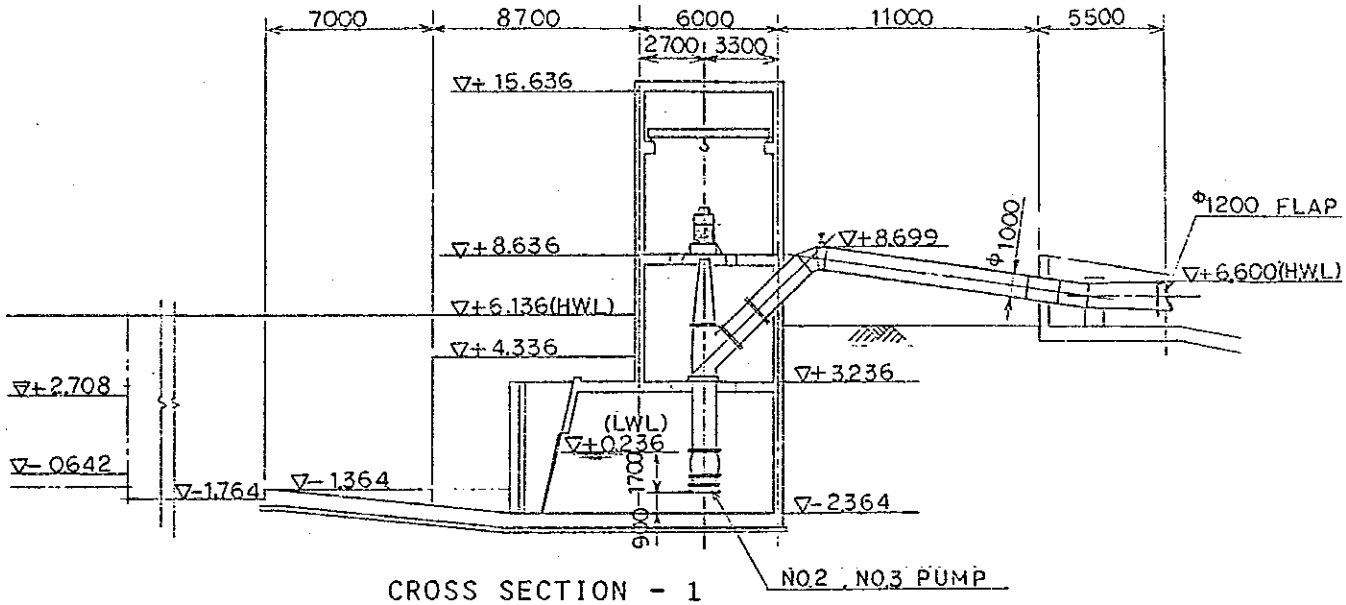
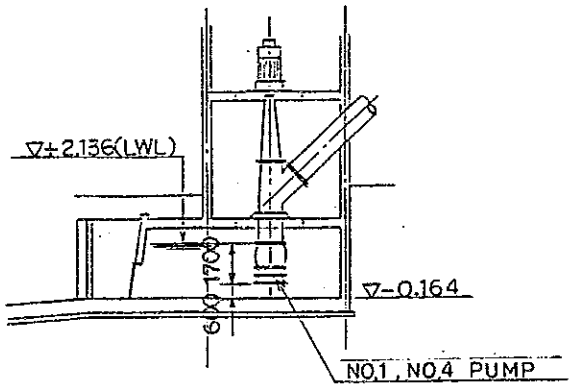




**FIG. E.14** EXISTING NARINDA PUMP STATION (1)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH




CROSS SECTION - 1




CROSS SECTION - 2

**FIG. E.15** EXISTING NARINDA PUMP STATION (2)

STORM WATER DRAINAGE SYSTEM IMPROVEMENT PROJECT IN DHAKA CITY, THE PEOPLE'S REPUBLIC OF BANGLADESH

# SUPPORTING REPORT F

# FLOOD AND FLOOD DAMAGE

SUPPORTING REPORT F FLOOD AND FLOOD DAMAGE

Table of Contents

## List of Tables



## List of Figures

SUPPORTING REPORT F

FLOOD AND FLOOD DAMAGE

# 1. Flood Area and Flood Condition

## 1.1 General

A flood survey was made by the JICA study team for the Study Area except for the Cantonment area through interviews with the ward commissioners and inhabitants. The interviews were made at 1,400 sites in the flood prone areas and were in regards to maximum floods of the past 10 years and habitual floods.

Floods of the Study Area are classified into two (2) types. One is the external flood type that results from the high water levels of the surrounding rivers; the other is the internal flood type caused by storm rainfall. External floods generally take place in the low-lying fringe areas once every five (5) to ten (10) years. However, in some very low-lying areas of Gandaria, Southeast Edge (Jatrabari, Kamlapur, Bashabo, Khilgaon), and Kallyanpur, the floods occur annually.

On the other hand, internal floods occur in the inner areas of the city several times a year.

## 1.2 Maximum Flood

The flood area, at the maximum flood time, in the past 10 years is estimated to be 5,727 ha, of which the urban flood area is 1,930 ha, accounting for 34%. The urban flood area consists of the external flood area of 1,194 ha and the internal one of 736 ha. The urban area affected by external floods will increase from 1,194 ha in 1986 to 1,742 ha in 2000 due to urban development in low-lying areas.

The flood areas are as illustrated in Fig. F.1.

From place to place, the depths and durations of maximum external floods range from 0.3 to 2.0 m and 10 to 60 days respectively. Internal floods vary in depth from 0.37 to 1.0 m with durations of from 5 to 162 hours.

Flood area, depth, and duration by drainage zone and by flood type are estimated as shown in Table F.1 and are illustrated in Fig. F.2.

Depths and durations of the external floods are derived from flood water levels and ground elevations. Internal floods are greatly affected by local conditions, such as capacity of the existing drainage facilities and building density as well as topography.

Flood depths and durations of each drainage zone are very much different from site to site. Those are shown in Table F.1. The most serious internal flood appears in Bakshi Bazar area of Old Dhaka (B-zone). The flood depth and duration reach 1.0 m and 162 hours at the maximum flood respectively.

## 1.3 Habitual Flood

The flood area at habitual flood time is estimated to be 4,567 ha, of which the urban flood area is 1,082 ha, equivalent to 24% of the total flood area. The urban flood area includes the external flood area of 214 ha and the internal one of 868 ha. The urban area affected by external floods will increase from 214 ha in 1986 to 632 ha in 2000, due to urban development.

The flood areas are as illustrated in Fig. F.3.

Depths and durations of habitual external floods range from 0.3 to 1.0 m and 1 to 30 days respectively from site to site. Those of internal floods are from 0.31 to 0.76 m and 2 to 102 hours respectively. Internal floods occur very frequently, 3 to 50 times a year. Flood area, depth, duration, and frequency by drainage zone and by flood type are estimated as shown in Table F.2 and are illustrated in Fig. F.3.

The habitual internal flood depth, duration, and frequency also varies to a great extent from place to place in each drainage zone. The extent of the variations is as shown in Table F.2.

Bakshi Bazar of Old Dhaka experiences the most serious habitual internal flooding with depths of 0.76 m, duration of 102 hours, and a frequency of 22 times a year.

2. Flood Causes

The cause of external floods is simple. They occur when the water levels of the surrounding rivers rise above the ground elevation of the urban areas.

On the other hand, the internal floods are mainly the results of inadequate existing drainage facilities and their improper operation and maintenance as follows:

(1) Insufficiency of drainage pipes

(2) Low discharge capacity of existing drainage pipes

- Most of the existing drainage pipes have discharge capacities too small to handle habitual storm rainfalls.

(3) Clogging of existing drainage pipes

- This problem takes place just about everywhere due to dumped garbage and sediment deposits.

(4) Problems at the pump station

- The Narinda pump station can not be fully operated due to mechanical problems.

(5) Damming up of khal water due to the encroachment of buildings and bottlenecks created at roads and railway crossings.

- These problems are serious in the Segunbagicha and Begunbari khals.

3. Flood Vulnerable Population

The total population in the Study Area was $3,162 \times 10^3$ in 1986, of which $1,102 \times 10^3$ of the population were estimated to be living in the maximum flood prone area. This population will increase to $1,521 \times 10^3$ by 2000. Population figures are broken down by flood type as follows:

| | 1986 | 2000 |
|---|---|---|
| External flood area | $576 \times 10^3$ | $1,004 \times 10^3$ |
| Internal flood area | $436 \times 10^3$ | $517 \times 10^3$ |
| Total | $1,012 \times 10^3$ | $1,521 \times 10^3$ |

$586 \times 10^3$ people lived in the habitual flood prone area in 1986. The population will increase to $1,008 \times 10^3$ by 2000.

These figures are broken down as follows:

| | 1986 | 2000 |
|---|---|---|
| External flood area | $120 \times 10^3$ | $459 \times 10^3$ |
| Internal flood area | $466 \times 10^3$ | $549 \times 10^3$ |
| Total | $586 \times 10^3$ | $1,008 \times 10^3$ |

The flood vulnerable population in 1986, by drainage zone and by flood type, are shown in Table F.3. Those for 2000 are shown in the same table.

## 4. Flood Damage

### 4.1 Flood Damage Survey

The principal objective of the flood damage survey was to collect any information on actual damage with regard to private and public property. In spite of the frequent occurrence of floods, detailed flood damage studies had not been conducted. This study aims at providing an accurate data base for measuring the impact of the drainage system improvement project.

For the purpose mentioned above, the following types of surveys were conducted by the JICA Study Team:

- Flood/inundation damage survey
- Traffic count survey

The survey area was confined to drainage zones B, C, and F. And the most severely affected parts within these zones were assigned as the sampling surveys.

A. Flood/inundation damage survey

| | |
|---|---|
| Period: | January, 1987 to March, 1987 |
| No. of samples: | 665 for residential houses |
| | 513 for shops and factories |
| Major survey items: | - value of houses |
| | - value of household articles |
| | - water levels and duration |
| | - actual maintenance cost caused by flood |
| | - period of off-work due to flood |
| | - income/sales loss |
| Method: | Home visit interviews |

In addition to interviewing with the inhabitants, some authorities responsible for public facilities such as roads, electricity, telecommunications, etc. were interviewed.

B. Traffic count survey

Period: February 2, 3, 8, and 9, 1987

Time : 1 point, 7:00 a.m. to 8:00 p.m.

19 points, 7:00 a.m. to 12:00 a.m.

Categorization of vehicle type:

1. Rickshaw
2. Motorcycle and Baby Taxi
3. Sedan, Mini Bus, and Mini Truck
4. Bus and Truck

Actual traffic volume is shown below:

Results of Traffic Count Survey

| Item | Rickshaw | Baby Taxi, Motorcycle | Sedan, Mini Bus, Mini Truck | Bus, Truck |
|---|---|---|---|---|
| 13 hours survey point (1 point) | 15,904 | 1,989 | 3,244 | 428 |
| 5 hours survey points in total (19 points) | 148,230 | 20,793 | 23,617 | 3,281 |

## 4.2 Estimation of Project Benefit

The basic data used in estimating the future damage potential are the actual values of damages for the years 1974, 1984 and 1985. These figures were obtained through the flood/inundation damage survey which the Study Team conducted from January to February, 1987. The damage value for the years 1986 and 2000 were arrived at by increasing these basic values by the GDP growth rate amount.

In the process of estimating the benefits of the entire project, certain basic conditions were established and applied to the estimation work carried out for each of the damaged items. These conditions were:

- Land use
- Population

## 4.3 General Property Damage Potential

This property consists of three major items, each covering some sub items as shown below:

| | Main items | Sub-items |
|---|---|---|
| . General Property | . Houses | (high, medium, lower) |
| | . Household articles | |
| | . Commercial buildings | (depreciating assets, stock) |

The estimation procedure used in determining the general property damage potential is shown in Fig. F.5.

(1) Houses

House damage potential is given by the following function:

$$D_{House} = HV \times D \times N \times DR$$

Where, HV: Original value of house at 1986 year price
D : Depreciation ratio
N : Number of houses in the flood prone area
DR: Damage Ratio

Houses are classified into 3 types according to the level of owner's income as follows:

House Class

| Class | Income level (Tk/month) | Share(%)* | Value of House (Tk) |
|---|---|---|---|
| Low | less than 2,000 | 48 | 17,000 |
| Medium | 2,000 - 16,000 | 51 | 125,000 |
| High | more than 16,000 | 1 | 750,000 |

Source: the Study Team

Note: * indicates the share against the total number of home owners interviewed.

Low and medium class homes accounted for half of all the houses. The average house value is listed in the column to the right.

The number of houses in the drainage zones B, C, and F was estimated by dividing the total flood prone area by the drainage zone by the unit area of a house after excluding the open space area (see Table F.4).

As for the damage ratios, figures based on Japanese experience are adopted for this study. As house types and materials differ, some estimation errors may occur. However, by adjusting the depth of flood water by the ground height, which is usually flooded by 1 foot of water, reliability of damage ratios is assured. These are:

| Depth: | less than 50 cm | 50 - 99 cm | 200 - 299 cm | more than 300 cm |
|---|---|---|---|---|
| Damage Ratio: | 0.053 | 0.072 | 0.109 | 0.152 |

House damage potential is summarized in Table F.5.

(2) Household Articles

The quantity of household articles such as clothes, furniture, kitchen commodities is expected to increase at the same rate as that of the GDP. The aggregate value of sub-items per household, therefore, increases as the time passes.

The estimation function is given as follows:

$$\text{Value of household articles at year t} = \text{Value at year 1986} \times \left(1 + \frac{r}{100}\right)^{t-1986}$$

where, t: year

r: growth rate of GDP in percentage

The Third Five Year Plan (1985-1990) sets a target of GDP growth rate at 5.4 percent after 1985.

Estimation results are tabulated in Table F.6.

(3) Commercial Buildings

This sub-item consists of two components:

- Houses/buildings for commercial activities
- Equipments and stock

The first component is considered equivalent to the residencial houses in terms of floor area and in value; it is thus treated together with the item of "house".

The second component is estimated based on the figures for 1986, collected through the asset survey for commercial houses. However, damage of equipments/stock per one commercial house is almost negligible and is thus excluded.

4.4 Public Property Damage Potential

This item consists of five sub-items. The actual value of flood/ inundation in various years was increased by the GDP growth rate, and the value of damage potential with an annual frequency for the years 1986 and 2000 was determined. Results are shown in Table F.7. These two figures are converted into the damages for the case having a 10-year frequency by multiplying the ratio of the annual and the 10-year flood durations.

For the 10-year frequency flood, the damage potentials are estimated as follows:

1986: 45.5 million TK x 45 days/18 days = 113.8 million TK
2000: 95.0 million TK x 45 days/18 days = 237.5 million TK

## 4.5 Agricultural Products Damage Potential

Agricultural products, in general, suffer damage from flood/inundation in terms of both quality and quantity. However, estimation of this damage item was not conducted in this study for the following reason:

- Cultivated land in the study area is so small that the damage to agricultural products was considered to be negligible.

Estimation error attributable to this exclusion is examined in the sensitivity analysis.

## 4.6 Income/Sales Loss Potential

This item consists of four sub-items, which are briefly explained below, and the results are presented in Table F.8:

(1) Labourers Income Loss

Flood/inundation usually causes inconvenience to or obstruction of access to transport routes. Subsequent interruption of commercial/ production activities results in the loss of income, especially for the day labourers engaged in construction work or work at the brick factories.

Off-work periods and the average losses of income were studied in the flood/inundation damage survey by the Study Team. Results are shown in Table F.8.

(2) Shop Sales Loss

Average sales performance is assumed to be 6,500 Tk. per day. However, the sales loss attributable to flood/inundation is remarkably low, being less than one percent of the annual sales performance. This tendency is apparent in overall areas prone to flood/inundation within drainage zone B, C, and F.

(3) Electricity Consumption Loss

This loss for the year 1986 is reported as follows:

| | |
|---|---|
| Average interruption: | 2 hrs/day |
| Average number of affected areas: | 8 areas/day |
| Period: | 90 days/year (rainy season) |
| Unit charge (estimated): | 2000 Tk/h |

Total loss = 2 x 8 x 9 x 2,000
= 2.9 million Tk/year

Source: "Dhaka Electric Supply", Executive Engineer

This loss is attributable to electric supply interruption due to the flood/inundation within the study area.

By means of the same calculating method as for the public property damage potential, the figure was increased to show the damage value for the year 2000 and the damages for the case with a 10-year flood frequency. They are:

1986 damage with 1/1 frequency: 2.9 mil. Tk/year
2000 damage with 1/1 frequency:
2.9 million x $1.054^{14}$ = 6.06 million/Tk
1986 damage with 1/10 frequency:
2.9 million x 45/18 = 7.25 million/Tk
2000 damage with 1/10 frequency:
6.06 million x 45/18 = 15.15 million/Tk

(4) Transportation

According to the BRTC, the monthly revenue from bus fares during rainy seasons is assumed to be about 10 percent less than in dry seasons. The BRTC handles 50 percent of total bus operations in Dhaka City while private bus companies account for the other 50 percent. This sales loss is estimated as follows:

| | |
|---|---|
| Average revenue per month (in 1986): | 22.1 million Tk |
| Loss ratio: | 0.1 |
| Rainy season: | 4 months |
| 1 - BRTC's share: | (1 : 0.5) = 2 |
| Total loss (= 22.1 x 0.1 x 4 x 2) | 17.68 million Tk/year |

Source: BRTC

Rickshaw charges: Rickshaw pullers' working conditions and rickshaw traffic volume in the flood/inundation area were surveyed by the Study Team. The results of the Study Team's survey present a similarity to those of the Final Report on Investigation, Design and Construction of Second Buriganga Bridge at Babu Bazar, Dhaka (June, 1986).

| | |
|---|---|
| Average revenue per day | 96.0 Tk |
| Number of trips per day | 20.6 Trip |
| Volume of rickshaw traffic at major 10 points prone to flood/inundation (7:00 a.m. to 8:00 p.m.) | 103,023 rickshaws |
| Off-work days due to flood/inundation per year | 3.5 days |
| Total loss (96.0 x 20.6 x 103,023 x 3.5) | 1.68 million Tk |

Both estimated figures are converted into future figures and into those having a 10-year frequency.

They are:

| | Bus Charge loss | Rickshawmen's loss |
|---|---|---|
| 2000 with 1/1 frequency | 44.2 million Tk | 3.5 million Tk |
| 1986 with 1/10 frequency | 36.9 | 4.2 |
| 2000 with 1/10 frequency | 92.3 | 8.77 |

## 4.7 Vehicles' Running Cost Loss

The disruption to the urban traffic due to the flood/inundation is one of the most apparent adverse effects perceived by the society other than general and public property damage.

The major manner in which flood/inundation disrupts traffic is by decreasing the travel speed of vehicles. The subsequent damage can be perceived in terms of increased vehicle operating cost and incremental time of travel.

Increase in vehicle operating cost and travel time value are estimated by the following formula:

(1) L (VOC) = (VOC flood - VOC non-flood) X Q

where:

| | |
|---|---|
| L (VOC): | Loss due to increase in vehicle operating cost |
| VOC flood: | Vehicle operating cost at an average travel speed in flood situation |
| VOC non-flood: | Vehicle operating cost at an average travel speed in non-flood situation |
| Q: | Traffic volume in Project area expressed in terms of vehicle-km |

(2) L (TL) = (PH without - PH with) x TV

where:

| | |
|---|---|
| L (TL): | Loss in time value |
| PH flood: | Passenger-hours in flood situation |
| PH non-flood: | Passenger-hours in non-flood situation |
| TV: | Time value of passengers |

Vehicle operating cost increases drastically as the speed decreases, especially when travel speed becomes slower than about 20 to 15 km/h.

According to driver interviews, the normal travel speed in the urban area is about 30 km per hour. The average speed in the flood prone area is about 10 km per hour.

The distance travelled by vehicle going through the Study Area, i.e., drainage zones B, C, and F, is assumed to be three kilometers.

Traffic demand in the study area is derived from the actual traffic volume. For this purpose, traffic volume survey was conducted at major streets prone to flood (19 points). Actual traffic volume is summarized by vehicle type in Table F.9.

Finally, economic vehicle operating cost and passenger time value are quoted from the Final Report of "Feasibility Study on Meghna, Meghna-Gumti Bridge Construction Project" (March, 1985; JICA) and are shown in Table F.10.

Total incremental costs due to annual flood/inundation calculated are as follows:

(1) Vehicle Operating cost: 0.8 million TK/day

(2) Time Cost:

| | |
|---|---|
| - Vehicle Time Cost | 5.4 million TK/day |
| - Passengers Time Cost | 8.6 million TK/day |
| Subtotal | 14.0 million TK/day |

(3) Grand Total of Incremental Cost: 14.8 million TK/day

This grand total of incremental cost is applied to the case having a 10-year flood frequency. This figure is increased by the GDP for determining the figure for the year 2000, 30.0 million TK/days.

## 4.8 Summary of Flood Damage

The estimated flood damage potential is summarized in Table F.11.

## Table F.1 Summary of Maximum Flood Condition

| Item | | | Drainage Zone A | B | C | D | E | F | G | H | I | J | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drainage Zone Area (ha) | | | 1,285 | 776 | 904 | 832 | 1,393 | 1,602 | 1,764 | 1,278 | 3,142 | 769 | 13,745 |
| Urbanization | 1986 | Urbanized Area (ha) | 675 | 743 | 642 | 491 | 758 | 1,378 | 1,342 | 788 | 1,739 | 317 | 8,873 |
| | | Un-Urbanized Area (ha) | 610 | 33 | 262 | 341 | 635 | 224 | 422 | 490 | 1,403 | 452 | 4,872 |
| | 2000 | Urbanized Area (ha) | 1,079 | 760 | 657 | 591 | 1,035 | 1,492 | 1,450 | 1,164 | 1,934 | 364 | 10,516 |
| | | Un-Urbanized Area (ha) | 206 | 16 | 247 | 241 | 358 | 110 | 314 | 114 | 1,208 | 405 | 3,229 |
| External Food | Area | Total (ha) | 647 | 211 | 300 | 683 | 850 | 252 | 241 | 438 | 1,030 | 339 | 4,991 |
| | | Urbanized Area (ha) | 37 (37) | 178 (195) | 80 (95) | 342 (442) | 227 (227) | 39 (69) | 63 (63) | 140 (438) | 88 (176) | 0 (0) | 1,194 (1,742) |
| | Depth (m) | | 0.3-1.0 | 0.6-1.8 | 0.6-2.0 | 0.6-2.0 | 0.6-1.5 | 0.3-1.0 | 0.6-1.5 | 0.6-2.0 | 0.3-1.5 | - | - |
| | Duration (day) | | 10-30 | 15-60 | 15-60 | 15-60 | 15-60 | 10-30 | 15-50 | 15-60 | 10-50 | - | - |
| Internal Food | Area | Total (ha) | 102 | 207 | 80 | 39 | - | 170 | 30 | 43 | 65 | - | 736 |
| | | Urbanized Area (ha) | 102 | 207 | 80 | 39 | - | 170 | 30 | 43 | 65 | - | 736 |
| | Depth (m) | | .52-.92 * 0.64 | .46-1.0 * 0.76 | .40-.88 * 0.70 | .61-.70 * 0.67 | - - | .37-.82 * 0.67 | .37-.70 * 0.61 | .55-.67 * 0.61 | .61-.74 * 0.71 | - - | - * 0.69 |
| | Duration (hr) | | 11-40 * 26 | 5-162 * 45 | 5-39 * 18 | 20-27 * 24 | - - | 15-60 * 32 | 20-36 * 26 | 15-68 * 48 | 24-72 * 60 | - - | - * 37 |

Note : (1) The figures in parenthesis show the urbanized area by external flood in the year 2000.
(2) The figures marked in * show the average value by weighted mean method.

Table F.2 Summary of Habitual Flood Condition

| Item | | | Drainage Zone A | B | C | D | E | F | G | H | I | J | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drainage Zone Area (ha) | | | 1,285 | 776 | 904 | 832 | 1,393 | 1,602 | 1,764 | 1,278 | 3,142 | 769 | 13,745 |
| Urbanization | 1986 | Urbanized Area (ha) | 675 | 743 | 642 | 491 | 758 | 1,378 | 1,342 | 788 | 1,739 | 317 | 8,873 |
| | | Un-Urbanized Area (ha) | 610 | 33 | 262 | 341 | 635 | 224 | 422 | 490 | 1,403 | 452 | 4,872 |
| | 2000 | Urbanized Area (ha) | 1,079 | 760 | 657 | 591 | 1,035 | 1,492 | 1,450 | 1,164 | 1,934 | 364 | 10,516 |
| | | Un-Urbanized Area (ha) | 206 | 16 | 247 | 241 | 358 | 110 | 314 | 114 | 1,208 | 405 | 3,229 |
| External Flood | Area | Total | 610 | 80 | 230 | 468 | 595 | 206 | 191 | 293 | 721 | 305 | 3,699 |
| | | Urbanized Area (ha) | - | 47 (64) | 10 (25) | 127 (227) | - | 0 (23) | - | 30 (293) | - | - | 214 (632) |
| | Depth (m) | | - | 0.3-1.0 | 0.3-1.0 | 0.3-1.0 | - | - | - | 0.3-1.0 | - | - | 0.3-1.0 |
| | Duration (day) | | - | 1-30 | 1-30 | 1-30 | - | - | - | 1-30 | - | - | 1-30 |
| Internal Flood | Area | Total | 102 | 339 | 80 | 39 | - | 170 | 30 | 43 | 65 | - | 868 |
| | | Urbanized Area (ha) | 102 | 339 | 80 | 39 | - | 170 | 30 | 43 | 65 | - | 868 |
| | Depth (m) | | .31-.52 * 0.35 | .31-.76 * 0.46 | .31-.61 * 0.48 | .40-.55 * 0.47 | - - | .31-.61 * 0.43 | .31-.46 * 0.39 | .31-.49 * 0.39 | .31-.41 * 0.38 | - - | - * 0.43 |
| | Duration (hr) | | 2.5-14 * 7 | 3.5-102 * 18 | 2-17 * 8 | 6-10 * 8 | - - | 2-22 * 12 | 4-13 * 10 | 6-24 * 15 | 4-19 * 15 | - - | - * 14 |
| | Frequency (in one year) | | 5-19 * 8 | 4-22 * 12 | 3-27 * 8 | 7-13 * 9 | - - | 5-50 * 10 | 3-14 * 12 | 5-15 * 8 | 6-8 * 7 | - - | - * 11 |

Note : (1) The figures in parenthesis show the urbanized area by external flood in the year 2000.
(2) The figures marked in * show the average value by weighted mean method.

## Table F.3 Summary of Flood Vulnerable Population in the Study Area

| Item | | | Drainage Zone | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | H | I | J | |
| Population | | 1986 | 442.3 | 597.9 | 306.9 | 329.3 | 67.8 | 480.9 | 227.9 | 230.7 | 343.5 | 119.3 | 3,146.5 |
| | | 2000 | 570.3 | 649.6 | 388.4 | 615.6 | 244.0 | 631.8 | 337.0 | 455.6 | 613.3 | 271.7 | 4,777.3 |
| Flood Vulnerable Population | Habitual Flood 1986 | External Flood | - (-) | 14 (2.3) | 15 (4.9) | 86 (26.1) | - - | - - | - - | 5 (2.2) | - - | - - | 120 (3.8) |
| | | Internal Flood | 45 (10.2) | 265 (44.3) | 33 (108) | 16 (4.9) | - - | 68 (14.1) | 8 (3.5) | 7 (3.0) | 24 (7.0) | - - | 466 (14.8) |
| | | Total | 45 (10.2) | 279 (46.7) | 48 (15.6) | 102 (31.0) | - - | 68 (14.1) | 8 (3.5) | 12 (5.2) | 24 (7.0) | - - | 586 (18.6) |
| | Habitual Flood 2000 | External Flood | - (-) | 57 (8.8) | 48 (12.4) | 238 (38.7) | - - | 8 (1.3) | - - | 108 (23.7) | - - | - - | 459 (9.6) |
| | | Internal Flood | 63 (11.0) | 275 (42.3) | 36 (9.3) | 24 (3.9) | - - | 80 (12.7) | 11 (3.3) | 20 (4.4) | 40 (6.5) | - - | 549 (11.5) |
| | | Total | 63 (11.0) | 332 (51.1) | 84 (21.6) | 262 (42.6) | - - | 88 (13.9) | 11 (3.3) | 128 (28.1) | 40 (6.5) | - - | 1,008 (21.1) |
| | Max. Flood in Past 10 Years 1986 | External Flood | 24 (5.4) | 71 (11.9) | 114 (37.1) | 232 (70.5) | 17 (25.0) | 18 (3.7) | 21 (9.2) | 71 (30.8) | 8 (2.3) | - - | 576 (18.3) |
| | | Internal Flood | 45 (10.2) | 235 (39.3) | 33 (10.8) | 16 (4.9) | - - | 68 (14.1) | 8 (3.5) | 7 (3.0) | 24 (7.0) | - - | 436 (13.9) |
| | | Total | 69 (15.6) | 306 (51.2) | 147 (47.9) | 248 (75.3) | 17 (25.0) | 86 (17.9) | 29 (12.7) | 78 (33.8) | 32 (9.3) | - - | 1,012 (32.2) |
| | Max. Flood in Past 10 Years 2000 | External Flood | 28 (4.9) | 96 (14.8) | 181 (46.6) | 464 (75.4) | 17 (7.0) | 24 (3.8) | 21 (6.2) | 161 (35.2) | 12 (2.0) | - - | 1,004 (21.0) |
| | | Internal Flood | 63 (11.0) | 243 (37.4) | 36 (9.3) | 24 (3.9) | - - | 80 (12.7) | 11 (3.3) | 20 (4.4) | 40 (6.5) | - - | 517 (10.8) |
| | | Total | 91 (16.0) | 339 (52.2) | 217 (55.9) | 488 (79.3) | 17 (7.0) | 104 (16.5) | 32 (9.5) | 181 (39.7) | 52 (8.5) | - - | 1,521 (31.8) |

Note : The figures in parenthesis show the percentage (%).

**Table F.4 Number of Houses in Flood Prone Area 1986 and 2000**

| Year | Flood Zone | House Class | Flood Frequency | |
|---|---|---|---|---|
| | | | 1/1 | 1/10 |
| 1986 | B | Low | 17,740 | 41,380 |
| | | Medium | 4,430 | 10,350 |
| | | High | 0 | 0 |
| | C | Low | 1,580 | 4,970 |
| | | Medium | 6,310 | 19,880 |
| | | High | 0 | 0 |
| | F | Low | 2,280 | 2,880 |
| | | Medium | 9,100 | 11,500 |
| | | High | 0 | 0 |
| | Total | | 41,440 | 90,960 |
| 2000 | B | Low | 20,770 | 41,400 |
| | | Medium | 51,880 | 103,390 |
| | | High | 0 | 0 |
| | C | Low | 2,530 | 6,600 |
| | | Medium | 101,090 | 236,000 |
| | | High | 0 | 0 |
| | F | Low | 2,440 | 3,170 |
| | | Medium | 97,340 | 126,500 |
| | | High | 0 | 0 |
| | Total | | 276,050 | 517,060 |

Table F.5 House Damage Potential, 1986 and 2000

(Unit : million TK)

| Year | Flood Zone | House Class | Flood Frequency | |
|---|---|---|---|---|
| | | | 1/1 | 1/10 |
| 1986 | B | Low | 7.99 | 18.64 |
| | | Medium | 19.95 | 46.56 |
| | | High | 0.00 | 0.00 |
| | C | Low | 0.71 | 2.24 |
| | | Medium | 28.41 | 89.46 |
| | | High | 0.00 | 0.00 |
| | F | Low | 1.03 | 1.30 |
| | | Medium | 40.97 | 51.77 |
| | | High | 0.00 | 0.00 |
| | Total | Low | 9.73 | 22.18 |
| | | Medium | 89.33 | 187.79 |
| | | High | 0.00 | 0.00 |
| 2000 | B | Low | 10.39 | 20.70 |
| | | Medium | 25.94 | 51.70 |
| | | High | 0.00 | 0.00 |
| | C | Low | 1.27 | 3.30 |
| | | Medium | 50.54 | 131.83 |
| | | High | 0.00 | 0.00 |
| | F | Low | 1.22 | 1.58 |
| | | Medium | 48.67 | 63.25 |
| | | High | 0.00 | 0.00 |
| | Total | Low | 12.87 | 25.58 |
| | | Medium | 125.15 | 246.78 |
| | | High | 0.00 | 0.00 |