UNPLANNED URBANIZATION OF DHAKA CITY: INCREASE OF RAINFALL INDUCED FLOOD VULNERABILITY

A Dissertation for the Degree of Master in Disaster Management

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ABBREVIATIONS AND ACRONYMS

AAT	Arc Attribute Table
BBS	Bangladesh Bureau of Statistics
BDF	Basin Development Factor
BGMEA	Bangladesh Garments Manufacturing & Exporters' Association
BIWTA	Bangladesh Inland Water Transport Authority
BKMEA	Bangladesh Knitting Manufacturing and Exporters' Association
BWDB	Bangladesh Water Development Board
CNG	Compressed Natural Gas
DEM	Digital Elevation Model
DCC	Dhaka City Corporation
DIT	Dhaka Improvement Trust
DLRS	Directorate of Land Records and Survey
DMA	Dhaka Metropolitan Area
DMDP	Dhaka Metropolitan Development Plan
DPHE	Department of Public Health Engineering
DSMS	Dhaka Statistical Metropolitan Area
DWASA	Dhaka Water and Sewerage Authority
DWEM	Department of Water Engineering & Management
GCP	Ground Control Points
GIS	Geographic Information System
GoB	Government of Bangladesh
IWFM	Institute of Water and Flood Management
IUCN	World Conservation Union
JICA	Japan International Cooperation Agency
LGED	Local Government Engineering Department
MDB	Meteorological Department of Bangladesh
MEC	Event Mean Concentration
msl	Mean Sea Level
MSW	Municipal Solid Waste
NGO	Non Government Organization
PPDM	Post Graduate Program in Disaster Management
RAJUK	Rajdhani Unnayan Kartripakkha
RS	Remote Sensing
SWD	Storm Water Drainage
SWM	Solid Waste Management
IWMC	Institute of Water Modeling Center
UNDP	United Nation Development Program
WASA	Water and Sewerage Authority
WHO	World Health Organization

(i)

ABSTRACT

Dhaka, the capital city of Bangladesh is one of the most populous megacities in the world. As the growth of urban population tacking place at an exceptionally rapid rate, the city is unable to cope with changing situations due to their internal resource constraints and management limitations. In recent years Dhaka City is facing extensive water logging during the monsoon (May to October) as a common and regular problem of the city like water pollution, traffic congestion, air and noise pollution, solid waste disposal, black smoke etc. This research applied remote sensing and GIS techniques to detect the low land status in different time period and the trend of unplanned urbanization that is one of the major causes of water logging in Dhaka City. Remote sensing could provide timely and low-cost information on floods and land use status whereas GIS is an excellent tool in handling information in land management and flood mitigation. Management of drainage system of Dhaka City is presently a challenge for the urban authorities because of rapid growth of population and unplanned development activities. Therefore, a close coordination among urban authorities and agencies and collaboration between public and private sectors is needed for effective management and sustainable operation of urban drainage system. It ascertain the inherent causes of such water logging and its effects on the city life from the perception of authorities of different development organizations, experts and people living in different parts of Dhaka City.

Chapter 01

INTRODUCTION

Dhaka, the capital of Bangladesh is one of the most densely populated cities of the South-Asian countries. Due to rapid urbanization process, the city is emerging as a mega-city and this trend generates numerous economic and social externalities and social cost such as deterioration of environmental quality, increased pollution and congestion. Dhaka City is beset with a number of socio-environmental problems. Water logging, traffic congestion, solid waste disposal, black smoke from vehicular and industrial emissions, air and noise pollution, pollution of water bodies by industrial discharge etc. are problems of the city.

The level of urbanization in Bangladesh is still quite low; only around 25% of the population live in urban areas. However, the capital city Dhaka has a population of 10 million, which is growing annually at the rate of 4-5% (Islam, 2001). It is predicted that the population of Dhaka City would reach 22 million in 2015, when it will become the second most populous city in Asia. Internal migration has caused a surge in residential demand in Dhaka City. Such a situation has forced the people to build their houses in an unplanned way and indiscriminate filling up of low-lying flood plains as well as rivers and the canals, which used to carry the rain water to the rivers. The water bodies which used to act as retention ponds to store flood water, are gradually being filled up. A recent phenomenon has been the inundation of Dhaka City after rainfall which brings life almost to a standstill. For example in 2004, after a heavy rainfall of 600 mm in 5 days, large areas of the city went under water and it took more than a week for the water to recede (MDB, 2005).

1.1 Statement of the Problem

During the monsoon from May to October, the drainage of the Dhaka City is mostly dependent on the water levels of its peripheral river systems. During this period, river water levels generally remain higher than the internal drainage level. This major constraint to the effective surface drainage within the city area is aggravated by the wide range of rainfall intensities that prevail during the monsoon period. The situation worsens when monsoon runoff generated from short duration and high intensity rainfall coincide with high water level in the river systems. Flooding in the Dhaka Metropolitan area can be classified into two types. One results from high water levels of the peripheral river systems, thus rendering any natural drainage impossible. Another is caused by high intensity storm rainfall runoff in the city area which causes flooding also in situations where natural drainage might be possible.

1.1.1 River Flooding

River floods generally take place in the low-lying fringe areas outside the protective embankments once every five to ten years. Dhaka City has experienced major flooding in 1954, 1955, 1970, 1974, 1980, 1987, 1988, 1998 and 2004. Among them, the 1988 and 1998 flood were the largest ever recorded. Poor drainage capacities of the existing *khals* caused long flood duration in inland areas and aggravated flood damage.

1.1.2 Rainfall Induced Flooding

Floods caused by local rainfall occur in the built-up areas of the city several times a year. These floods are mainly caused by inadequate existing drainage paths and their improper operation and maintenance. The severe water logging which occurred in September 2004 was caused by blockages of the drainage system due to huge volumes of garbage and poly-bags. The areas of Shantinagar, Paltan, Motijheel, Tejgaon, Gulshan, Mirpur which include many of the important business and Government offices of the country suffered most. Important street intersections were inundated for four days during this time. The situation was severely aggravated because of reducing detention basin, which conveys storm runoff from the areas to the receiving rivers.

Bangladesh is located on the extensive floodplains of the Ganges and Brahmaputra. Therefore, flooding is a natural part of the life of its inhabitants. Thus water logging in Dhaka City is not a new problem but the frequency of this problem is increasing day by day (Haq and Alam, 2003). Even a little rain causes a serious problem for certain areas so that parts of Dhaka are inundated for several days.

1.2 Application of GIS and RS

The use of RS and GIS has become an integrated, well-developed and successful tool in land use mapping, identifying the urban trend and hazard identification etc. It is defined as a "powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from a real world for a particular set of purpose". GIS allows the combination of different kinds of data using models. GIS allows the combination of the different kinds of spatial data, with non-spatial data, attribute data and use them as useful information in the various stages of planning and development.

Remote sensing and GIS provide a data base from which the evidence left behind by disasters can be interpreted, and combined with the other information to arrive at hazard maps, indicating which area is potentially dangerous. Using remote sensing data, such as satellite imageries and Aerial photos, allows us to map the variability of terrain properties, such as vegetation, water, geology, both in space and time. Satellite images give a synoptic overview and provide very useful environmental information, for a wide range of scales, from entire continents to detail of a few meters. Many types of disasters, such as floods, droughts, cyclones, volcanic eruptions, etc. will have certain precursors that satellite can detect. Remote sensing also allows monitoring the event during the time of occurrence while the forces are in full swing. The vantage position of satellite makes it ideal for us to think of, plan for and operationally monitor the event.

This research reflects the increase of built-up areas with progression of urbanization using GIS and Remote Sensing (RS) techniques.

1.3 Objectives

The present research was conducted for detection of land filling expansion from 1955-2006 in Dhaka City with detailed focus on the Begunbari *khal* and it's surrounding retention area, which is one of the most important wetlands in the city. The city rainfall-runoff is accumulated in this retention area and discharged to the surrounding rivers through canals. Besides using remote sensing technology, the study aims to

i) assess practical applicability of aerial and satellite data in land use mapping
ii) integrate RS survey information in disaster evaluation
iii) assess impact on drainage system due to unplanned expansion.
iv) scrutinize the vulnerabilities due to the impact of drainage system.

1.4 Scope of the Study

During the last 25 years substantial increase in built-up areas has taken place due to development of residential and commercial areas mostly through private land developers and real estate business. These activities resulted in substantial increase in impervious area, created obstruction to natural drainage pattern, and reduced detention basins, which in turn led to shortening of the runoff concentration time and an increase in the peak flow.

As population and land values increases, the effect of uncontrolled runoff became an economic burden and poses a serious threat to health and well being of citizens (Bari and Hasan, 2001). Management of runoff from even a minor storm is rapidly becoming an engineering requirement to help reduce water logging, flooding and stream erosion. It is important to realize that very few urban drainage systems are designed and built as a complete system. To overcome the water-logging problem of Dhaka City, it is necessary to find out the inherent causes of this problem considering its associated impacts on human life. Thus the study focuses to find out the causes addressing its effects of water logging due to storm water, which will be helpful to take appropriate steps for better management of the problem.

1.5 Literature Review

Water logging due to storm water is a very common problem like the other regular environmental problems of Dhaka City. But very few studies have been conducted on water logging and drainage system of the city and there is no study on the causes of such problem that exploited the potential of Geographic Information System (GIS) and Remote Sensing (RS) Technology. Some studies related to the drainage system and water logging of Dhaka City are described below.

Bari and Hasan (2001) investigated the impact of land use changes due to urbanization on storm runoff characteristics in the eastern part of Dhaka City. They found that the volume of peak rate runoff increases with growth in urbanization. Most of the low lying lands, which once acted as retarding basin, have been filled up. Computed results show that runoff volume is increasing with increase in built-up area in Dhaka city.

Chowdhury, J. U. et al. (1998) have shown from the analysis of rainfall data that the spatial variability is quite large. The aerial reduction factor is likely to be substantially lower than that used in the storm water drainage master plan for Dhaka City. Analysis of storm rainfall and runoff data indicates that the initial loss is much higher than those expected in cities in developing countries. The runoff ratio and runoff coefficient are found substantially smaller than those used in the storm water drainage master plan for Dhaka City. There is domestic wastewater discharge in the storm sewers and the relative magnitude was highest in the unplanned high-density residential area. Deposition of solid materials and rubbish is larger in the surface drains than that in the underground sewers.

Dhaka Water and Sewerage Authority (DWASA) (2000) described that before 1947, storm water of Dhaka City drained out through different natural canals. But thereafter, the city developed spontaneously without any master plan causing depletion of natural drains.

Institute of Water Modelling Center (IWMC) in order to evaluate and optimize the various alleviation schemes conducted a pilot hydrodynamic drainage model study for a sub-catchment of the city. The MOUSE model was selected for the modelling study. MOUSE computes water levels and flow both for the drainage pipes and for the streets. In order to evaluate the results in terms of street flooding for the various alleviation schemes a Digital Elevation Model (DEM) has been established for the catchment area. The ArcView based MOUSE GIS system uses results from MOUSE (given as water depths in the streets) and the DEM to generate flood inundation maps. Flood maps visualises the spatial variation of the depth and extent of urban flooding scenarios for both historic as well as future scenarios

The integration and application of the MOUSE model with ArcView GIS provides a methodology for developing sustainable alleviation schemes. Such an integrated approach provide a very cost efficient system for planning and management of the drainage system of Dhaka City in the future. The developed technology can easily be transferred and applied to catchment areas experiencing similar problems.

1.6 Limitations

Some limitations were encountered during the study period to complete research work according to the selected objectives. These limitations are described below:

Very few studies were conducted related to water logging and drainage system of Dhaka City. As a result, there was not sufficient literature to enrich the analysis of this study by reviewing their study findings.

There was no sufficient secondary data to collect related to past drainage system in terms of width, length, depth, capacity, peak flow rate, drainage coefficient etc. and their layout. Therefore, it was not possible to compare the capacity of present drainage system to drain out the stagnant water with the past, which was needed to enrich the recommendations to reduce the problem.

It was very difficult to get reach of the required RS data for bureaucratic problem. Due to the lack of detailed elevation data, sometimes it was very hard to measure the actual depth of low land. The defensive attitude of responsible authorities related to the problem and their reluctance to provide relevant data has limited the information.

Chapter 02

METHODOLOGY

Workflow of the study is shown in Figure 1.1. This shows the main input information and generated output for mapping and estimating land cover map. It was observed that the land use as well as land cover of the city is very heterogeneous. Therefore, visual interpretation, the most primitive method in land cover mapping was adopted here to relate human knowledge with machine power to generate most accurate land cover of the city. As the main task was to identify general land use in the area, very detailed land cover classes were not considered in this research.

It was not difficult to identify land coverage variation from high resolution RS image. However in some cases, topography map was used to further clarify high and low land areas where there was ambiguity in interpreting RS data.

2.1 Hardware and Software Used in the Study

For the research ERDAS Imagine version 8.7 was used for image processing, image analysis by digital interpretation statistics generation etc. ARC/INFO GIS software was also used. Bangladesh Space Research and Remote Sensing Organization's (SPARRSO) provided hardware support.

2.2 RS Data Sets

The shift from wetland to build up areas was detected by visual and digitized interpretation of different aerospace data sets of different years as follows:

- Aerial photo of 1955
- Aerial photo of 1983
- Satellite Image (Digital Globe) 2006

2.3 Other Maps

For the purpose of the present study, topographic survey maps (1962 & 1998) were collected from Survey of Bangladesh. The existing land use map was collected from Rajdhani Unnayan Kartripakkha (RAJUK) and the land use of different periods were collected from some relevant literatures and organizations. The existing drainage layout map was also needed and this was collected from the Institute of Water and Flood Management (IWFM).

2.4 Other Secondary Data

Rainfall data and the storm water drainage system data were needed for the study. The rainfall data was collected from the Bangladesh Meteorological Department (BMD) and the drainage data was collected from the Drainage Department of Dhaka City Corporation (DCC). The past and present data on natural drainage system was collected from different land use maps prepared by RAJUK. Some literature related to the topic has been reviewed for better understanding of the problem and their main objectives and outputs are attached at the end of this chapter.

2.5 Ground Truth & Filed Survey

Extensive field works were made for ground truthing with a view to collecting information regarding the land use changes and environmental concern of local people through the informal interview. It also covered the people's perception on conservation and sustainable development. Informal interview of official experts of different development agencies was also done in order to know their view of causes and effects of water logging in Dhaka city and sustainable solutions.

2.6 Data Analysis, Integration and Presentation

All the data, both spatial and aspatial collected from different sources have been analyzed separately. The spatial data have been analyzed using some Geographic Information System (GIS) software like Erdas Imagine, Arc/info, Arc/View and aspatial data was analyzed using some other statistical computer software like, Microsoft Excel. Finally both types of analyzed data have been integrated and presented as maps, tables, and graphs and inserted in the report.

As mentioned before satellite and aerial photographs of different time period were used for this research to extract information about land and water bodies. In order to extract the above information images were processed using digital image processing techniques. An overview of the inter-linked methods that was used in the research is presented in Figure: 2.1

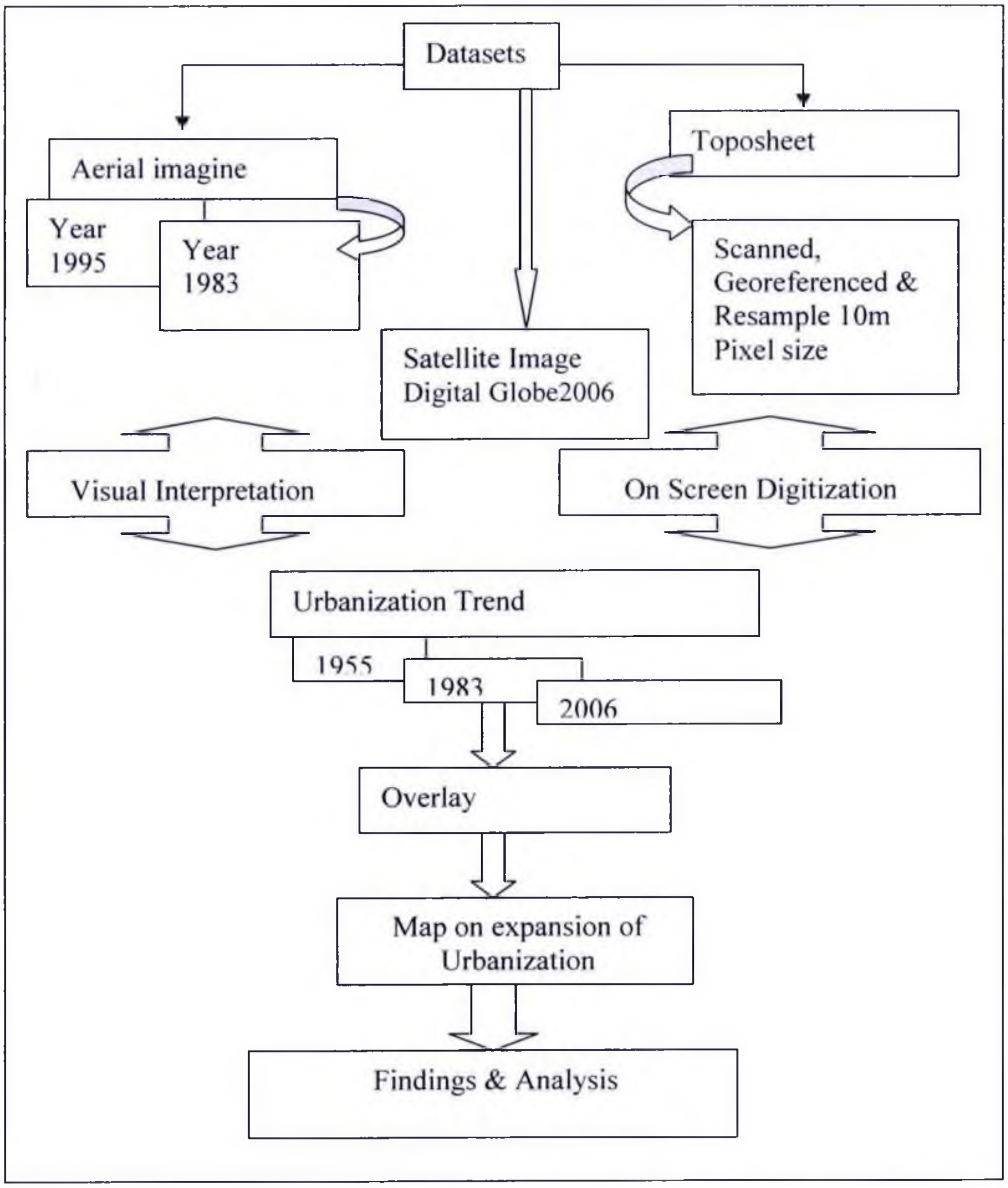


Figure 2.1: Flowchart of the methodology

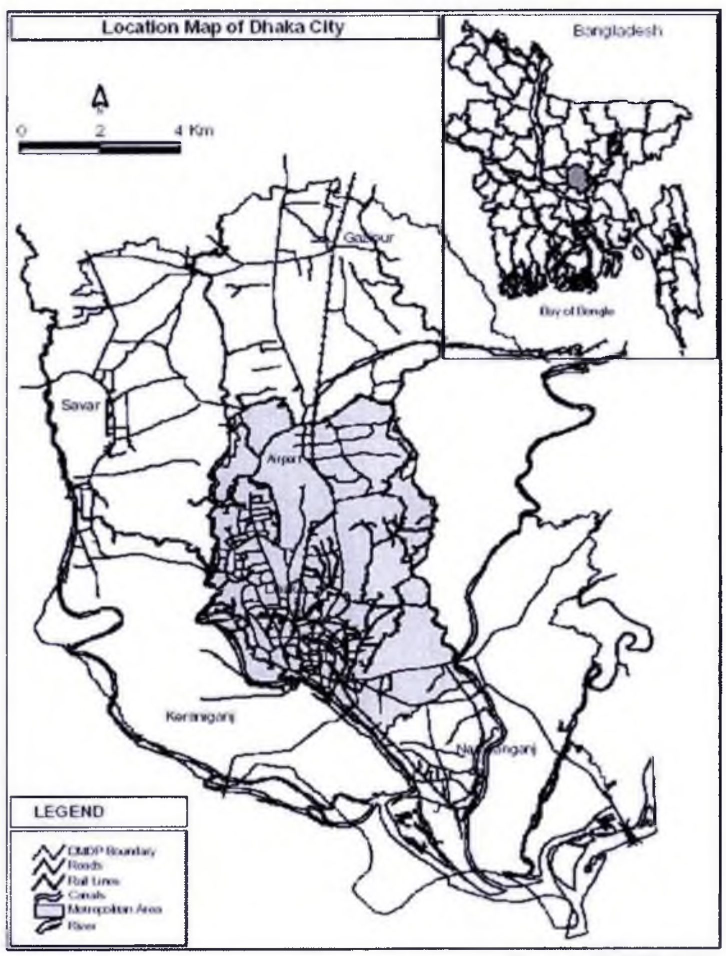
Chapter 03

BACKGROUND OF THE STUDY

3.1 Study Area

3.1.1 Location

Dhaka is confined between latitudes 23°40'N to 23°50'N and longitudes 90° 20'E to 90° 30'E. Geographically, Dhaka is located in Bangladesh and situated on the northern bank of the river Buriganga (Figure: 3.1). The City is surrounded by the river Buriganga in the south, the Balu and the Shitalakhya Rivers in the east, Tongi *Khal* in the north and the Turag River in the west. It occupies a land surface with an elevation of 1.5 to 13 meters above mean sea level and most of the part remains above normal flooding



Source DMDP, 2004

Figure 3.1: Location of Dhaka City

3.1.2 Area and Population

Dhaka, a mega city stretching around an area of 590 sq. mile, is now a city of about 10 million people growing in an annual rate of 6 percent (Islam, 2000). Metropolitan Dhaka has two connotations, first is that of central city i.e. Dhaka City Corporation covers an area of 200 sq. mile and the population is about 8 million, and the other one is the Dhaka Statistical Metropolitan Area (DSMA) (Figure: 3.2) covers an area of 550 sq. mile (Islam, 2000). Dhaka Statistical Metropolitan Area (DSMA) was considered as the study area but instead of 550sq.mile only 485 sq. mile was taken into account due to accessibility of the aerial images.

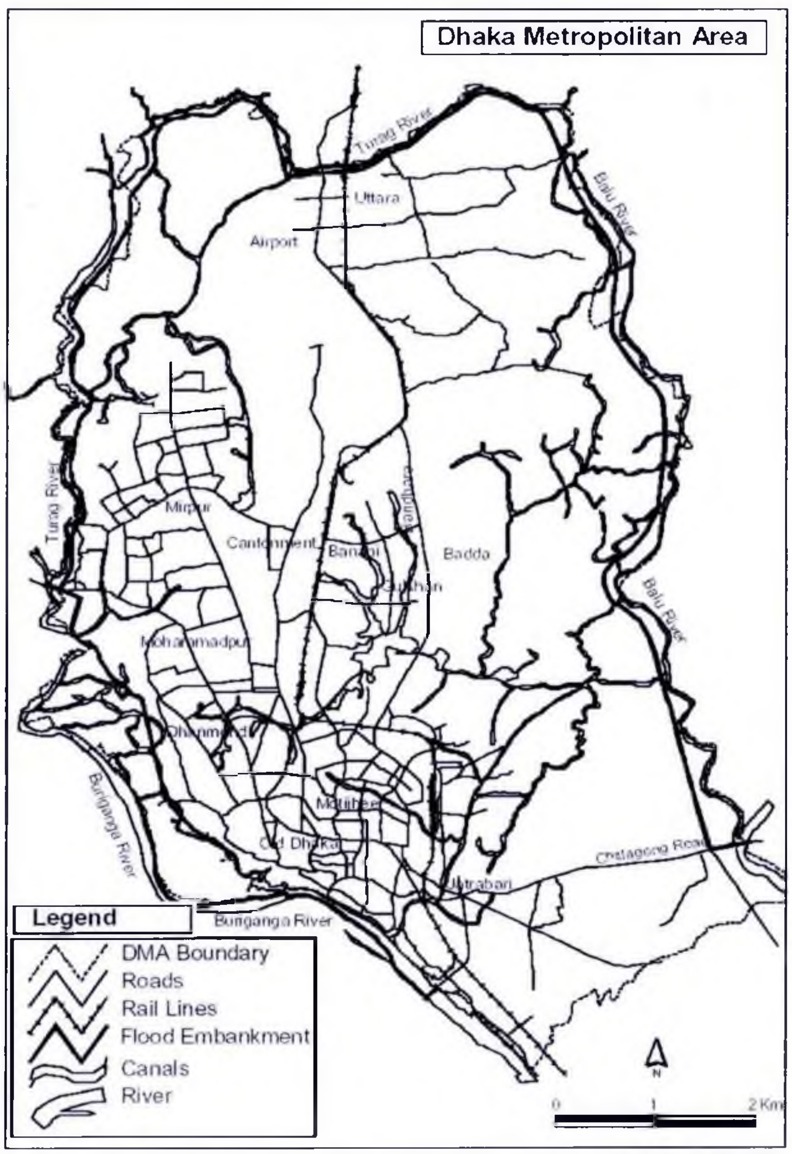


Figure 3.2: Study Area (Dhaka Metropolitan Area)

3.1.3 Population Growth and Unplanned Development

Dhaka City, being the administrative, commercial and cultural capital of Bangladesh has now turned into the 26th Mega City and the 10th most populous city of the world. It is the nerve center of the country. The population of Dhaka has grown from only 0.1 million in 1906 to 3,36,000 in 1951 and 10.71 million in 2001 (BBS, 2003). It is growing at an alarming rate (5.6% during 1991-2001 inter-census periods). As per prediction, this population will further grow to about 20 million by the year 2020 and to 25 million by 2025 (DMDP, 1997). A principle reason of such a rapid growth is over concentration of activities and development work in the city and little improvements in other cities, towns and villages in terms of infrastructures development and economic activities. Improved road communication in the country further made it easy to converge on the capital in search of employment and better quality of life.

Table-3.1 Changes in Area and Population of Dhaka since the Year 1600

Year	App. Area (sq. mile)	Total Population
1600	1	200,000
1700	50	900,000
1800	8	200,000
1901	10	104,385
1921	12	137,908
1941	12	239,728
1961*	26	556,712
1981*	155.4	3,430,311
1991*	522.34	6,950,920
2001*	590	10,712,206
1981**	50	2,475,710
1991**	54.4	3,839,000
2001	225	5,339,880

Source: Islam (2001)

* DSMA: Dhaka Statistical Metropolitan Area
** DCC: Dhaka City Corporation

3.1.4 Land Use

Dhaka started to develop in a comparatively planned way after 1947 when it gained regional and political importance (Chowdhury, 1998). Previously, commercial and residential areas were situated side by side, mostly concentrated beside the narrow roads, Old Dhaka still presents this situation with a mixture commercial, residential and small industries. After preparation of the Master Plan of the city in 1958, the commercial centers of the city was located in Motijheel and a high class residential area was developed at Dhanmondi. Housing colonies for government employees, universities, parks, commercial and industrial zones, lakes and other public facilities were developed gradually to meet the demands of the expanding city.

Around 1980 RAJUK (Rajdhani Unnayan Katripakhya) prepared a housing development program and after that many private housing developers started filling up low lands that caused serious damage to the environment. The encroachment is now proceeding so quickly that the transformation of the lower areas into a built up zones is just a matter of time. Absence of adequate parks, open water bodies, and drainage system has degraded the quality of living in the city in many ways.

The low land used to get flooded to a depth of 1.5 to 4.5 m during the monsoon season, with the water level rise in the river Turag , Balu and Buriganga. The land use distribution pattern in recent times of greater Dhaka City includes residential 52%, commercial 34%, industrial 12%, water bodies 7%, and open fields 2% (Bari and Hasan, 2001).

3.1.5 Climate

The tropical climate of Dhaka is marked by the fairly different six seasonal variations. Rainfall in Dhaka occurs from three main sources: i) the western depression of winter, ii) the early summer thunderstorms know as Nor'westers, and iii) the summer monsoon. It is hot and humid during May to October while cool and dries during November to February. The rainy season generally prevails from May to October. Approximately 90 % of the annual rainfall occurs during this time and the average annual rainfall is about 2000mm. Heavy rainfalls, sometimes extending up to several days, are common during the monsoon. The total annual rainy days vary from 95 to 131 days.

Rainfall is rather scarce during the months from November to February. The lowest temperature during this period may drop down to about 5^0C. On the other hand, temperature as high as 40^0C may occurs during the warm months of March and April. Monthly evaporation varies from 80 to 130 mm. (MDB, 2006)

3.2 Water Logging in Dhaka City

Water logging in urban areas is an inevitable problem for many cities in Asia. In Bangladesh, Dhaka has serious problems related to water logging. The situation was highlighted in September 2004 when residences experienced ankle to knee-deep water on the streets. Daily activities in parts of the city were nearly stuck and heavy traffic jams occurred due to stagnant water on the streets.

3.2.1 Drainage System of Dhaka City

Dhaka simply does not have a proper drainage and sewerage infrastructure. The city, moreover, is expanding both horizontally and vertically at an uncontrollable pace, along with its population. In comparison, the drainage and sewerage facilities have grown little over the years. WASA has 8 Km of box culvert, 225 Km of storm sewer line and 1100 Km of surface drain, which covers only 38 % of the city area.

The existing facilities cannot operate at full capacity because of poor maintenance. DCC and WASA, both government bodies are supposed to be responsible for protecting Dhaka from water logging. According to DCC, WASA is responsible for solving the water logging problem of Dhaka. Clearing the surface drain is DCC's duty, while WASA deals with underground drains. Since WASA has not been cleaning the underground drains for long time as a result water cannot pass at its normal pace through these clogged drains. WASA however, stated that as DCC has not cleared the surface drains properly, it further worsened the situation. The feuding between the two illustrates the lack of co-operation between various service providing agencies.

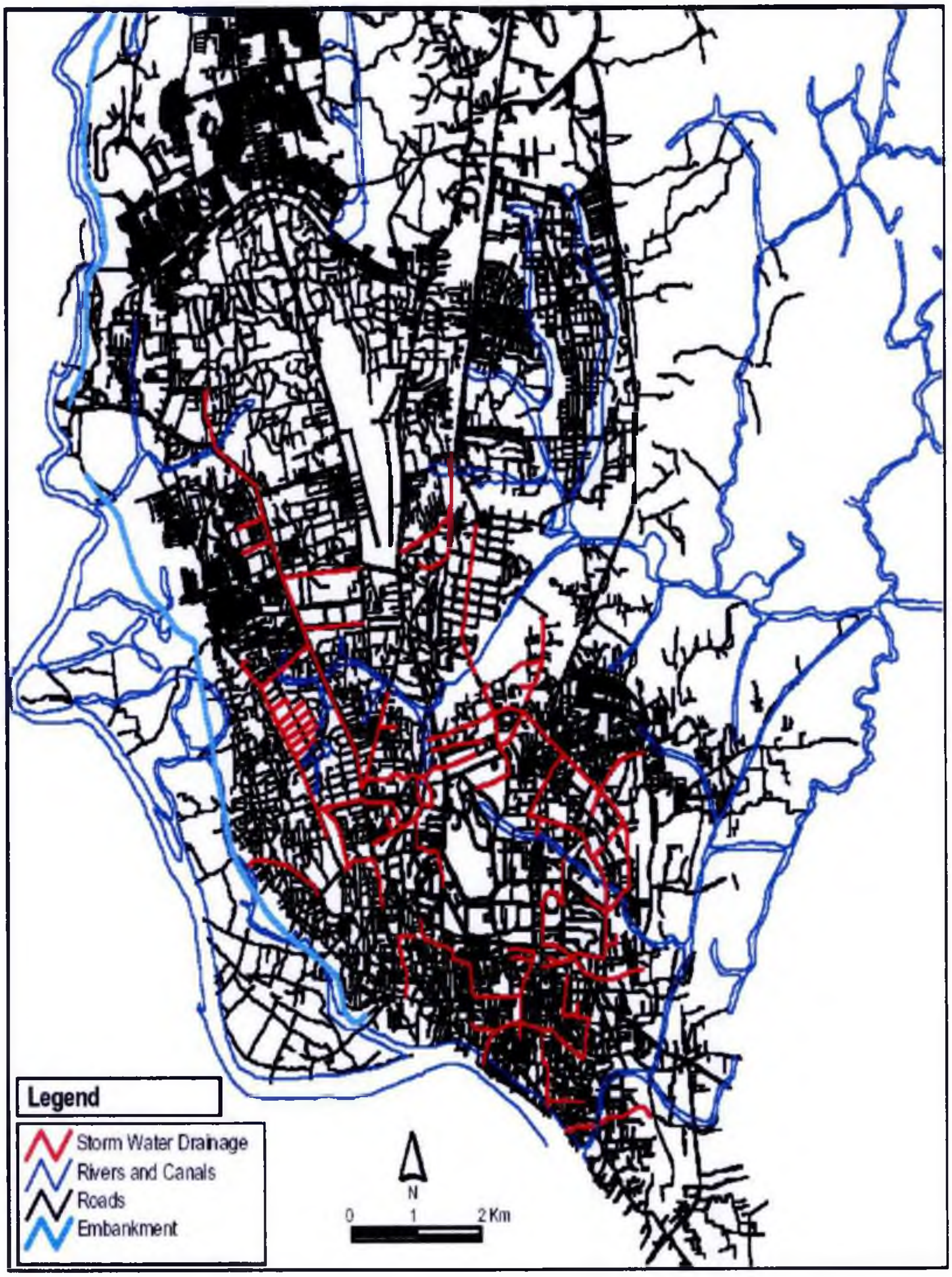
As a part of the drainage improvement plan of the Dhaka Metropolitan City, WHO and DWASA is currently rehabilitating the natural channel section of Segunbagicha *Khal* by replacing it with a concrete box culvert. After completion of 85% of the total works the construction has been stopped by court order due to land dispute with the owners. The total length of the box culvert is 2.1 km. Additionally; the following problems in the Dhaka drainage system have been identified by DWASA

- Unplanned urbanization,
- Expansion of the urban areas,
- Increases in built-up areas and metal roads,
- Filling of low-lying areas to construct buildings, with no or little provision for drainage,
- The main drainage systems of the urban area (*khals*) are blocked by unauthorized constructions,
- Insufficient storm sewers constructed in the extensions to the urban area,
- Lack of maintenance to the system,
- Lack of co-ordination among the different organizations engaged in the development works,
- Solid waste disposal in the storm sewer.

3.2.1(a) Drainage Zones and Storm Sewer Network

Dhaka WASA is responsible for the water supply and drainage of Dhaka City. Drainage is managed through two separate sewer systems: one for drainage of domestic wastewater and the other for drainage of storm water. The research topic is confined to the storm water drainage system.

Operation and maintenance of the storm water drainage system is organized by the Drainage Circle of Dhaka WASA. Greater Dhaka City area is divided into 12 drainage zones (JICA, 1991). The division is on the basis of drainage channels and outfall to the surrounding rivers. The storm water drainage network is shown in Figure 3.3



Source: Water and Flood Management (IWFM).

Figure 3.3: Drainage Zones and Storm Sewer Network of Dhaka City

The present storm water drainage network under Dhaka WASA covers an area of approximately 140 sq. km. Important components of drainage network are briefly summarized below.

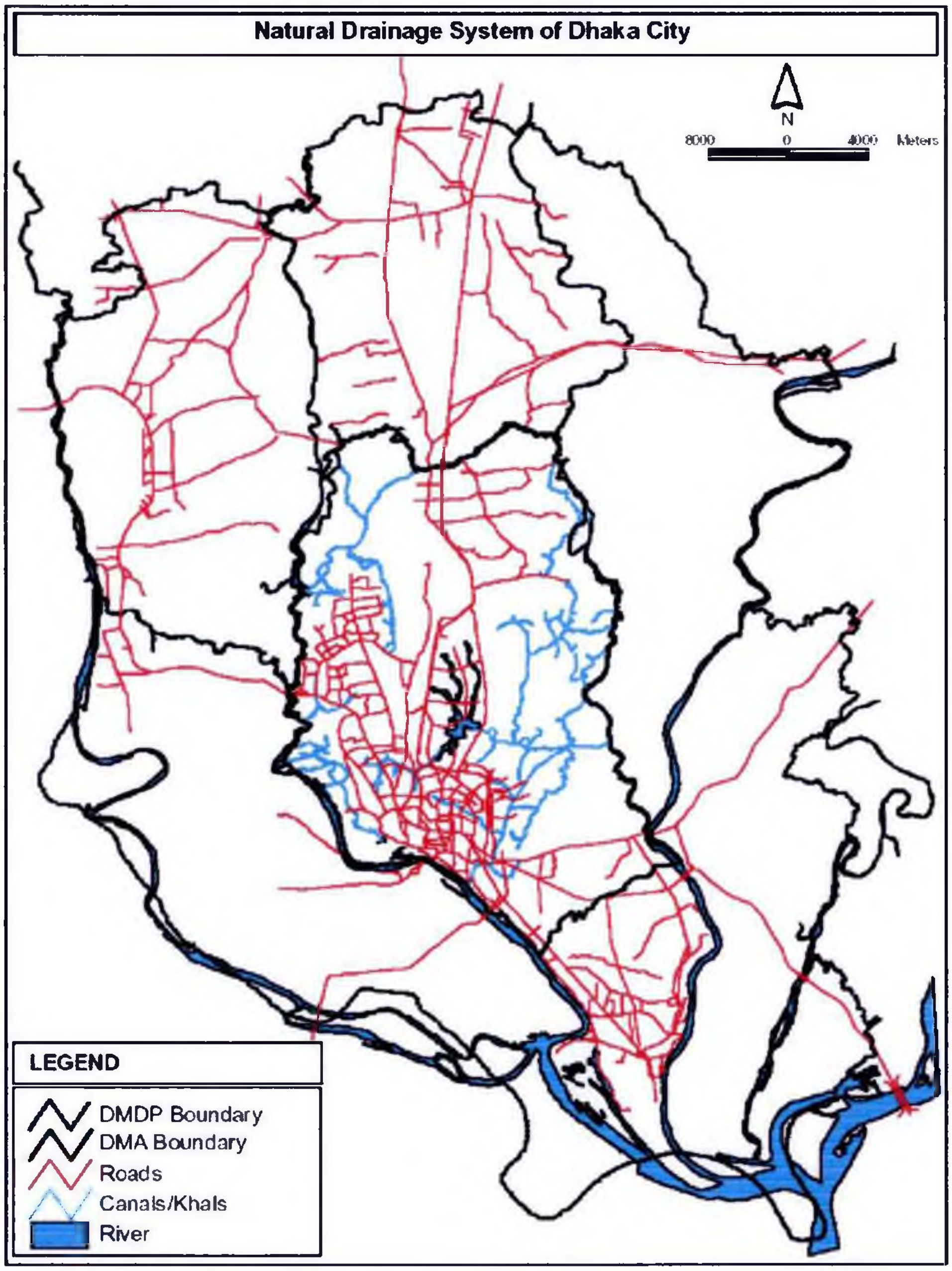
- 22 open canals having a width of 10 to 30 m and total length of approximately 65 km.
- 185 km. of underground pipes having diameter ranging between 450 to 3000 mm.
- 6.5 km. of box culvert of sizes between 2.5 m * 3.4 m to 6 m * 4.1 m.
- 2 storm water-pumping stations, having a capacity of 9.6 m^3/s and 10 m^3/s situated at Narinda and Kallyanpur respectively.
- Recently DCC has constructed one storm-water pumping station, having capacity of 22 m^3/s at the confluence of river Buriganga and Dholai *khal*. Dhaka WASA has taken over the operation and maintenance of the pumping station.

Bangladesh Water Development Board (BWDB) has also constructed one pumping station (capacity 22 m^3/s) at the northwestern part (Goran Chadbari at the outfall of the Degun khal into the Turag River) of the city. There are also 65 small pumps with individual capacities of 0.142 m^3/s, installed temporarily by Dhaka WASA to drain out storm water from various locations.

Moreover, DCC have constructed and maintained at least 130 km small diameter underground drains and approximately 1,200 Km surface drains, which carries storm water to the main sewer lines. RAJUK also constructs roadside underground drainage lines during the construction of new roads. The responsibility of development, operation and maintenance of drainage system in Dhaka City lies with Dhaka WASA. But several agencies are working for development of the city drainage system, with little or no coordination among them.

3.2.1(b) Natural Drainage System

The natural drainage system in greater Dhaka City comprises of several retention areas and *khals* (channels) which are linked to the surrounding rivers. The city rainfall-runoff is accumulated in the retention areas and discharged to the surrounding rivers through *khals*. (Figure: 3.4) Unplanned spatial development activities and growth of habitation due to rapid population growth are causing encroachment on retention areas and natural drainage paths with little or no concern for natural drainage system. Excessive rainfall, inadequate drainage sections, conventional drainage system with low capacity and gravity, natural siltation, absence of inlets and outlets, indefinite drainage outlets, lack of proper maintenance of existing drainage system, and disposal of solid waste into the drains and drainage paths are accounted for the prime causes of blockage in drainage system and water logging. In addition, seasonal tidal effect and the topography of the city are also reasons for water logging.



Source: Water and Flood Management (IWFM).

Figure 3.4: Natural Drainage System of Dhaka City

Chapter 04

DISAPPEARANCE OF NATURAL DRAINAGE SYSTEM

The disappearance of the natural drainage system is one of the main causes for water logging. Rapid population growth and unplanned development, unplanned land filling to develop new residential areas, uncontrolled and haphazard disposal of solid wastes and garbage into the existing drainage system, encroachment on lakes, *khals*/canals and rivers with unauthorized construction are the different general anthropological and social activities related to the disappearance of natural drainage system.

4.1 GIS Study of Dhaka City

4.1.1 Remote Sensing and GIS Integration

(a) Mutual Registration of Images

Since multi-temporal images have been used in this study mutual registration of these images were needed in order to extract the same study area from the images. Registration is the process of making image data confirm to another image. To perform registration, following steps were followed:

- Locate ground control points (G.C.P.)
- Re-sampling of image data
- Create an output image file

(b) Digitization

Aerial and satellite images have been used in the research were in digital format. The topographic maps were scanned to convert them into digital layout. The maps have been scanned using 300 DPI to restore all the map features in digital data layers.

All digitized images were accurately geo-referenced using control points from a reference image. After geo-referencing of the images the sample collection points have been digitized from the images using the ERDAS imagine digitization tools. A total of 158 points were digitized. The digitized data layers were managed to render GIS standard data layer using the ARC/INFO data management tools. The Arc Attribute Table (AAT) of the digitized data layer contains user interface for additional attribute data entry. The codes/attributes for the land use class have been entered for the digitized points. The points therefore contain the identification of the land use class for the particular sample.

(c) Image Interpretation

Aerial and high-resolution satellite images were used to identify the lakes, *khals* and low land. The imagery were interpreted using visual analysis techniques on large format. The interpret details were transferred on the output map that was prepared with the help of graticular information taken from the topographic map.

(d) Data Generation from RS Images

The ultimate objectives of data generation from RS images are to estimate the low land and other land use feature. However, this estimation involves a series of data generation functions to be applied to the images.

The study area is identified on images using a pre- geo-reference image with DCC boundary superimposed on it. Using a pre geo-reference image as reference, the images used in the study area were geo-referenced accurately. A total of 16-control points were derived from the reference images for geo-referencing.

Using a vector database of the study area was extracted from each of the geo-referenced images. The vector data layer of the points created in ARC/ INFO format has been exported to ERDAS Imagine point coverage compatible for surface generation using ERDAS Imagine interpolation tools. The data layers were then interpolated to generate the land use classes for the study area.

(e) Creation of GIS Database

- Aerial and high resolution satellite images contained the line coverage of roads railway, water bodies (lake, *khal*), low land and other infrastructure which were visible in tile imagery:
- Length of lakes, *khals* and adjoining low-lying area were measured in digital form with the help of vector database (Leaner and polygon ID)
- Depth of the low land was measured from digitized topography map by overlaying with the base map.
- By overlaying with a RAJUK layout map and RS images coverage of occupied lands by different organizations were measured.
- All the coverage were transferred into the real world coordinate system (Lambert conic conformal system, Everest Projection)
- The polygon and line topology were built for all the above coverage.
- Overlay coverage was created using satellite and aerial photographs of different time period (1955-2006) for analysing the land use changes.

(f) Creation of Map

As part of the GIS study three maps of Dhaka City have been produced. The map generation tool of ERDAS Imagine is used to create the maps of different time periods. (Figure 4.1-4.3)

The detailed maps of Begunbari area show the spatial distribution of various feature types, specially the *khal* and adjoining low area in three different years. Finally an overlayed map was created where the encroachment of low land from 1955-1983 and 1983-2006 have been shown. (Figure: 4.6) These maps are very useful to find out the trend of grabbing land over the period in the area.

4.1.2 GIS Based Statistical Analysis

The lakes, *khals* and adjoining low area statistics have been obtained from the GIS-based statistical analysis (Table- 4.1). The area of low land as calculated from this data base of 1955 image was found to be around 329.80 mile^2, which is 68 % of the total land (considering the study area) where in 2006 the low land has been found to be around 92.15 mile^2, which was 19% of the total land area. (Appendix-D)

Table 4.1: Total land area (high, low) in different time period

Land Type	Year		
	1955	1983	2006
High Area ($mile^2$)	155.20	218.25	392.85
% of Total Land (Study area)	32%	45%	81%
Low Area ($mile^2$)	329.80	266.75	92.15
% of Total Land (Study area)	68%	55%	19%

*Study area = 485 $mile^2$

4.1.2.a Urbanization Trend and Impact on Wetland

Dhaka Metropolitan City is bounded by Tongi *khal* on the north, the Turag and Buriganga Rivers on the west and as the Balu River on the east (Figure-3.1). A good number of *khals* crisscrossing the city have some of their out falls in these rivers and are playing a very significant role in the drainage of the city area. Most of the natural drainages of Dhaka City disappeared or are in way to lose their existence due to illegal encroachment. Encroachment on the rivers and *khals*/drains through unauthorized construction and solid waste, and the lack of regulations to prevent encroachments make the drain ineffective to drain out the run off.

(i) Between 1955-1983

Between 1955 and 1983 the trend of urbanization was slower than in the period of 1983-2006. In 1947, India become independent of British rule and Pakistan was created. Dhaka became the capital of East Pakistan. To cater to the ever-increasing residential needs of the new capital, Dhanmondi area, which had much marshland in the early 1950s, was developed as a residential area after 1955. The pressure of the increased population created an impact on the marshlands and lakes of Dhanmodi. Around 0.705 km^2 (Table: 4.2) of lake area vanished within Dhanmondi to meet the dense population demand. (Figure 4.5 & 4.6)

Table 4.2: Major Characteristics of Lakes in Dhaka City

Year 1955

Name of the lakes	Length (m)	Ave. depth (m)	Area (km^2)
Dhanmondi	3048	2.5	0.991
Ramna	674	4.5	0.057
Gulshan	5235	2.5	1.879

Year 1983

Name of the lakes	Length (m)	Ave. depth (m)	Area (km^2)
Dhanmondi	2960	2.5	0.286
Ramna	448	4.5	0.043
Gulshan	4328	2.5	1.258

Dhaka Improvement Trust (DIT) developed the Gulshan Model Town in 1961, Banani in 1964, Uttara in 1965 and Baridhara in 1972 (though first conceived in 1962). The creation of Gulshan, Banani, and Baridhara Model Town has left a huge impact on Mohakhali, Begunbari and Gulshan Lake.

Along with the government agencies, private organizations and individuals encroached on the adjoining low-lying areas for high demand as this was declared the 'Diplomatic Zone' of the country. From 1955 to 1983 huge amount of low land was filled in Gulshan area that is around 0.621 km^2 and constructed the Gulshan-Baridhara road intersecting the lake, which affected the length of the lake.

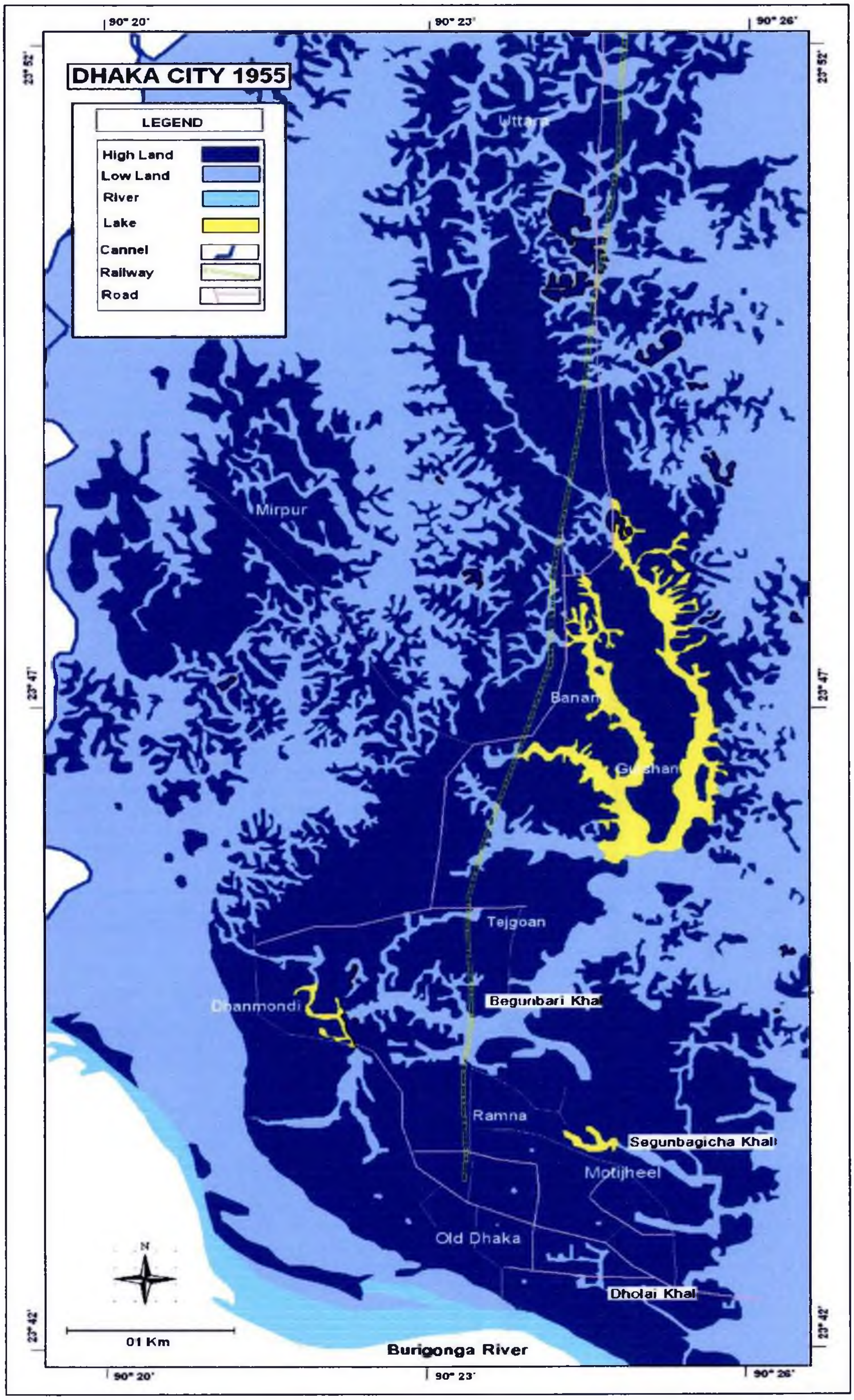


Figure 4.1: Dhaka City in the year 1955

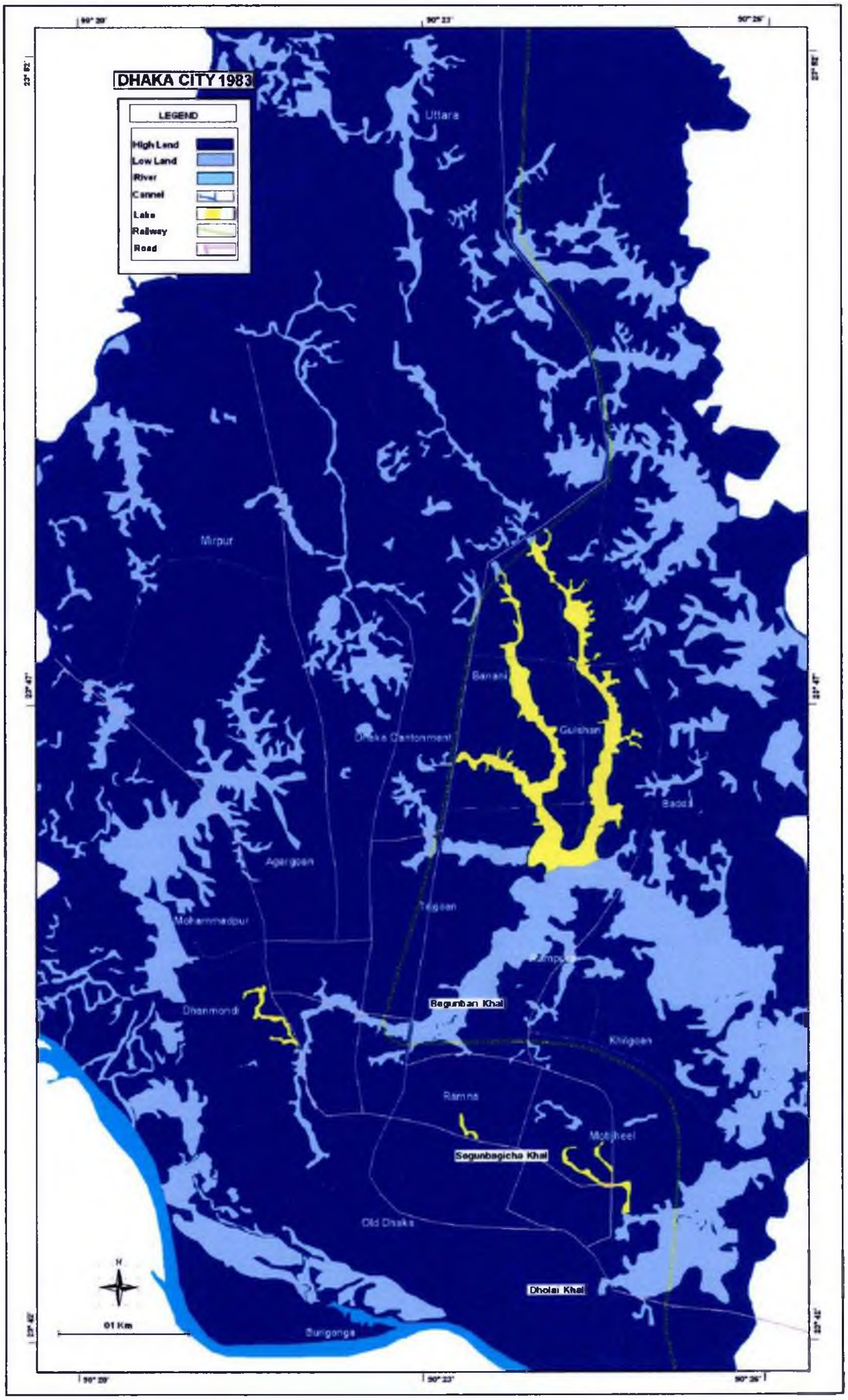


Figure 4.2: Dhaka City in the year 1983

Because of this 'diplomatic zone' area, the price value of land increased along with the demand, and the surrounding low-lying area of Gulshan-Baridhara and Badda were filled up which further affected the adjoining low area of Begunbari *Khal*. On the other hand in the second half of the 1960s after Dhaka declared as the capital of East Pakistan, development started in the area of west Tejgaon Industrial area and the Airport (now known as Sher-e-Bangla Nagar). With the establishment of DIT in 1956 (transformed into the Rajdhani Unnayan Kartripakkha in 1987) greater interests and care was undertaken in road construction and city planning. This sort of development caused disappearance of the Begunbari low land which was about 0.09 km^2 (Table: 4.3) The encroachment rate in Begunbari area was 6.78% where in year 1983-2006 was 41.32% (Calculating from GIS database 4.3)

Table 4.3: Characteristics of major *khals* in Dhaka City

Year 1955

Name of the khals	Length (Km)	Area (km^2)
Dholai khal	4.9	0.039
Segunbagicha khal	3.5	0.024
Begunbari khal	4.4	1.317 (Include adjoining low area)

Year 1983

Name of the khals	Length (Km)	Adjoining Low Area (km^2)
Dholai khal	4.6	0.031
Segunbagicha khal	3.5	0.022
Begunbari khal	4.4	1.224 (Include adjoining low area)

Dilkusha Gardens adjacent to Motijheel came to be engulfed by the ever-growing commercial needs. In the mid-1960s the main railway line was shifted and directed eastward. Moreover Dhaka Railway Station was moved from Phulbaria to Kamlapur. This eliminated the landmark that had long stood between the 'Old Dhaka' of the Mughals and the 'New Dhaka' of the British. The rapid growth and development of the area between the old railway track and Kawran Bazar forced this change. Segunbagicha *Khal*, once a time connected with Ramna Lake faced serious threat due to growth and development of Motijheel and Ramna area. Around 0.002 km^2 of adjoining low land from Segunbagicha *Khal* vanished during this period but Ramna Lake located in the park area remained quite safe and sound. It should be noted that during this period, *Dholai Khal* also under threat for rapid encroachment (from 0.039 km^2 in 1955 to 0.031 km^2 in 1983). (Table: 4.3)

Mirpur Road formed an axis, and the highlands on both sides of the road were occupied till Mohammadpur and Mirpur. In the mid-1960s these two areas were developed by the government mainly to accommodate the migrant Muslim population. Due to the expansion of residential areas huge amount of wetlands vanished within a short period of time.(Figure 4.1 & 4.2)

Dhaka City became the capital of the independent state of Bangladesh in 1971. This additional factor as well as the initiatives of private sectors led to Dhaka's phenomenal growth since 1971. With increased population pressure the highlands spreading northward were occupied and built up. The intervening ditches, swamps and marshes were filled in, not in any planned manner, but as exigencies arose and private initiatives dominated the process.

Development under the aegis of the DIT dictated nature rather than allowed nature to direct planned growth. In selecting the sites for the Model Towns of Gulshan, Banani, Baridhara and Uttara, the method of selecting the highlands on the main Dhaka-Tongi axis road is clearly discernible. No serious effort at reclaiming land under a well-planned scheme to give the city a homogenous and cohesive growth is visible. Dhaka has grown on its own in a haphazard manner and the topography of the area dictated the terms and direction of the growth.

(ii) Between 1983-2006

Since Dhaka became the capital of an independent country the pressure on it was enormous. The permanent inhabitants of the city have registered a steady growth. Along with it, there was a very large floating population, the pressure of which has resulted in the growth of slums many available vacant and low lands.

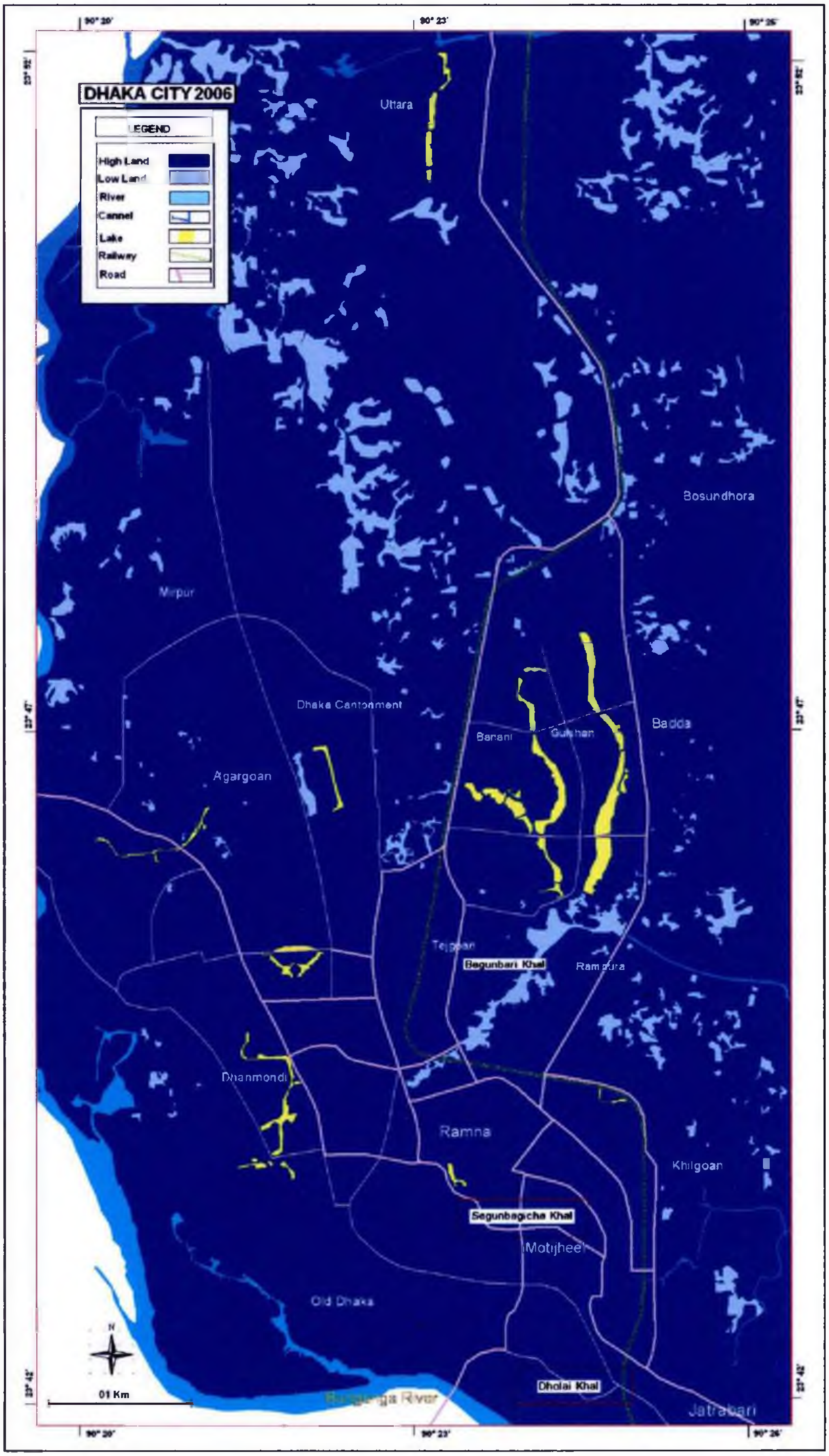


Figure 4.3: Dhaka City in the year 2006

Table 4.4: Characteristics of major lakes in Dhaka City 2006

Name of the lakes	Length (m)	Ave. depth (m)	Area (km^2)
Dhanmondi	2360	2.5	0.209
Ramna	422	4.5	0.040
Gulshan	3605	2.5	0.495

Table 4.5: Characteristics of major khals in Dhaka City 2006

Name of the khals	Length (Km)	Catchments Area (km^2)
Dholai khal	4.0	0.024 (convert to box culvert)
Segunbagicha khal	3.5	0.017(convert to box culvert)
Begunbari khal	4.27	0.719 (Include adjoining low area)

From the GIS data it was found that, the rate of encroachment in Begunbari and Gulshan area is far higher than that of Dhanmondi and Segunbagicha *Khal.* It is because of Dhanmondi and Segunbagicha area there were very few lands left for grabbing. In the period of 1983-2006, only in Gulshan area, around 0.763 km^2 of low land filled for development. The Begunbari Khal, one of the most important retention areas is under serious threat of encroachment during this period. Around 501 km^2 of land were grabbed by different private developers, individuals as well as the government. During this period, a culvert was constructed over the *Dholai Khal* which reduced the catchment area of the *khal* and the land surrounding it was grabbed by various quarters.

Compare the 1983 and 2006 GIS data, in Khilgaon area, the Ministry of Housing and Public Works is filling up a large area under a rehabilitation programme to compensate those who lost their land to Kamlapur railway station more than 50 years ago. Housing companies have embarked on filling up whatever is left of the flood plains in Boather, Gaoir, Joarsahara, Baiderter, Meradia, Goran, Madartek and Manda areas.

The recent phenomenon of high rise buildings, both in the commercial and residential sectors occupy the city's highlands and demonstrate ever-increasing pressure on Dhaka as it builds upwards, an inevitable and common phenomenon in all modern cities facing population growth. It has been observed that more than the government agencies the private developers are main land grabbers of the city. As there is less land left the private organization are now filling in the main channel flow.

Since the 1990s, Dhaka has been on the verge of change in its urban character with vertical growth replacing horizontal expansion. The filling-up of vast areas in Ashulia, Banashree, Aftabnagar, Meradia, Baunia, Badda, Amin Bazar and Hatirjheel, increased the hazards of water logging that swamped much of the city. The Dhaka Master Plan has clearly marked these areas for flood retention and the Wetland Conservation Act, 2000 bars land development in water bodies. According to the Conservation Act, no one has the right to develop wetlands, flood flow zones or catchments. But the developers and land owners have occupied and filled the areas. illustrates that a developer filled-up the low land for the development of housing that is clearly marked as flood flow zone in DMDP (Figure- 4.4)

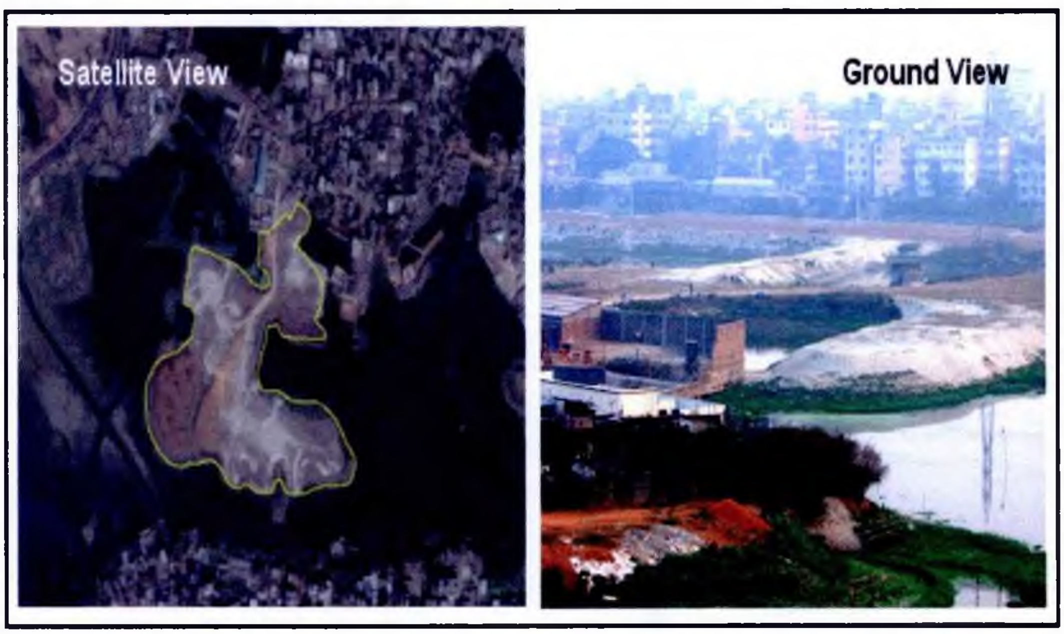


Figure 4.4: Begunbari *Khal* and adjoining lowland filled up by a private developer

4.2 GIS Study of Focus Area: Begunbari *Khal*

4.2.1 Location of the Focus Area

The emphasized area is locally named "Begunbari *Khal* (Canal)" is about 0.719 km^2 of total retention area. Some of its portions are situated in Dhaka City Corporation's (DCC) Ward no 37 and the rest is at ward no 22 (near Rampura). This canal is surrounded by Gulshan, Badda, Rampura, Madhubag, Mirbag, Tejgaon Industrial Area, Ulan, Karwanbajar and Eskaton. (Fig: 4.5)

The *khal* drains storm water from the upstream drainage catchments area of 24.76 km^2. The elevation of the area is 2 to 13 meters above the mean sea level (msl)

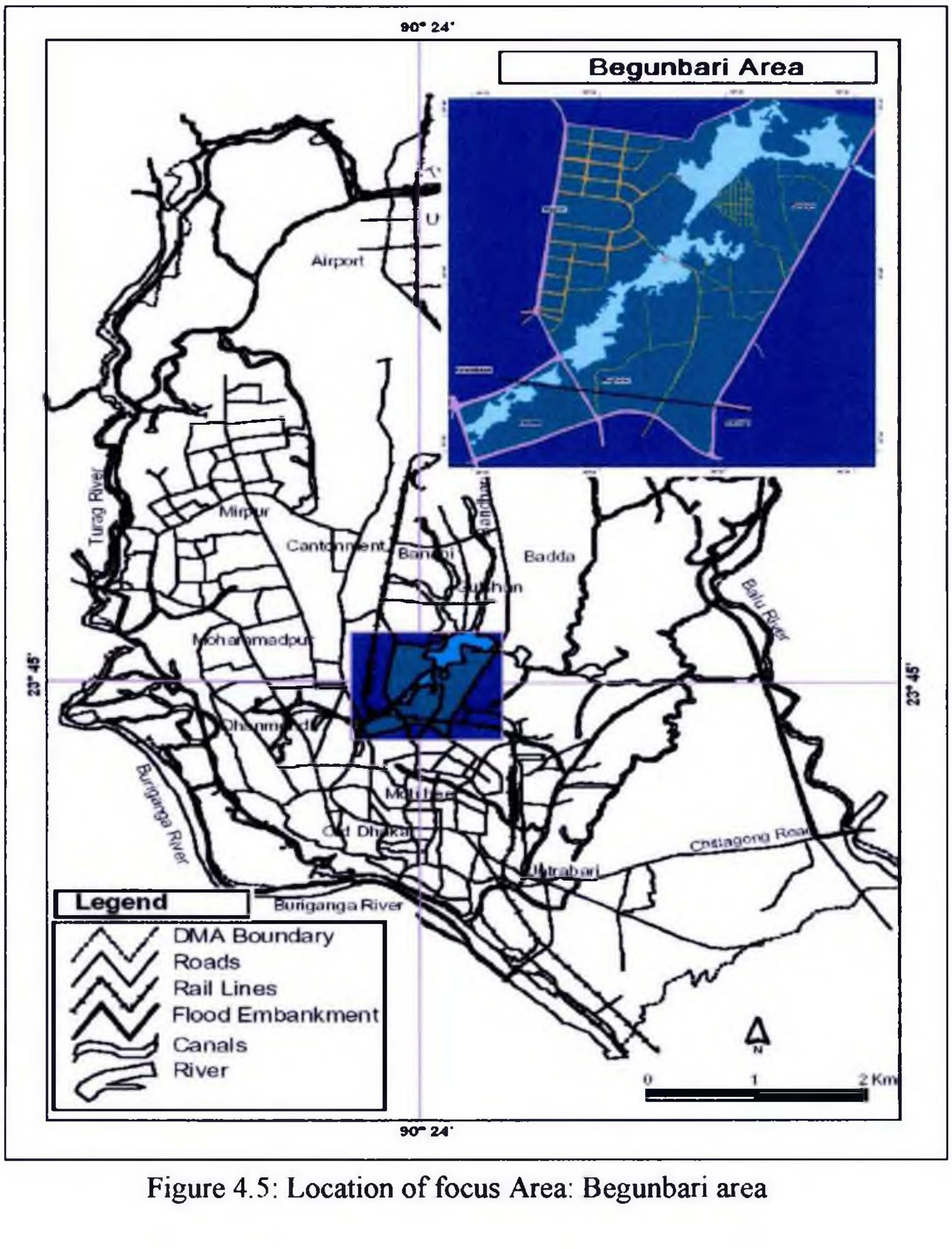


Figure 4.5: Location of focus Area: Begunbari area

4.2.2 Drainage System in the Catchments Area

Water from the Dhaka Metropolitan area is conveyed through drainage channels into the Turag River on the West, the Buriganga River on the South, the Balu River on the East, and Tongi *Khal* on the North. Now in the year 2006 Begunbari *Khal* originates from the Eskaton area and flows through the areas of Karwanbazar – Eskaton, Tejgoan – Mirbag, Gulshan – Modhubag, and Badda – Rampura. A distance of 4.27 km further downstream, it crosses Rampura Bridge and then meets with Bonosri *Khal* before draining finally into the Balu River. Previously drainage from the Begunabari *Khal* used to depend on the water levels in both the Balu and the Buriganga rivers. At present, an upgrade of the drainage system has taken place and a number of new sewer lines have been installed in the area. From the figure below, we observe that a total of 11-storm water drainage lines drain into the Begunbari Khal.

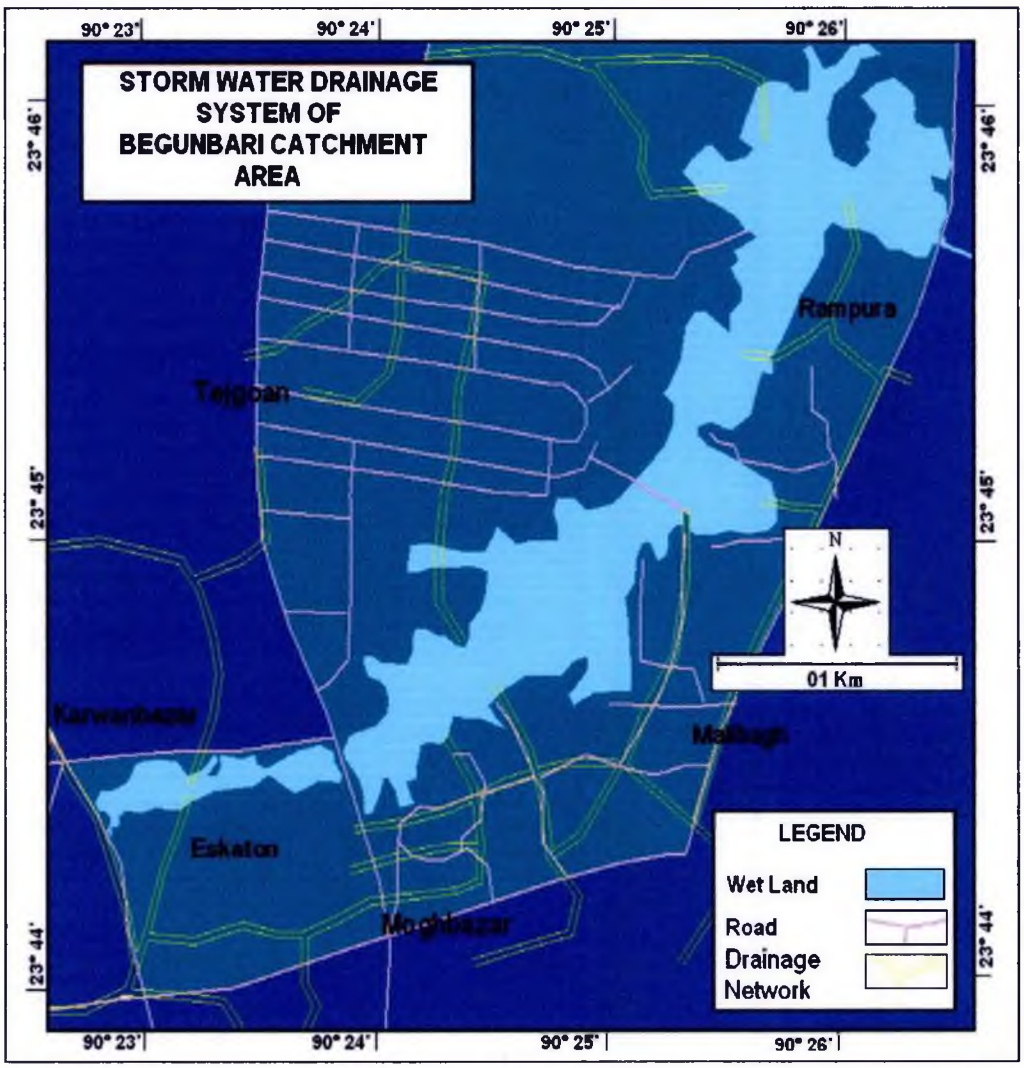


Figure 4.6: Storm water drainage system of Begunbari catchment area

As a part of the Dhaka Integrated Flood Protection Project a ten-vent sluice gate has been constructed on the Begunbari *Khal* at the intersection with Bonosri *khal*. The collected storm water from each subcatchments is drained by sewer pipes to the *khal* and finally it is drained to river system by pumps at the basin in front of the sluice gate.

4.2.3 Changing Status of the Catchment Areas

In the early period Dhaka contained about 20 wetlands had a strong network with each other through canals. From 1955 aerial photography of Dhaka City (extent of the city as of 2006) it was found that the percentage of highland was only 38%, where as low or marshland was about 62%. (Table: 4.1) The Begunbari *khal* and its adjoining low areas are part of this 62% low land. This canal and low land areas are also under serious threat due to rapid unplanned land filling. Its surface features changed so quickly that after one or two months what will be stand, no one can predict. Even in the 80's, it was connected with Dhanmondi Lake and Dhanmondi Lake was with Turag River through Katashur canal. The other side of Begunbari canal was connected with Balu River and still they are connected through Bonosri Channel. (Fig: 4.1) Balu River is now being filled up on a daily basis by the plots of Bashundhara - one of the largest real estate developers of the country, are created over there. From GIS database of different time period, it is found that in the period of 1983-2006 the rate of encroachment is much higher than the period of 1955-1983. Around 501 km^2 of land was grabbed during 1983-2006, whereas it was only 0.763 km^2 during 1955-1983. This is due to tremendous pressure of population and high demand of land.

Table 4.6: Area of Begun-Bari lowlands in Different Time Periods

Year	1955	1983	2006
Area (Km^2)	1.31	1.22	0.719

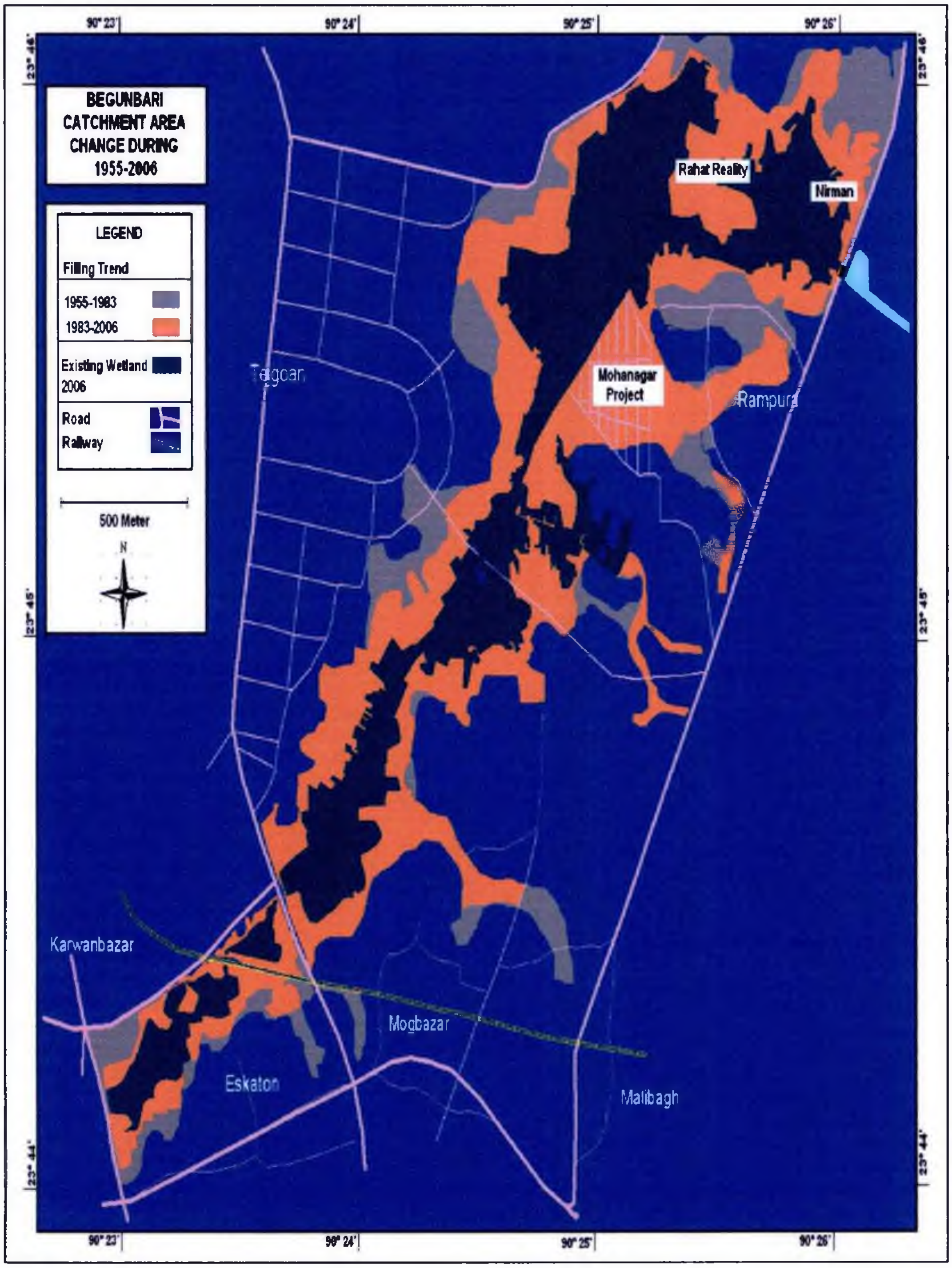


Figure 4.7: Changes of Brgunbari catchment area during 1955-2006

Due to the development and building of the road and railway network the Government filled up around 21056 m^2 of lowland in Begunbaria area. (Table: 4.7) Build the road between Shahbagh to Farm Gate Begunbari canals was detached from Katasur and Hatirpul canals. (Figure 4.8) Now only a narrow pipeline serves as a remainder of the existence of the big channel. In the early 60's the low-lying areas in Eskaton were filled up for commercial purposes. Hotel Intercontinental was the landmark of that whole area which was also established on marshy land. Privately about 12678 m^2 of land grabbed during the period of 1955 –1983. (Table: 4.7)

Table 4.7: Encroachment Land by Different Organization over the years

From 1955-1983

Name of the Organization	Area Encroachment (m^2)
Government	21056
Private (Commercial)	12678
Private (Home)	9675
Slum / Temporary Structure	48960

From 1983-2006

Name of the Organization	Area Encroachment (m^2)
Government	6649
Private (Commercial)	24213
Private (Home)	31005
Slum / Temporary Structure	108920
Private Housing Company	332725

Tejgaon Industrial Area was designed in the Pakistan Period. But for some unknown reasons no residence was arranged for the laborers. It might be possible that ample space was vacant in that time. Nowadays, that ample land has already been occupied along with an illicit establishment over Begun Bari Canal viz Kunipara slum. (Fig: 4.9) All the dwellers of this place are industrial and garment workers. The entire dwelling place is hanging over the canal, where the majority of the workers are living. There is no kitchen and sanitary latrine. An unhealthy atmosphere and malodor hangs over this place. During floods the entire area becomes inundated. Day by day Begunbari area is getting polluted by industrial and human waste. From the above table it is found that around 48960 m^2 land is occupied by slums, which was the largest occupation of the land during 1955-1983, but during 1983-2006, the largest occupation of the land went to real estate developers. (Figure 4.10)

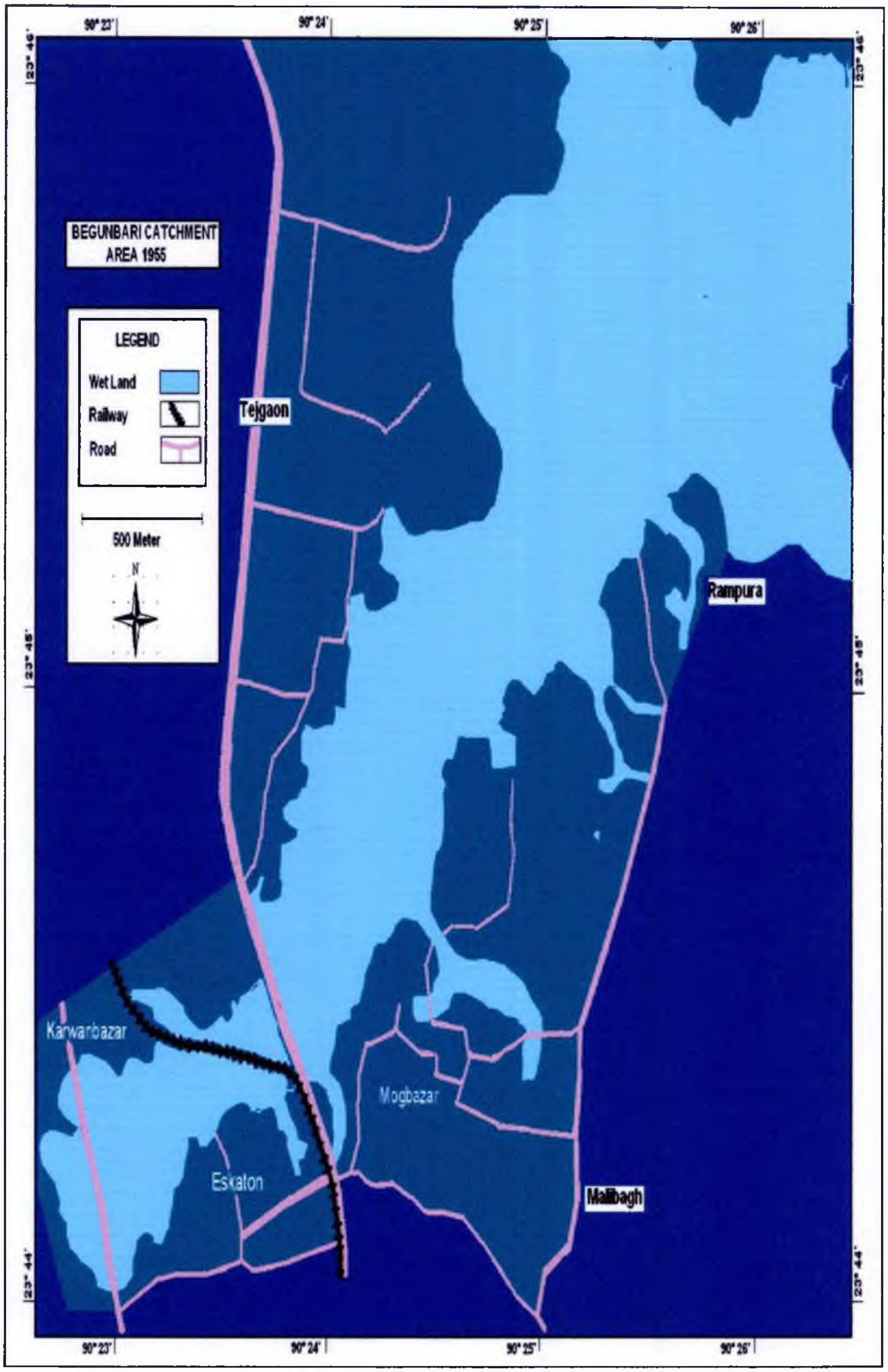


Figure 4.8: Begunbari catchment area 1955

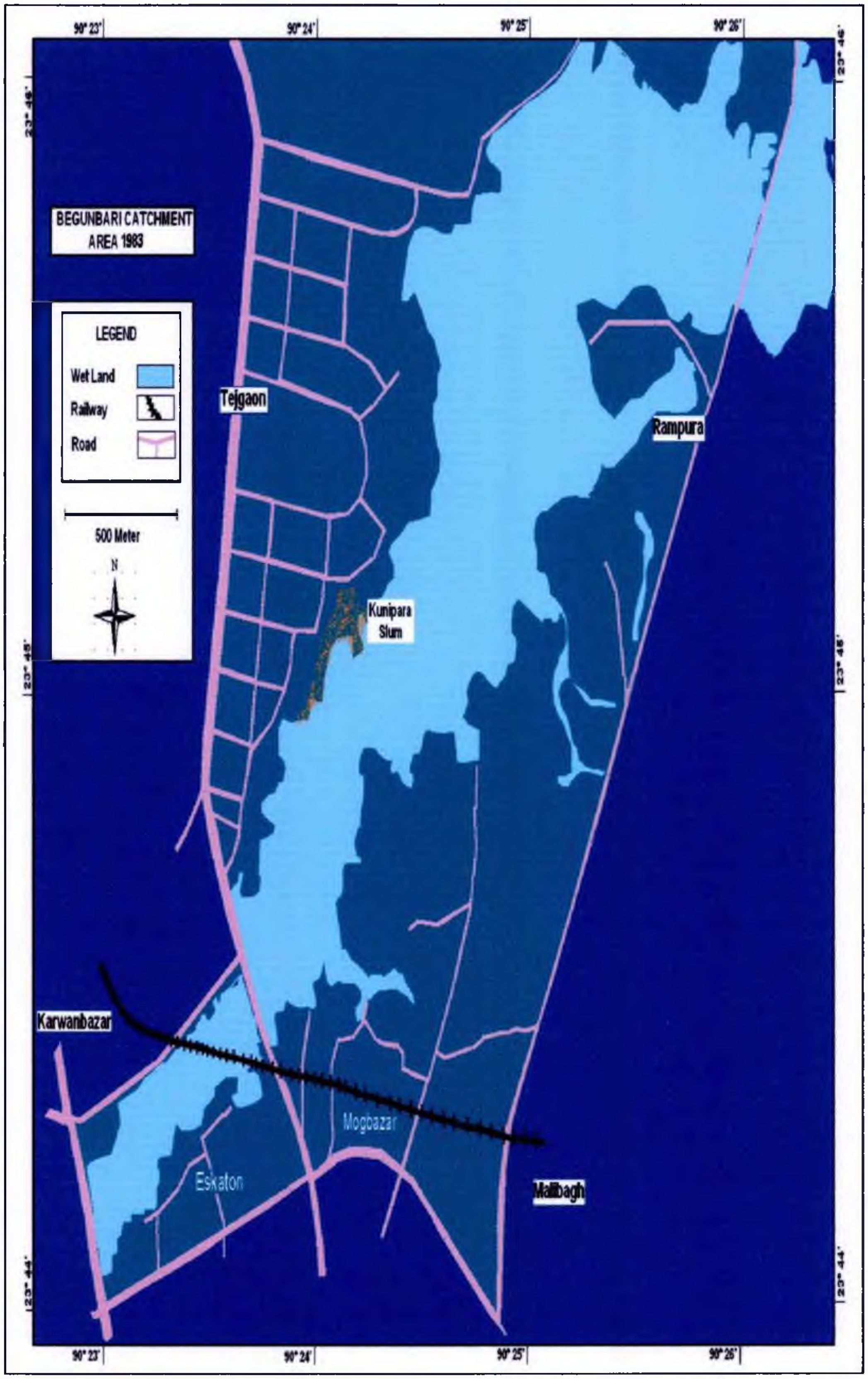


Figure 4.9: Begunbari catchment area 1983

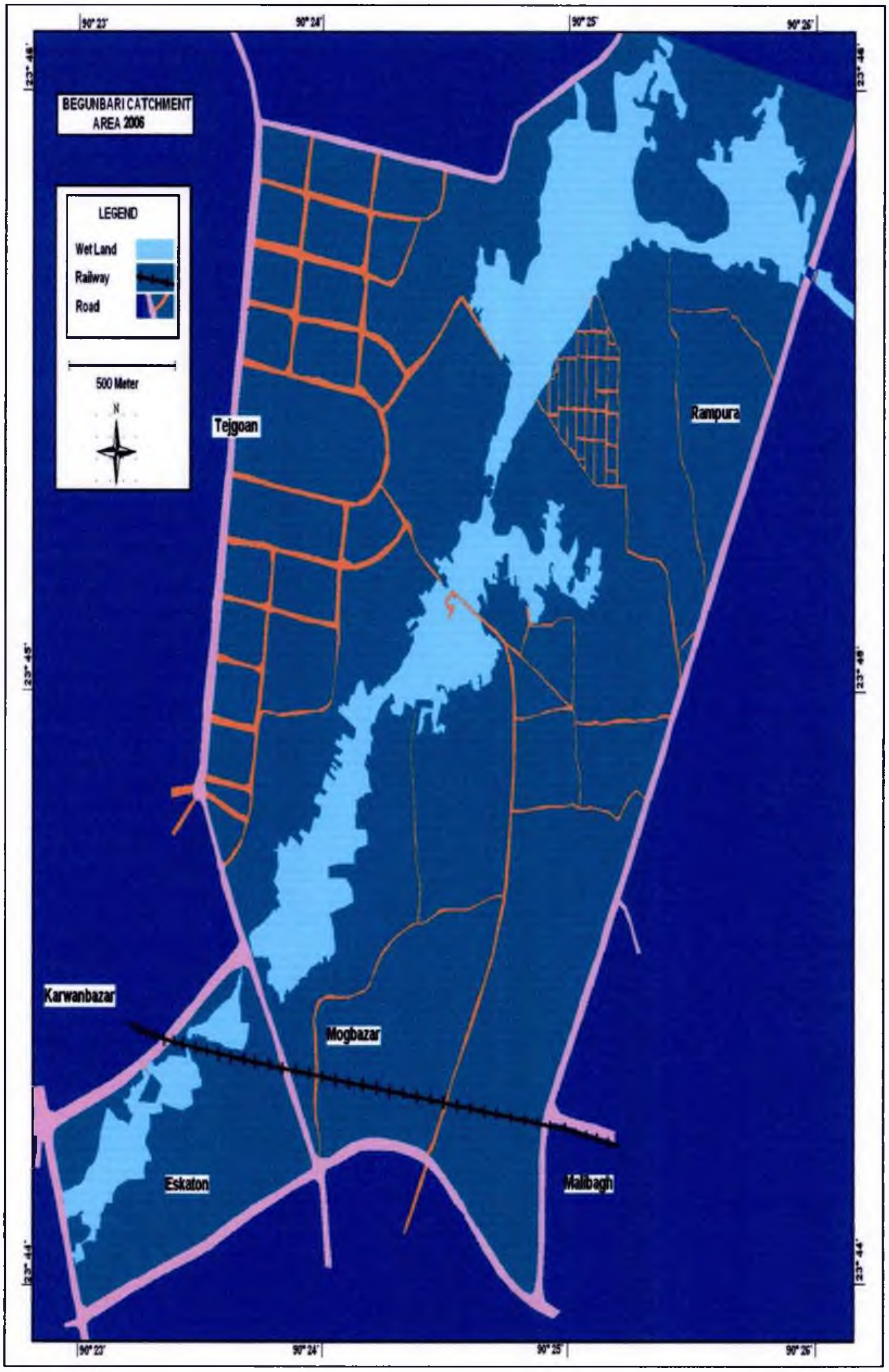


Figure 4.10: Begunbari catchment area 2006

Table 4.8: Land grabbed by different housing company

Private Housing Company	Area Encroachment (m^2)
Mohanagar Project (Eastern Housing)	253610
Rahat Reality Ltd.	69315
Nirman Brizehead	9800

In mid 80's Eastern Housing - a big real estate company emerged with its Mahanager Housing Project which occupied an area of 253,610 m^2 (Calculated from the satellite image, 2006) (Table 4.8) Most of its area is situated over low lying areas adjoining Begunbari *khal*. During the field survey, it was found that the land of the housing project has been extended more compared to the information given by the Land Survey Department. In recent years the project has extended its new phase with an area of 47,460 m^2 (Calculate from Satellite image, Digital Globe, 2006), which is totally situated in the catchments and in the main water flow region. Getting inspired by the big real estates, small developers have come up with projects in the wetland. From the image it has been found that Rahat Reality Ltd has already filled up 69315 m^2 of lowlands within 10 years and another company named Nirman Bridgehead captured 9,800 m^2 of land in the Begunbari area. (Table: 4.8)

4.2.4 Recent Encroachment

It is disappointing that even Gulshan Aarong, an enterprise of BRAC the largest NGO, and the plot of BRAC University are also situated over this canal. Another illegal establishment worth mentioning is the Bangladesh Garments Manufacturing & Exporters Association (BGMEA) high-rise building, situated on the edge of Begunbari canal. Government itself has allotted this low wetland to BGMEA for erecting of their corporate office building. Filling of this land created tremendous pressure on the drainage run off. Moreover the Public Works Department has constructed infrastructure by filling the low-lying areas beside Hotel Sonargoan.

Table 4.9: Recent Encroachment (Continue)

Name of the Organization	Area Encroachment (m^2) (on date)
Government	
Public Work Department	9949
Private (Commercial)	
BGMEA	4480
BKMEA	3150
CNG Station	7390
BRAC	11250
Private Housing Company	
Mohanagar Extension Project (Eastern Housing)	47460
Rahat Reality Ltd.	43260
Nirman Bizehead	3780

In the year 2002 the government allocated land for Compressed Natural Gas (CNG) station and BKMEA that were the wetland near Moghbazar rail crossing. Despite this alarming situation instead of giving such cogent and useful solutions, the Government does not even bother to give a little effort for Begunbari canal. The restoration of this canal is very essential and inevitable for the citizens of Dhaka as well as the whole country. So, this is the high time to unite those people, who are yearning to save their souls by saving BegunBari Canal, and also to force the disinterested government for taking proper steps to make BegunBari Canal a dependable friend for our environment.

Figure 4.11: Retention area encroached by BGMEA and government authority

Chapter 5

RESULTS AND DISCUSSION

A proper drainage system does not mean a few sewerage lines and drains only; it means building up a network that interconnects drains and sewerage lines with the natural water-bodies such as ponds, lakes and canals. Unfortunately, Dhaka, which once used to be dotted with only two dozen ponds, canals and lakes, has been bereft of those water-bodies by the city's unplanned, wholesale urbanization in the last two decades. As mentioned before The area of low land as calculated from this data base of 1955 image was found to be around 329.80 mile^2, which is 68 % of the total land (considering the study area) where in 2006 the low land has been found to be around 92.15 mile^2, which was 19% of the total land area. (Table: 4.1) Numerous high rise buildings have suddenly sprung up all over the city, all sorts of natural water reservoirs both inside Dhaka and on its suburbs have been quickly filled up by developers. The lakes, once large and healthy, have shrunk and grown sickly by indiscriminate encroachment of the land grabbers. The consequence of such indiscriminate construction is right before our eyes. A few hours of rain inundates many of the city streets and during floods the entire low-lying areas of Dhaka goes under water for days on end. If water bodies had still been around they could have easily contained the extra volume of water that might have invaded the city because of floods or excessive rains.

From different time periods RS data, lists some of the natural water reservoirs that have vanished from Dhaka's landmark and the areas that have been suffering from water logging as a consequence of that usurpation. Billions of cubic meters of sand are being dumped to fill up the low-lying areas to accommodate housing projects every day. Miles of natural canals and ponds have already been filled up. From Khilkhet to Kanchpur along the river Balu, massive signboards have been installed announcing the start of mega housing projects.

The encroachment on Katasur canal causes water logging in Rayerbazar and Mohammadpur areas. Filling up Ramchandrapur canal is responsible for waterlogging in Islambagh, Nawabgonj and Hazaribagh. A more than 30 metre wide open canal in the southern part of Dhaka, Dholai Khal, was filled up and a 2.5 metre by 2.5 metre box culvert was installed in its place. Narrowing the canal has led to water-logging in BUET, Bakhsibazar, Hosnidalan, Nimtali, Nazimuddin Road, Bangshal, Aga Sadek Road, Gandaria, Postogola, and Faridabad areas. Encroachment on Segunbagicha Khal at Maniknagar and Manda causes waterlogging in Shantinagar, Inner Circular and Middle Circular Roads, Arambagh, Fakirapul, Gulisthan Zero Point, Motijheel, Dilkusha and Saidabad areas.

Shrinking of the Jirani Khal and choking shrinking of the Jirani Khal and choking up of the Shajahanpur Khal are responsible for waterlogging in Malibagh, Mouchak and Shantibagh areas. Infringement on Shahjadpur Khal prevents flushing out of rainwater and wastewater from Kuril, Pragati Sarani and adjacent areas. Filling up a large portion of Begunbari Khal has resulted in waterlogging in Tejgaon, Gulshan 1 and Mohakhali areas. Encroachment on Mohakhali Khal is causing water logging in Nakhalpara, Arjatpara, Rasulbagh and Shahinbagh. The Kalyanpur pump regulating pond of the water supply agency has been filled up, causing waterlogging in Taltala, Agargaon, Kazipara, Shewrapara, Barabagh, Mirpur Section 1 and adjacent areas. Encroachment on Ibrahimpur Khal and filling up of Diabari Khal by the developers are responsible for creating water logging in Uttara and Banani.

Rapid population growth creates extra pressure on the land of already overcrowded Bangladesh. Agricultural lands give way to housing developments and roads. This rapid development and urbanization has almost undoubtedly must have aggravated the flooding problem in Bangladesh.

Unplanned urbanization can adversely impact flooding situation in a watershed. Prior to urbanization there exists a greater lag time between intense rainfall and peak stream flow. After urbanization the lag time is shortened, peak flow is greatly increased, and the total run-off is compressed into a shorter time interval, creating favourable conditions for intense flooding. For example, in a city that is totally served by storm drains, and where 60 per cent of the land surface is covered by roads and buildings (like Dhaka City), floods are almost six times more numerous than they were before urbanization.

Following urbanization, it is necessary to adjust drainage capacity in the watershed to take into account the "basin development factor (BDF)" in order to accommodate the extra runoff that results due to urbanization. The amount of adjustment in the carrying capacity of natural streams following urbanization depends on the degree of BDF. For an increase in the amount of impervious surface by 10 per cent in a watershed, a 23 per cent increase in the drainage capacity by dredging or deepening of streams is required. Dhaka City is located in the watersheds of Buriganga and Sitalakhya Rivers. A significant increase in the amount of impervious surface in these watersheds has taken place due to expansion of the Dhaka Metropolitan area over the last few decades. However, no attempts have been taken to increase the carrying capacity of these rivers to accommodate for the BDF. On the contrary, many of the rivers including Buriganga are being filled up by people. The illegal encroachment onto the rivers is contributing to the reduction in water carrying capacity during floods. Moreover, the internal drainage system consisting of tributaries to Buriganga and Sitalakhya Rivers has been diminished due to unplanned land use practices. For instance, it is apparent from topographic maps that Dhanmondi Lake and Baridhara Lake are remnants of tributaries to Bugiganga-Sitalakha Rivers. Also, filling up of Dholaikhal channel has reduced the runoff capacity from Dhaka City. The lack of an efficient storm sewer system in Dhaka City also contributes to the reduction of water carrying capacity, causing water logging throughout the monsoon season. According to reports published in national newspapers, Dhaka City has experienced serious water logging problems during the wet months of July to October in 1999, during July to September in 2000 and September 2004.

From this research it could be acknowledged that the unabated encroachment on most of the natural water reservoirs like Gulshan Lake, Dhanmondi Lake, Dholai *Khal*, Segunbagicha *Khal* and Begunbari *Khal* is the main factor to cause the city areas to be beset with water stagnation even after moderate rainfall. Continuous filling up of Savar, Ashulia and areas on the eastern fringe of the city in the name of development resulting serious water logging. And all this has been happening right under the nose of RAJUK (Rajdhani Unnayan Katripakkha), the government agency entrusted with the job of giving approval of any sort of buildings in Dhaka. Most surprisingly, besides private developers, RAJUK itself is filling up wetlands and the peripheral of the low-lying areas.

Apart from this, the box culverts that were set up at different place of the city remain clogged because of lack of proper cleaning drives. Besides, the surface drains and storm sewerage lines of both Dhaka Water Supply and Sewerage Authority and Dhaka City Corporation do not operate properly for lack of cleaning activities that lead the city to submerge under ankle-to-knee-to-waist deep water during the monsoon.

Dhaka has also grown into a concrete jungle, without very little greenery. There is hardly any soil left in the city. So when there is water either because of floods or heavy showers, it cannot seep into the ground. Consequently, rainwater or floodwater takes longer to recede. This is also another reason why the water level in Dhaka is going further down.

There is also another reason that makes the waterlogging situation still worse. There is a tendency to raise the city streets to save them from getting water logged. So, if water cannot stay on the streets it will then get into the houses more quickly than before.

5.1 Limitations of the Analysis

Various limitations were felt in analyzing the information. In the imagery of 1955 it has been observed that all the water bodies were attached with each other as a result there was no demarcation of where the Gulshan Lake would start or Begunbari *khal* would end. So it was very complicated to find out the actual area of the water body.

During the 80's with the development of different roads and culverts there was disconnection of the wetlands and the water bodies were named according to the name of the places for instance Gulshan Lake, Baridhara Lake. The areas of the lakes and *khals* decreased in size to meet the emerging population demand. The water body caught the attention of the land grabbers and they were being filled within a short span of time.

Error in GPS reading magnified the constraint when it came to the time of groundtruthing. Moreover the RAJUK Layout map, which had been used for the study, was not upgraded. Thus when it had been compared with the satellite image huge differences were observed so it created obstacles to get the accurate data. As a result for all these difficulties the area of the lakes and water bodies were taken approximately but all possible technical attentions were taken in order to minimize the errors.

Chapter 6

RECOMMENDATIONS

Rapid population growth and its growing demand for housing in Dhaka City are encouraging the real state business and private developers to grab and encroach of wetlands, low lands, water bodies and natural drainage system for housing, roads and commercial activities. These unplanned development activities are grossly violating the Dhaka Metropolitan Development Plan (DMDP) and the Wetland Conservation Act. Due to such activities, the natural drainage pattern and flood retention areas are destructed and creating the unprecedented water logging. Therefore, the concerned authorities need to take appropriate measures immediately to overcome the situation.

The chief of the World Conservation Union (IUCN), Bangladesh Dr. Inun Nishat, addresses, a densely populated city like Dhaka requires 25 per cent wetland for ecological balance and sustainability of the habitats. But Dhaka has less than 10 per cent wetland, which too is threatened. There were a large number of lakes and *khals* in the city in the past like Dhanmondi Lake, Gulshan- Baridhara Lake, Dholai *khal*, Begunbari *khal*, Segunbagicha *khal* etc. Some of these *khals* and lakes are totally disappeared due to development activities. Many others have lost their actual widths and are at the edge of death due to encroachment and waste disposal. Water bodies and flood retention areas have been filled in the name of development.

Therefore, the concerned authority like RAJUK, DCC, DWASA, BWDB etc. should take the appropriate measures immediately to solve water logging problem through the protection of wetlands, low lands, natural canals, water bodies and rivers in and around the city area for its survival.

Following steps of measures can help the authorities for comprehensive management of storm water and minimize the suffering of the city dwellers from physical, social, economical and environmental point of view.

- First of all, RAJUK will have to stop giving permission of constructing buildings on low lands and wetlands.
- There should be a clear definition of the water body, which could be filled, or not.
- The DMDP should monitor the development activities which are taking place.

- Many *khals* and lakes should be retained with strict measures to maintain the natural drainage system.
- In order to regain the wetlands the authority should apply laws and the Wetland Conservation Act as a legal instrument in this regard and take action against the violators of the laws. The act should be amended if necessary.
- Immediate action and steps will have to be taken by the concerned authority to remove all blockade and unauthorized constructions, encroachments etc. from the existing natural drainage system by enforcing necessary regulations.
- Proposed channel geometry will have to be ensured by the authority to keep waterway free from all unwanted intrusion and encroachment.
- Institutional set up for effective operation and maintenance of drainage network should be strengthened.
- The concerned authority should ensure regular and careful maintenance of all the interconnected secondary and tertiary drains through proper monitoring program to secure its efficient operation.
- Steps should be taken to rehabilitate the drainage system.
- There should be a high degree of close communication and co-ordination between the different urban authorities responsible for operating and maintaining the various components of the drainage network.
- Public information campaign will have to be introduced to make people more aware of the problems, hazards and unacceptable practices.
- The concerned development authority should take steps for awareness development about the necessity of natural canals and if necessary they can involve NGOs for this purpose.
- Consolidation of all environment laws into a single law and arrangement of all environmental activities under one umbrella may bring good result towards conservation and improvement of environment.
- Co-ordination must be between urban authorities and agencies those are responsible for different aspects of urban infrastructure provision and management.
- Training and workshops should be organized for human resource development to improve planning, design, and operation of urban drainage systems.

Chapter 7

CONCLUSION

Economic development of a country linked with the process of urbanization but when the growth of urban population takes place at exceptionally a rapid rate, most cities and towns are unable to cope with changing situations due to their internal resource constraints and management limitations. Since Dhaka is the capital of the country and have a massive pressure on its land, mutual understanding and cooperation among the co-riparian organization will be necessary to formulate any long-term and permanent solutions to the unplanned urbanization water logging problems. Due to continuous encroachment on most of the city canals and wetlands and lack of proper drainage system, the residents of the capital city may face serious water logging during the onset of monsoon showers.

Formulating solutions to water logging problems requires a comprehensive understanding of the geologic settings of the area, and a better knowledge of hydrodynamic processes that are active in watersheds. Only solutions that take into account the underlying long-term factors contributing to water logging problems can prevail. Such contributing factors include unplanned urbanization, illegal encroachments, lack of maintenance of drainage system and poor management etc.

Current research shows the applicability of the RS and GIS system to reproduce and visualize the land use scenarios of the past and present in Dhaka City. However, the present efforts to finding a vital solution to the water logging problems in Dhaka city should only be considered as the starting point, as more data would be required in order to make a more detailed study. The conclusion of the study is that using the GIS technology along with relative data will provide a cost effective and informative methodology towards finding the cause and solution of the recurrent water logging in Dhaka City.

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APPENDIX - A

GIS and RS Terminologies

Aerial Photography: Photos taken from airplanes to assist growers to determine variations within an area of interest such as a field.

Base Map: The outline of field with its proper coordinates is base map. Data collected within the field by yield monitor will be defined in location by the base map, which is a binary digital map.

Database: A logical collection of files managed as unit. A GIS database includes data about both the position and the attributes of geographic features.

Database Management System (DBMS): A collection of software for organizing the information in a database that might contain routines for data input, verification, storage, retrieval, and combination.

Feature: A geographic component of the earth's surface that has both spatial and attribute data associated with it (e.g., field, well, waterway).

Geocode: A code associated with a spatial element, which describes its location. An example would be a coordinate such as longitude or latitude.

Geographic Information Systems (GIS): System of computer hardware, software, and procedures designed to support the compiling, storing, retrieving, analyzing and displaying of spatially referenced data for addressing planning and management problems.

Image Classification: Processing techniques which apply quantitative methods to the values in a digital filed or remotely sensed scene to group pixels with similar digital number values into feature classes or categories.

Layer: A logical separation of mapped information representing common data (e.g., roads, soils, yields, vegetation cover, and soil tests).

Pixel: A term used in remote sensing referring to the fundamental unit of data collection which is an abbreviation for 'picture element". A pixel is represented in a remotely sensed image as a rectangular cell in an array of data values and contains a data value that represents a measurement of some real-world feature.

Raster-to-Vector Conversion: A process in which one converts an image such as a yield map or grid cells into a data set layer of lines and polygons.

Remote Sensing: The act detection and/or identification of an object, series of objects, or landscape without having the sensor in direct contact with the object. The most common forms include color and color infrared aerial photography, satellite imaging and radar sensing.

Resolution: The ability of an entire remote sensor system including lens, antenna, display, exposure, processing and other factors to render a sharply defined image.

Scale: The ratio of fraction between the distance on a map, chart, or photograph and the corresponding distance on the ground. A topographic map has a scale of 1:24,000 meaning that 1-inch on the map equals 24,000 inches (2,000 feet) on the ground.

APPENDIX- B

Operational Definitions

Brahmaputra: One of the major river of Bangladesh, originated from Himalayantogether with Ganges and passes through the country beside DhakaCity, which locally called Brahmaputra.

Buriganga, Turag,Balu, Shitalakhya, etc. : Local name of the number of rivers passes through in and around of Dhaka City. These rivers play an important role to keep the city flood free as the out falls of other drainage system are connected with these rivers.

DMDP: Dhaka Metropolitan Development Plan, a Package of Structure Plan, Master Plan and Detailed Area Plan were prepared to develop Dhaka City in a planned way for 20 years (1995-2015). The project was one of UNDP's aided projects implemented in cooperation with UNCHS/HABITAT in Dhaka.

Drainage System: Channels, either constructed or natural, passes through surface or underground or both that are usually used to drain out the flood or rain water

***Khals*:** Canals passes through Dhaka City that are created naturally and used as drainage channel to drain out the flood as well as rain water of the city to the surrounded outfall rivers. Begunbari khal, Dholai khal, Shegunbagicha khal, Tongi khal etc. are some major khals in Dhaka City.

Mega City: A metropolitan area having population more than 5.0 million is termed as mega city (Population Census, 2001). According to population census 2001, Dhaka is the only mega city of the country.

RAJUK: Rajdhani Unnayan Kartripakkha (Capital Development Authority) is the planning and development management authority of Dhaka mega city. It is also responsible for building control. It was first created in 1955 as DIT and bestowed with the responsibility of implementing Dhaka's first Master Plan. As present implementing the DMDP-a twenty years plan consisting of different components for the development and growth of Dhaka- is RAJUK's major responsibility. RAJUK's geographical area now covers 1528 sq. km. However, the power of RAJUK is controlling the elements of urban growth is very limited because of the fragmented development management system.

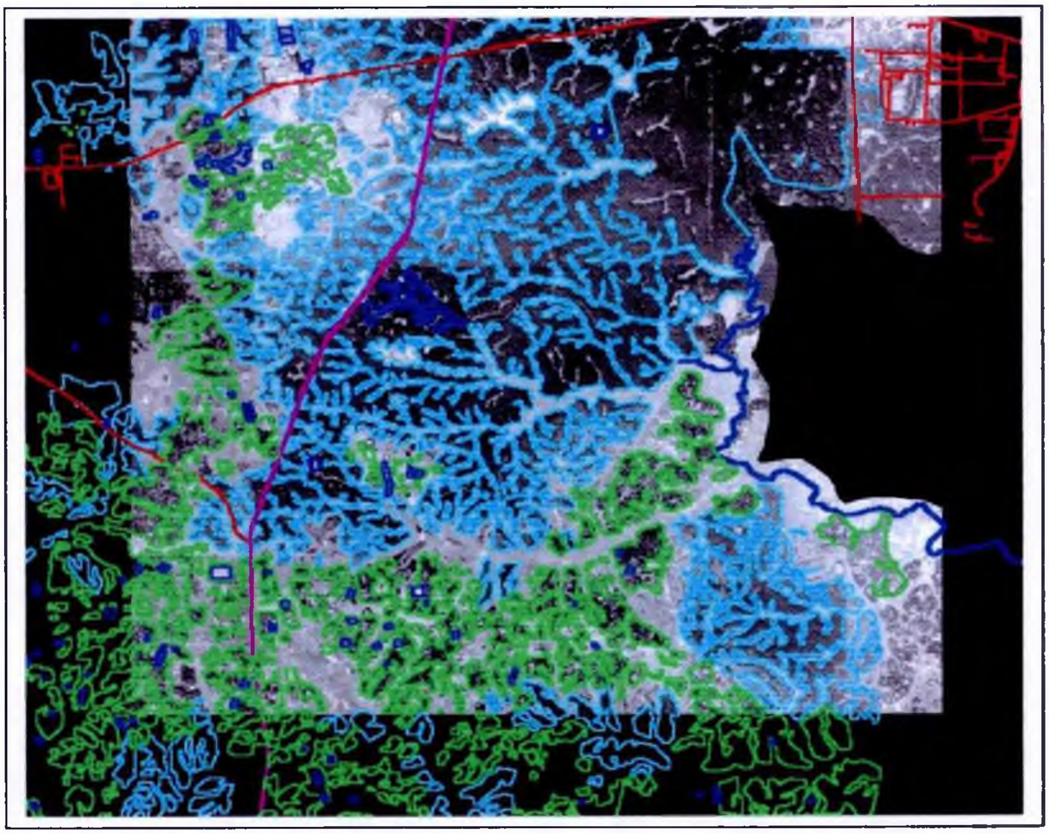
Retention Area: Natural or man-made depression usually reserved in urban area to retain the flood or rain water.

Water Logging: Flooding in built up areas caused by rainfall, where water remains stagnant for long time due to lack of proper drainage system and creates many adverse impact on daily life.

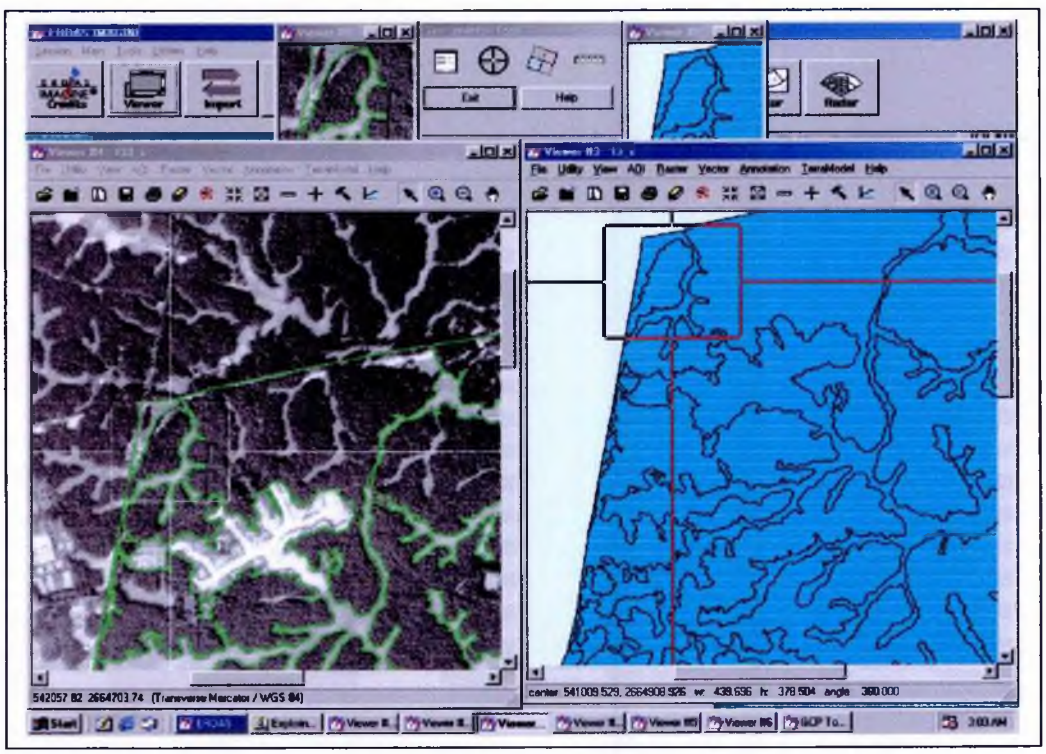
APPENDIX – C

RS Data and GIS Integration Process

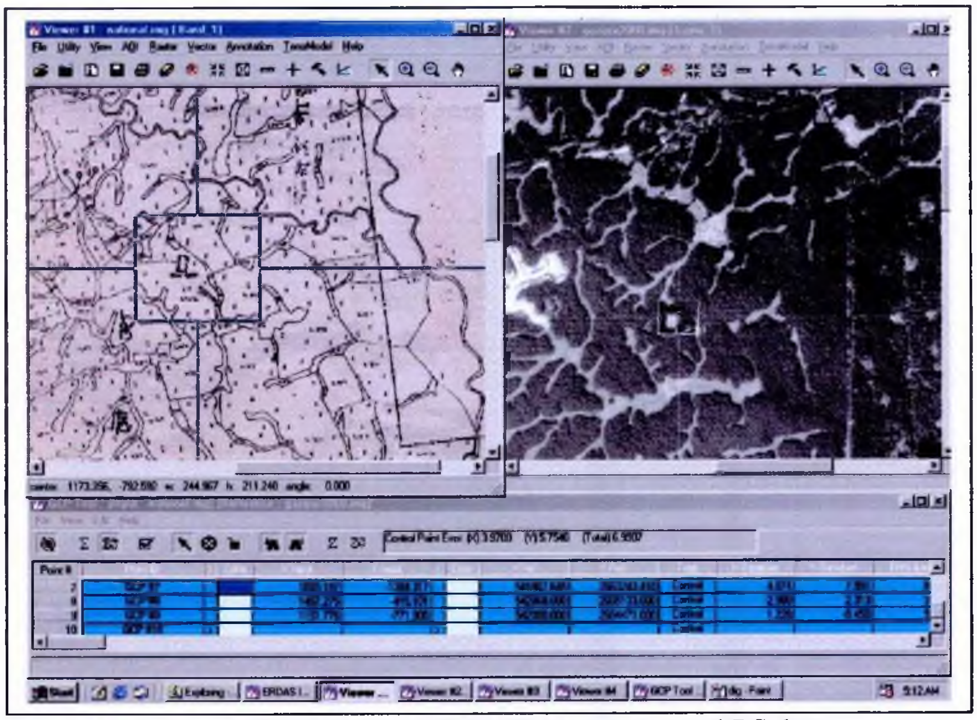

SATELLITE IMAGE



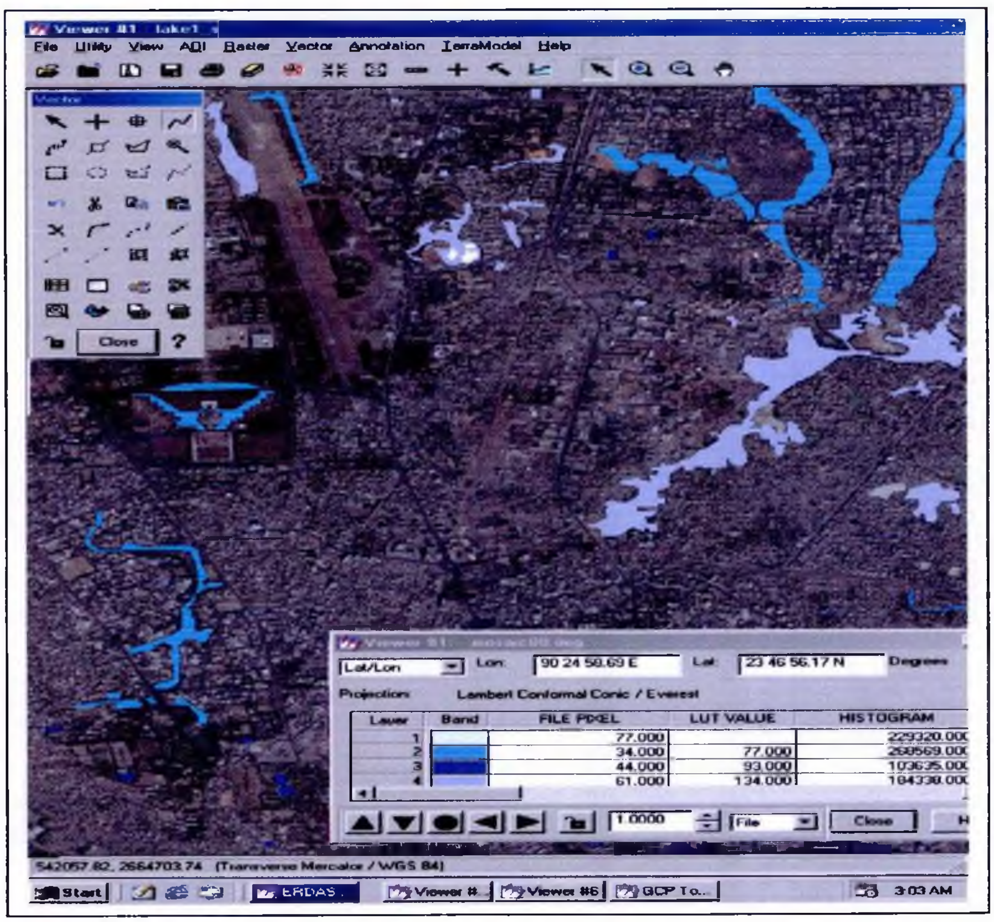
Digitization



Overlapping of RS data (different time period)



Overlapping of RAJUK layout map and RS data



Measurement of water bodies

APPENDIX –D

GIS Database

Image 1955

Class	ID	Polygon ID	Area in sq meter
High Land			
	111	01	3596824
	112	02	53709
	113	21	10568394
	114	30	836926
	115	32	1845726
	116	25	40378
	117	31	139854007
	118	19	6358797
	119	35	10038994
	120	24	982538
	121	20	65837120
	122	29	8306587
Total			248320000

Low Land			
	201	06	7392840
	202	07	3923568
	203	09	17835923
	204	03	96723
	205	04	856793
	206	05	323658930
	207	08	188769
	208	10	1981126
	209	11	52639232
	210	12	515610
	211	13	78962863
	212	14	9103712
	213	18	7830110
	214	27	2356980
	215	33	589620
	216	21	1710380
	217	34	73790
	218	36	5269230
	219	23	44620
	220	26	73215223
	221	37	844530
	222	28	9656008
Total			527683050

Image 1982

Class	ID	Polygon ID	Area in sq meter
High Land			
	111	01	48628390
	112	02	9123560
	113	21	53410
	114	30	8126817
	115	32	7983560
	116	41	44680
	117	15	53280
	118	33	2387
	119	52	92588050
	120	27	835692
	121	58	43080
	122	22	5892782
	123	60	3793860
	124	43	1076583
	125	57	43782
	126	31	99305
	127	40	457080
	128	71	879030
	129	26	7320932
	130	64	5843270
	131	19	8867
	132	61	53807
	133	42	846432
	134	51	339782
	135	29	7899670
	136	70	2386920
	137	46	76583658
	138	39	303584
	139	65	8344
	140	56	33946
	141	20	734587
	142	53	48508
	143	25	309003
	144	28	445858
	145	44	28307
Total			34920000
Low Land			
	201	06	3846528
	202	07	463820
	203	09	41580
	204	03	268078
	205	04	3370540
	206	05	308098
	207	08	443567

208	10	2689280
209	11	426780
210	12	5493208
211	13	3090827
212	14	1192864
213	49	3786940
214	36	15407800
215	55	13728640
216	18	458390
217	38	5877807
218	69	27830
219	35	47502
220	68	18903
221	23	778340
223	50	5580
224	63	48930
225	16	543705
226	48	6383920
227	45	64580
228	54	2870580
229	17	11370450
230	66	14387205
231	34	57236227
232	62	28705400
233	24	37970
234	69	104853209
235	67	30480
236	37	665370
237	47	137832090
Total		426800000

Image 2006

Class	ID	Polygon ID	Area in sq meter
High Land			
	111	01	8867084
	112	02	63907840
	113	21	3783540
	114	30	44580938
	115	32	137682090
	116	24	30287
	117	38	54320937
	118	19	28564080
	119	28	33809045
	120	29	53207
	121	59	9376280
	122	15	109683
	123	44	237854098
	124	58	4587084
	125	18	6839750
	126	39	3782540
	127	40	78543209
	128	41	902928
	129	23	8374500
	130	49	3745827
	131	50	7890045
	132	16	37070
	133	31	11780
	134	37	5358045
	135	33	5320894
	136	54	715658
	137	42	59405
	138	57	459707
	139	17	5892084
	140	43	9405635
Total			628560000
Low Land			
	201	06	4782370
	202	07	782380
	203	09	7653
	204	03	678390
	205	04	7905432
	206	05	54432809
	207	08	478345
	208	10	418398
	209	11	9708307
	210	12	43205873
	211	13	934723

	212	14	15430
	213	20	705870
	214	47	669030
	215	26	2186930
	216	27	137854
	217	46	3786930
	218	25	4597080
	219	34	437080
	220	51	7480325
	221	55	87549
	222	35	82375
	223	53	8602
	224	45	54320
	225	56	41509
	226	48	63704
	227	22	78790
	228	36	689432
	229	52	52312529
Total			147770000