Causes and Effects of Water Logging in Dhaka City, Bangladesh

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In the Name of God, the most Gracious, the most Merciful.

For my loving parents,
Khondoker Golam Rabbani and Aleya Begum
Thank you for your love and inspiration
For your never ending supports and prayers
And for being there always……

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Abbreviations and Acronyms

AIT	Asian Institute of Technology
BBS	Bangladesh Bureau of Statistics
BDF	Basin Development Factor
BIWTA	Bangladesh Inland Water Transport Authority
BOD	Biological Demand of Oxygen
BWDB	Bangladesh Water Development Board
CS	Cadastral Survey
DCC	Dhaka City Corporation
DHI	Danish Hydraulic Institute
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
DSE	Dhaka Stock Exchange
DSMS	Dhaka Statistical Metropolitan Area
DWASA	Dhaka Water and Sewerage Authority
DWEM	Department of Water Engineering & Management
GIS	Geographic Information System
GoB	Government of Bangladesh
HSC	Higher Secondary Certificate
ICDDRB	International Center for Diarrhea Disease Research, Bangladesh
IFCDR	Institute of Flood Control and Drainage Research
IWFM	Institute of Water and Flood Management
IWM	Institute of Water Modeling
JICA	Japan International Cooperation Agency
LGED	Local Government Engineering Department
MEC	Event Mean Concentration
MDB	Meteorological Department of Bangladesh
msl	Mean Sea Level
MSW	Municipal Solid Waste
NGO	Non Government Organization
RAJUK	Rajdhani Unnayan Kartripakkha
RS	Revenue Survey
SWD	Storm Water Drainage
SWM	Solid Waste Management
SWMC	Surface Water Modeling Center

Currency Equivalent

(As of December 20, 2004)
Currency Unit = Taka
US$ 1 = Taka 60.85

Abstract

Dhaka, the capital city of Bangladesh is one of the populous Mega City 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 paper focuses on the rainfall induced flooding that is caused by high intensity storm rainfall runoff in the city area that is inundated for several days mainly due to lack of proper drainage system and inefficient management. 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.

Heavy downpour occurs in Dhaka City during monsoon, as it is located on the extensive floodplains of Ganges and Brahmaputra. But the 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 care of natural drainage system that creating obstacles to properly drained out the urban runoff. Therefore water logging is tacking place as different parts of the city remains inundated for several days. 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 over and above 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 area also causing water logging.

This water logging becomes a burden for the inhabitants of Dhaka City and creating adverse social, physical, economic and environmental impacts. Disruption of traffic movement and normal life; damage of structures and infrastructure; destruction of vegetation and aquatic habitats; loss of income potentials are the encountered effects of water logging on city life. The storm water becomes polluted as it mixes with solid waste, clinical waste, silt, contaminants, domestic wastes and other human activities that increase the water born diseases. The stagnant storm water leads to the creation of breeding sites for diseases vectors that becomes a hazard to health as well as being unsightly and foul smelling.

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.

Operational Definitions

Brahmaputra	:	One of the major river of Bangladesh, originated from Himalayan together with Ganges and passes through the country beside Dhaka City, 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.
CS Map	:	Cadastral Survey (CS) map prepared for all over Bangladesh based on the survey from 1912 to 1915. People use these maps to find location and actual area of land in the filed.
Dengue	:	A disease vector, which is dangerous threat to public health that spreads by a special mosquitoes named ”Aedes”. Dengue breaks out in full-blown during rainy season as stagnant rain water is suitable breeding sites for Aedes mosquitoes.
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
Katcha	:	A term locally used for earthen infrastructure or structures made with mud, bamboo and thatch.
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.

RS Map : Revenue Survey (RS) map prepared for different part of Bangladesh based on the survey from 1966 to 1975 to collect revenue by the Government.

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.

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Chapter 01
Introduction

1.1 Introduction

Bangladesh is experiencing environmental degradation due to rapid urbanization, increase in population, and industrialization. The process of urbanization is linked with the economic development, which makes an increasingly higher contribution of the national economy. However, when the growth of urban population takes place at an exceptionally rapid rate, most cities and towns are unable to cope with changing situations due to their internal resources constraints and management limitations (Bari and Hasan, 2001). Provision of infrastructure services viz., water; drainage and sanitation along with waste disposal are greatest concern to human settlements. Failure to provide these services adequately results in many of well-known costs of rapid urbanization: threats to health, loss of urban productivity and environmental quality. On one hand, pressures for modernization give rise to continuous development activities, which deplete natural resources. On the other hand, deficiency in the coverage and delivery of urban infrastructures are seriously affecting the general environment and reducing urban efficiency with adverse implication to the national economy.

Dhaka, the capital of Bangladesh is one of the most densely populated cities of the South-Asian countries. Due to rapid urbanisation 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, all these are the regular problem of the city.

Most modern cities in Europe and the US have smaller scale local problems because their sewer systems have insufficient capacity. Other cities, for instance in Asia, can have more severe problems because there is insufficient drainage and much heavier local rainfall. The situation is further aggravated because Asian cities grow rapidly these days, but without the necessary funds to extend and rehabilitate their existing drainage systems (DHI, 2002)

1.2 Statement of the Problem

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. Flooding due to rainfall is also a severe problem for Dhaka City that is inundated for several days mainly due to the drainage congestion (Haq and Alam, 2003). Dhaka metropolitan area has experienced water logging for last couple of years. Even a little rain causes a serious problem for certain areas, so that parts of Dhaka are inundated for several days. The water depth in some of the areas may be as much as 50-70 cm, which creates large infrastructure problems for the city and a huge economical loss in production for the city together with large damages of existing property and goods (Mark and Chusit, 2002). In addition, deceases are spread and gives problems to the population e.g. in terms of diarrhoea.

Dhaka City is protected from river flooding by an encircled embankment called Buckland Flood Protection Embankment. During the monsoon (May to October), the water level of the surrounding rivers remains higher than the internal drainage level. Consequently, the drainage of the city

depends very much on the water levels of the peripheral river system. At present, the drainage depends mostly on the difference in water level between the river and the drainage system in the city and when the water level in the river increases the drainage capacity to the river is reduced (Mark and Chusit, 2002).

Flooding in Dhaka Metropolitan area can be classified into two types. One results from high water levels of 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.

River flooding

River floods generally take place in the low laying fringe areas outside the protective embankments once in every five to ten years (K. Rabbi et. al, 2001). A number of severe flood have struck Dhaka since its early days and its vulnerability is reflected in the Buriganga River's floods embankments first built in 1864. Severe floods in Greater Dhaka City area mainly caused by spill over from surrounding rivers flowing to and from the major rivers of the country. In recent history, Greater Dhaka City has experienced major floods in 1954, 1955, 1970, 1974, 1980, 1987, 1988, and 1998 due to the over flow of surrounding rivers (Huq and Alam, 2003). Among these, the 1988 and 1998 floods were catastrophic. Poor drainage capacities of the existing khals caused long flood duration in inland areas and aggravated the flood damage.

Rainfall induced flooding

Rainfall induced flooding, meaning flood in Dhaka City caused by local rainfall occurs in the built-up areas of the city several times a year on a various scale (Mark and Chusit, 2002). Inadequate existing drainage channels and their improper operation and management mainly cause these floods. The severe water logging was occurred in September and October in 1996. Some important street intersections were inundated for four days during 16 – 19 September 1996 and many of the important business and government offices of the city suffered the most from the flooding. The situation was severely aggravated because the natural drainage system, which conveys storm runoff from the areas to the surrounding rivers were not fully operational and surface runoff drainage and sewerage system were blocked due to huge volume of garbage and poly-bags.

1.3 Objectives of the Study

The primary focus of the study would be on the factors influencing the water logging problem in Dhaka city. The physical development trend, the rainfall intensity and the storm water drainage system of Dhaka city would be ascertained.

The effects on human life, economy and the environmental quality of the city due to water logging would be studied. At the end of the study, there are some recommendations from the technical, social and institutional point of views as an input for the concerned authorities for better management of storm water. These recommendations are based on the observation, discussion and primary information that have been collected for the study. However, the specific objectives of the study are:

i) to ascertain the causes of water logging problem in Dhaka city.
ii) to investigate the effects of water logging on city life.
iii) to provide some recommendations as an input for the concerned authorities for better management of storm water.

1.4 Scope of the Study

During the last 25 years, so rapid urbanization has taken place in Dhaka City. 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 lead to shortening of the runoff concentration time and an increase of the peak flow.

As population and land values increases, the effect of uncontrolled runoff become 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 design 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 the 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 Methodology

It has already been mentioned earlier that flooding in Dhaka Metropolitan area can be classified into two types. One is river flooding that results from high water levels of peripheral river systems and another is rainfall induced flooding that is caused by high intensity storm rainfall runoff in the city area. The study would be focus on the rainfall induced flooding treated as water logging due to storm water in this study. The methodological approaches of the study are as follows.

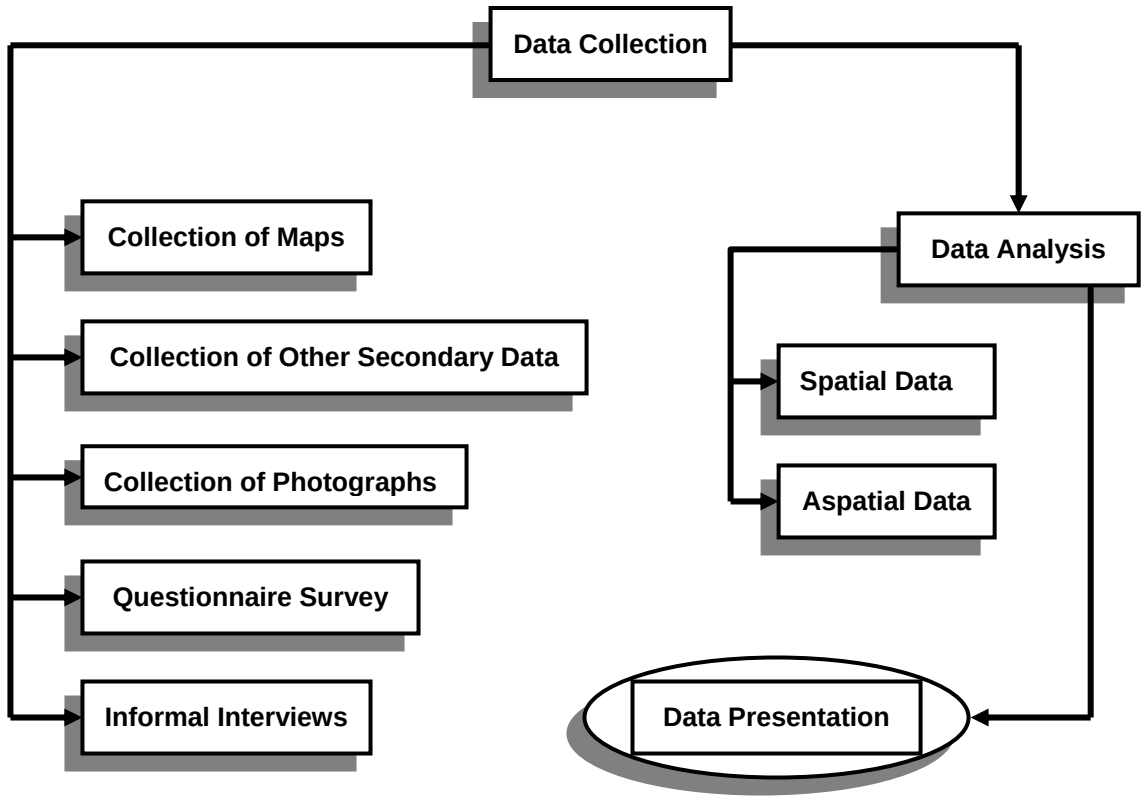


Figure-1.1 Methodological Flowchart of the Study

1.5.1 Data Collection

To fulfil the objective of the study both primary and secondary data were needed. All the necessary data has been collected from various sources.

Collection of Maps:

For the purpose of the present study, three different types of maps have been collected. These are Cadastral Survey (CS) map (1912-1915), Revenue Survey (RS) map (1965-1975) and Dhaka topographic survey maps (1998). First two types of maps have been collected from Directorate of Land Records and Survey (DLRS) the last map is from Survey of Bangladesh. The existing land use map has been collected from Rajdhani Unnayan Kartripakkha (RAJUK) and the land use of different periods has been collected from some relevant literatures and organizations. The existing drainage layout map was also needed and this has been collected form Institute of Water and Flood Management (IWFM).

Other Secondary Data:

Rainfall data and the storm water drainage system data were needed for the study. The rainfall data has been collected from Meteorological Department of Bangladesh (MDE) and the drainage data has been collected from Drainage Department of Dhaka City Corporation (DCC). The past and present data on natural drainage system has been 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.

Collection of Photographs:

Lot of photographs was also needed to illustrate the situation of water logging, related obstacles into the smooth drainage of urban runoff and its effects on urban life. Some of these photographs have been collected directly from field survey and some other from daily news papers as well as from internet websites.

Questionnaire Survey and Informal Interview:

To find out inherent causes of water logging in Dhaka City and its associate impact on city life, a field survey as questionnaire survey, informal interview and open discussion has been conducted with the authorities of different concerned organizations, experts and people living in different parts of Dhaka City. The questionnaire was designed in such a way that it would track down the problem from the inception and the impact of the water logging in the locality. The sample questionnaire is given in **Appendix A**. The sample size of these survey activities was 100. Again the respondents were selected in different water logging prone area of the city with different professions. To identify the quality of environment certain environmental parameters were fixed. It also covered the people's perception on conservation/sustainable development of drainage system. 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.

1.5.2 Data Analysis and Presentation

All the data both spatial and aspatial collected from different sources has been analysed separately. The spatial data has been analysed by using some Geographic Information System (GIS) like Arc/info, Arc/view etc. and aspatial data has been analysed using some other statistical computer software like, Microsoft Excel, SPSS etc. Finally the both types of analysed data have been integrated and presented as maps, tables, and graphs and putted in the report.

1.6 Literature Review

Water logging due to storm water is a very common problem like the others regular environmental problem of Dhaka City. But very few studies have been conducted on water logging and drainage system of the city and there is no study been conducted to find out the causes of such problem and

its impacts on the human life as well as the economy. Some studies related to the drainage system and water logging of Dhaka City, which has been conducted are described below.

A project taken by Dhaka Water and Sewerage Authority (DWASA), 2000 “Rehabilitation of Dholai Khal” described in its report 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. Henceforth water logging became a problem for the city. In 1964, Dholi khal was filled in for carrying out development works without taking any necessary steps to drain out the water of surrounding area and thus water logging turned out as a great problem.

A study named “Flood Management and Vulnerability of Dhaka City” done by Huq and Alam, 2003 described that after implementation of the flood control project in the Dhaka West, unplanned and uncontrolled expansion of urban area stretched rapidly toward the low-lying areas adjacent to the flood protection embankment. These are deeply flooded floodplain areas close to the river. The residents of the houses in these lowlands suffer from inundation due to accumulation of rainwater after heavy rainfall. Land development through land filling processes in the low-lying areas is causing a drastic reduction in water storage areas. Construction of embankments through low-lying areas without providing adequate drainage facilities has caused internal flooding adversely affecting the residents in those areas.

Bari and Hasan, 2001 in their study “Effect of Urbanization on Storm Runoff Characteristics of Dhaka City” 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. (July 1998) in their study, “Measurement and Analysis of Rainfall Runoff in Selected Catchments of Dhaka City” shown from the analysis of rainfall data that the spatial variability is quite large. The areal 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 are domestic wastewater discharges 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.

In the study “Dhaka City Storm Water Quality Assessment”, Khan S.A. and Chowdhury, J.U. (1998), described that the ddeterioration of storm water quality in Dhaka has become a matter of concern in the recent years. Identified as one of the most densely populated cities in the world, Dhaka is unable to provide urban quality of living to its over 6 million inhabitants. Much of this inability has resulted from failure to maintain the required water environment of the city.

1.7 Limitations of the Work

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

Two types of water logging occurs in Dhaka City that is water logging due to river flooding and water logging due to heavy rainfall. In this study, only rainfall induced water logging was tried to emphasize. But sometimes it was very difficult to differentiate these two types of water logging as they merged each other due to heavy rainfall.

Very few studies were conducted related to water logging and drainage system of Dhaka City. As a result, there was no 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, pick 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.

Due to the lack of detailed elevation data, sometimes it was very hard to measure the actual depth of water logging. The defensive attitude of responsible authorities related to the problem and their reluctance to provide relevant data has limited the information. Therefore, in some case it has to depend on photograph rather than numeric data to illustrate the causes and effects of the situation.

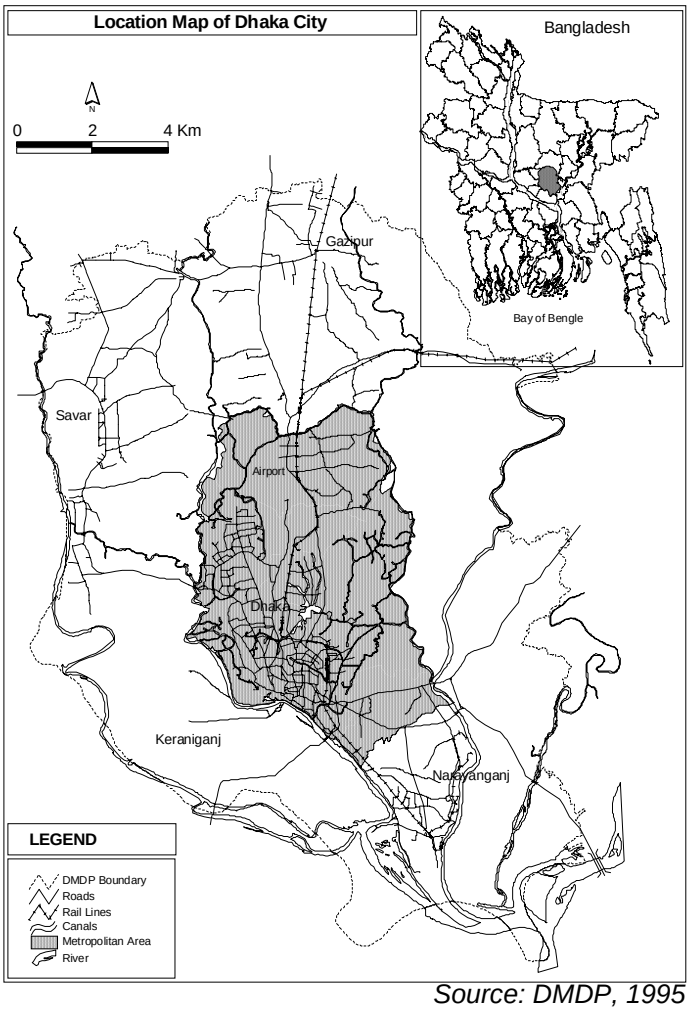
During the questionnaire survey, some interviewee did not want to make any comments against the responsible development authorities even they know the lack of efficiency of those authorities, because they think that any negative comments can be harmful for them in near future

Chapter 02
Background Study

2.1 Study area

2.1.1 Location

Dhaka, the capital and the largest city of Bangladesh is located in the central region of the flat deltaic plain of the three major international rivers, the Ganges, the Brahmaputra and the Meghna (**Figure-2.1**) which enjoys a distinct primacy in the national and regional hierarchy. The city is surrounded by the distributaries of these three major rivers. Geographically, Dhaka is located in Bangladesh and situated on the northern bank of the river Buriganga (**Figure-2.2**). The Balu River in the east and Turag bound it in the west and north. In spite of its water confinement on all sides Dhaka is considerably high above the water of surrounding rivers in ordinary seasons of inundation. The elevation of Greater Dhaka lies between 2 to 13 m above mean sea level (msl). Most of the urbanised area lies at the elevation of 6 to 8 m above msl. Dhaka's increasing growth and primacy is partly explained by its geographic location. Being centrally located enjoys good accessibility with rail, road, water and air connections with all major towns and cities of Bangladesh (Islam, 2001 in Islam (ed.), 2001).

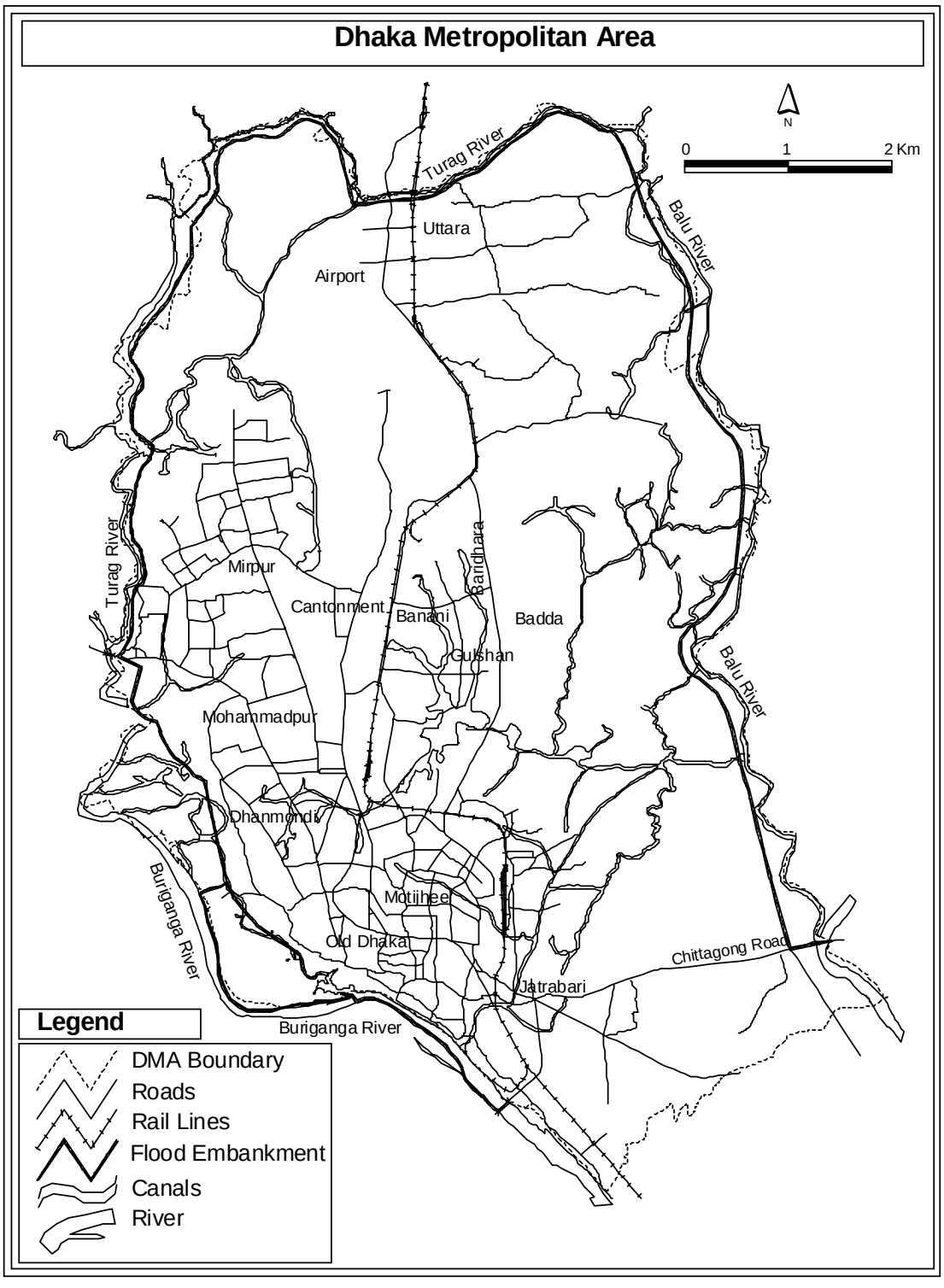


Source: DMDP, 1995

Figure-2.1 Location Map of Dhaka City

2.1.2 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 (ed.), 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, or Dhaka city as it is popularly known and the other one is the Dhaka Statistical Metropolitan Area (DSMA) covers an area of 550 sq. mile (Islam, (ed.), 2000).



Source: DMDP, 1995; Reconstructed by the Author

Figure-2.2 Map of the Study Area (Dhaka Metropolitan Area)

Table-2.1 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**	54.5	3,839,000
2001	225	5,399,880

Source: Islam, 1974; Census of Pakistan 1951; Statistical Year Book 1994, BBS. Pp. 28; Bangladesh Population Census, Zila series, (Dhaka) BBS 1991, pp. 25; Census of Bangladesh, 1974, 1981, 1991, BBS; Islam, 1966; Islam, 19991; BBS, 2001

* DSMA: Dhaka Statistical Metropolitan Area

** DCC: Dhaka City Corporation

2.1.3 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 per cent 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. The climatic condition of Dhaka city are summarised in the table.

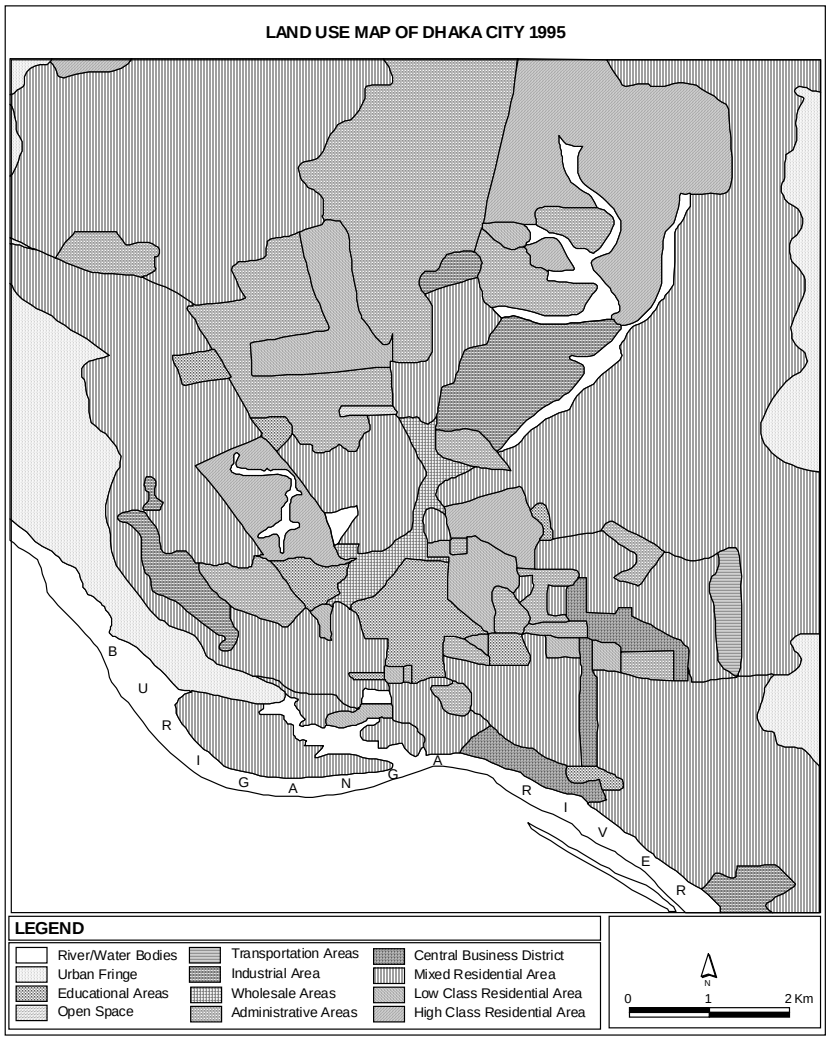
Table-2.2 Climatic Condition in Dhaka City Area

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. rainfall (mm)	6.5	20.2	52.3	124.0	283.0	398.0	391.4	328.0	264.0	160.0	25.3	7.4
Rainy days/m	1	2	4	8	14	19	22	22	16	9	2	1
Temperature ^{0}C												
High (extreme)	34.2	36.6	40.6	42.3	40.6	38.4	35.2	35.9	35.3	38.8	33.3	31.2
Low (extreme)	5.6	4.5	10.4	15.6	18.4	20.4	21.7	21.0	22.0	10.4	10.6	6.7
Average	18.8	21.5	26.1	28.7	28.9	28.7	28.7	28.7	28.7	27.4	23.6	19.8
Rel've Humidity	70.7	66.0	63.0	71.0	79.0	86.0	87.0	86.0	86.0	81.0	75.0	74.0
Evaporation	104.0	79.0	81.0	77.0	78.0	83.0	87.0	130.0	118.0	106.0	75.0	105.0
Wind velocity (Knot = 1.852 km/hr)	2.0	2.0	3.0	5.0	5.0	4.0	4.0	4.0	3.0	2.0	1.0	1.0

Source: Japan International Cooperation Agency (JICA), 1991

2.1.4 Land Use

Dhaka started to develop in a more planned way after 1947 when it gained regional and political importance (Chowdhury, J.U., 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 centres of the city was moved to Motijheel and a high 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.



Source: DMDP, 1995; Reconstructed by the Author

Figure-2.3 Land Use Map of Dhaka City (1995)

With the development of the city, wide roads and other paved areas replaced the unpaved areas, natural depressions, and agricultural land. In many cases, natural drainage canals and open water bodies were filled up for development works. However the present status of Dhaka city demonstrates that the development of the city did not succeed to fully meet the requirements of a mega city. Absence of adequate parks, open water bodies, and drainage system has degraded the quality of living in the city in many ways. The present type of land uses of the greater Dhaka city include residential 32%, commercial 4%, agricultural 57%, water bodies 5%, and open fields 2% (Hafiz *et al*., 1997). However, in the metropolitan city area, the percentage of the agricultural land is much lower.

2.2 Physical and Demographic Development

Dhaka has grown from a small settlement within the confines of the river Buriganga and Dholai Khal to to-days mega city. The physical features, topography and demographic features of Dhaka City have always influenced its physical expansion. During the Mughal and British regime, political importance and trade played significant roles in the city's growth and expansion. This section briefly describes the growth and expansion of the city in the scale of time under five major periods: Pre-Mughal (before 1604), Mughal (1604-1764), British (1764-1947), Pakistan (1947-1971) and Bangladesh (after 1971).

2.2.1 Pre-Mughal Period (before 1604)

Growth and expansion of Dhaka city in the pre-Mughal period is obscure. Before Mughals reign, Dhaka was a small Hindu trading centre. The name of localities indicates the predominance of Hindus craftsmen and professionals thus depicts the possibility of being grown as a centre of artisans and craftsmen (Ahsan, 1999, Chowdhury and Faruqui, 1991). The boundaries, size, and population of Dhaka city are relatively undocumented and unclear before 1604. It is evident from the various writings on Dhaka that the areas to the east, northeast and southeast of Babur Bazar up to the Dulai River on the left bank (northern bank) of the Buriganga formed the old town. The Dulai River possibly formed the northeastern boundary of the old city, though it is difficult to determine the western limit of the pre-Mughal 'old city'. Considering testimony to the existence of a mosque at that time, however, it can be assumed the city limits went beyond Babur Bazar on the western side (figure-3.2.1). It is quite likely that following the course of the Buriganga settlements grew on the southern, western and north-western parts of the city. These, of course, were sporadic growths with the riverbank determining the basis for settlements. The population size at that time of the Dhaka city is unknown (Islam, 1974).

2.2.2 Mughal Period (1604-1764)

Mughal Islam Khan inaugurated the fort, Chandnighat, located at "the new Dhaka", establishing a stronghold that held the status of provincial capital for a little over a century. Commercial activities and needs for administration and defence led growth of Dhaka from a small town to a metropolis. The accounts left by foreign travellers and the existence of Mughal ruins, as well as the names of the localities, which still survive, helps determine the extent of Mughal Dhaka (Karim, A., 1964). According to documents and remnants of Muslim Mughal sculptures in the "old city", Mughal Dhaka incorporated the "old Dhaka" within its boundaries. In this period the expansion to the west and the north was significant; with the fort in the centre the expansion to the west followed the riverbank and the city spread northward to Phulbaria on the fringe of the Ramna area. In this growth of Mughal Dhaka the general characteristics of a Mughal city were noticeable. The areas to the south and southwest of the fort up to the riverbank grew mainly as commercial areas while to the north and northeast residential areas sprouted. The northern limit of the city extended to the gateway built by Mir Jumla (1660-63). Mir Jumla's name is also associated with the construction of two roads connecting Dhaka with a network of forts built for the defence of the capital city. A road headed north to a fort at Tongi-Jamalpur and another toward the east connecting Dhaka with Fatullah, where two other defensive forts were constructed. These two roads influenced the growth of the city in these directions. In the available early records of the East India Company (1786 and 1800 A.D.) the boundary of the city is mentioned as: Buriganga in the south, Tongi in the north, Jafarabad-Mirpur in the west and Postogola in the east. The expansion of the city in the Mughal period was dictated by nature, particularly highlands. As provincial capital, Dhaka enjoyed a golden era, serving as the commercial headquarters and chief emporium for products of Eastern Bengal. Dutch, Portuguese, French, English, and Armenians were among those who established trading houses in the 17thC. The physical size of Dhaka was about 50 square kilometres with a population of 0.9 million (Taylor, 1840).

2.2.3 British Period (1764-1947)

After the East India Company, the British Colonial outfit, purchased Diwani in 1765, and the shift of the Bengal capital from Dhaka to Calcutta, Dhaka City suffered from lack of political and commercial importance. Gradually the administrative and commercial importance of the city dwindled and by 1828 the city was reduced to a mere district headquarters, though it retained its position as a provincial Circuit Court of Appeal. By 1840, this decline had reached its nadir and most of the former Mughal city had been deserted or had fallen victim to the encroaching jungle (Ahmed, S. U., 1986). The decline affected Dhaka seriously and during this period Dhaka also suffered physical shrinkage to such an extend that the physical boundaries actually shrunk from 50 km to 8 km (Islam, 1974) as did the population from 0.9 million to 0.2 million (Taylor, 1840).

However, the second half of the nineteenth century marked the beginning of the physical renewal of the city. In 1857, India came under the direct rule of the British crown and saw some development of utility services. In 1905, Dhaka was made the capital of the new province of East Bengal and Assam, allowing further development of roads and proper drains, as well as fully planned residential areas like “Wari”, an upper-middle class area considered “the sanatorium of Dacca.” Thus the ‘new Dhaka’ of the present century had its birth at the hands of the British rulers. The impetus for growth created by the 1905 partition of Bengal was seriously jolted by the annulment of the partition in 1911 when Dhaka reverted back to the status of a district town. However, the establishment of the University of Dhaka in 1921 helped to retain a semblance of prominence until 1947 when Dhaka again attained the status of the provincial capital of East Bengal, later named East Pakistan (Islam, 1974).

2.2.4 Pakistan (1947-1971)

In 1947, India become independent of British rule and Pakistan was created. Dhaka restarted its life as the capital of East Pakistan. The needs of the officials engaged in administration, the business community and the residents grew out of the sudden onrush of people to Dhaka. This contributed to the growth of the city in its new role as the provincial capital. The Motijheel area, once desolate and lying on the fringe of marshes and swamps where the Nawabs had built a garden house was earmarked as the commercial area in 1954. Planning continued such that open areas of the city were devoted to recreation, residences, and more commerce. To cater to the ever-increasing residential needs of the new capital, the Dhanmondi area, adorned with paddy fields in the early 1950s, was developed as a residential area after 1955. The Mirpur Road formed an axis and the highlands on both sides of the road came to be occupied right up to Mohammadpur and Mirpur. In the mid-1960s these two areas were developed by the government mainly to accommodate the migrant Muslim population. The Tejgaon Airport and the Tejgaon Industrial area came under governmental schemes in the early 1950s. In the second half of the 1960s the decision to have a capital for East Pakistan at Dhaka led to the development of the area to the west of Tejgaon farm and the Airport (now known as Sher-e-Bangla Nagar). With the creation of the Dhaka Improvement Trust (DIT) in 1956 (transformed into the Rajdhani Unnayan Kartripakkha in 1987) greater interest and care was undertaken in road construction and city planning. The DIT developed the Gulshan Model Town in 1961, Banani in 1964, Uttara in 1965 and Baridhara in 1972 (though first conceived in 1962). The 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. The Dhaka Railway Station was moved from Phulbaria to Kamalapur. This eliminated the landmark that had long stood between the ‘old Dhaka’ of the Mughals and the ‘new Dhaka’ of the English. The rapid growth and development of the area between the old railway track and Kawranbazar necessitated this change. In 1947, the area and population of Dhaka City was 12 sq. km (Islam, 1974) and 2.5 million (Census of Pakistan, 1951).

2.2.5 Bangladesh (1971 onward)

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.

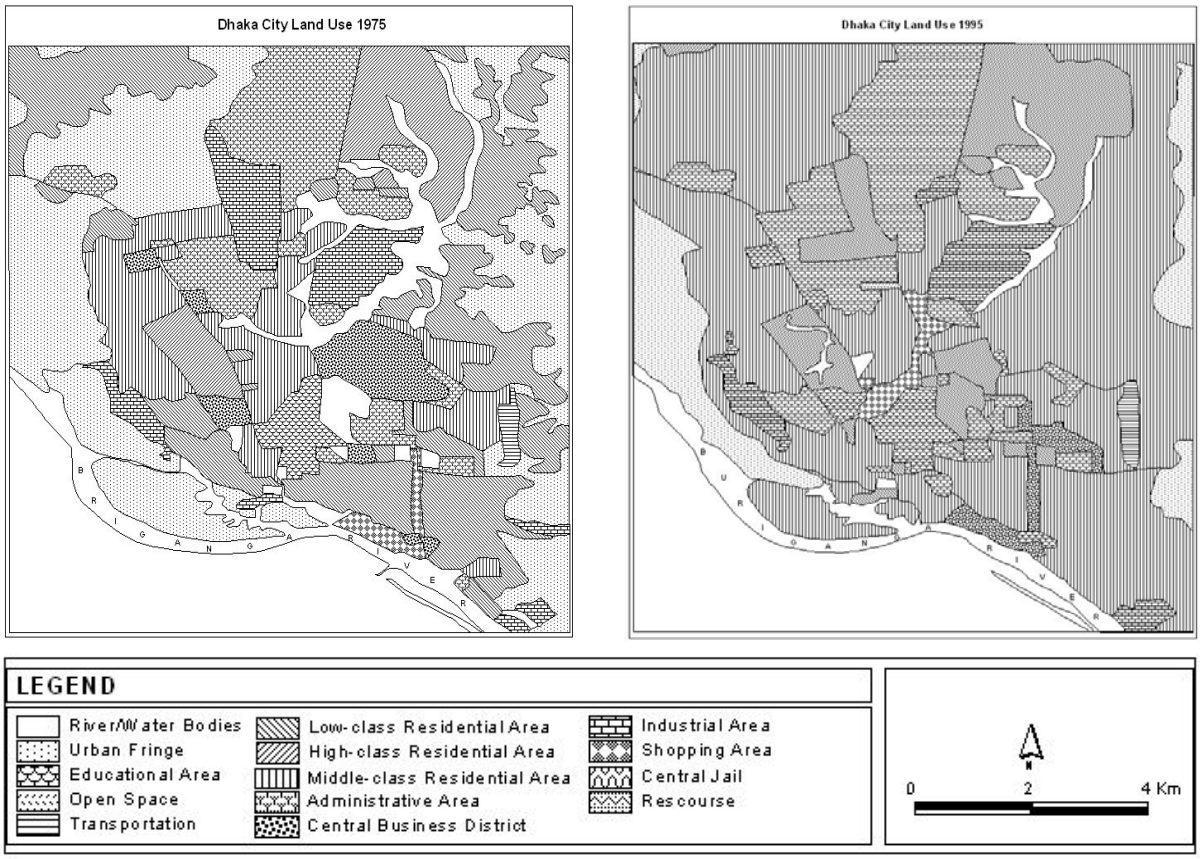
The growth outward, following the pattern set by the Mughal founders has been limited by the waterways surrounding the city. With increased population pressure the highlands spreading northward were occupied and built up. The intervening ditches, swamps and marshes were filled in, not in any planned 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. Since Dhaka became the capital of an independent country the pressure on it has been 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 on any available vacant land. 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. Since the 1990s, Dhaka has been on the verge of change in its urban character with vertical growth replacing horizontal expansion (Chowdhury and Faruqui, 1989). By 1981, the area of Dhaka SMA surpassed the Mughal Capital period by 12.4 sq. km at 155.4 sq. km (Census of Bangladesh, 1981). Population also had tripled to 3,440,147. The 2001 census recorded 9,912,908 inhabitants (Census of Bangladesh, 2001).

Table-2.3 Area and Population of Dhaka City, (1600 – 2001)

Year	Period	Area (Sq. mile)	*Source*	Population	*Source*
1600	Pre-Mughal Period	1	Islam, 1974	Unknown	
1700	Mughal Capital	50	Taylor, 1840	9,00,000	Taylor, 1840
1800	British Town	8	Islam, 1974	2,00,000	Taylor, 1840
1867	British Town	8	Islam, 1974	51,000	Census of Bengal, 1901
1911	British Town	--	--	1,25,733	Census of Bengal, 1911
1947	Capital of East Pakistan	12	Islam, 1974	2,50,000	Census of Pakistan, 1951
1951	Pakistan Period	--	--	3,35,928	Census of Pakistan, 1951
1961	Pakistan Period	28	Census of Pakistan, 1951	5,50,143	Census of Pakistan, 1951
1971	Capital of Bangladesh	40	Census of Bangladesh, 1974	15,00,000	Census of Bangladesh, 1974
1974	Capital of Bangladesh	40	Census of Bangladesh, 1974	16,00,000	Census of Bangladesh, 1974
1981	Dhaka Municipality	62.4	Census of Bangladesh, 1981	24,75,710	Census of Bangladesh, 1981
1981	Dhaka SMA	155.4	Census of Bangladesh, 1981	34,40,147	Census of Bangladesh, 1981
1991	Dhaka SMA	--	--	69,50,920	Census of Bangladesh, 1991
2001	Dhaka SMA	--	--	99,12,908	Census of Bangladesh, 2001

Source: M. Nabi, 2002; Reconstructed by the Author

Figure-2.5 Historical Development and Land Use Pattern of Dhaka City (1700 – 1962 A.D.)



Source: M. Nabi, 2002; Reconstructed by the Author

Figure-2.6 Development and Land Use Pattern of Dhaka City in Bangladesh Period

Chapter 03

Storm Water Drainage System of Dhaka City

3.1 Natural Drainage System

The natural drainage system in the 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 discharge to the surrounding rivers through khals. Important elements of storm water drainage system are briefly described below.

3.1.1 Storage Area

There are many water storage areas such as lakes, ponds, and low laying lands. The characteristics of major lakes in Dhaka City are shown in the **Table-3.1**.

Table-3.1 Major Characteristics of Lakes in Dhaka City during the Dry Season

Name of the lakes	Length (meter)	Ave. depth (m)	Area (sq. km)	Volume (m^3)
Dhanmondi lake	2400	2.5	0.176	$4.4*10^5$
Ramna lake	400	4.5	0.020	$0.9*10^5$
Crecent lake	650	2.5	0.016	$0.4*10^5$
Gulshan lake	3800	2.5	0.480	$12*10^5$

Source: JICA, 1991

3.1.2 Channels

There are more than 40 drainage channels (khals) including main and branch channels (**Fig.-3.1**). Approximately five-sixth of the city areas are drained through these channels to the surrounding rivers. The catchments area of the channels varies from 6 to 40 sq. km. The length and the catchments area of the major khals are given in **Table-3.2**.

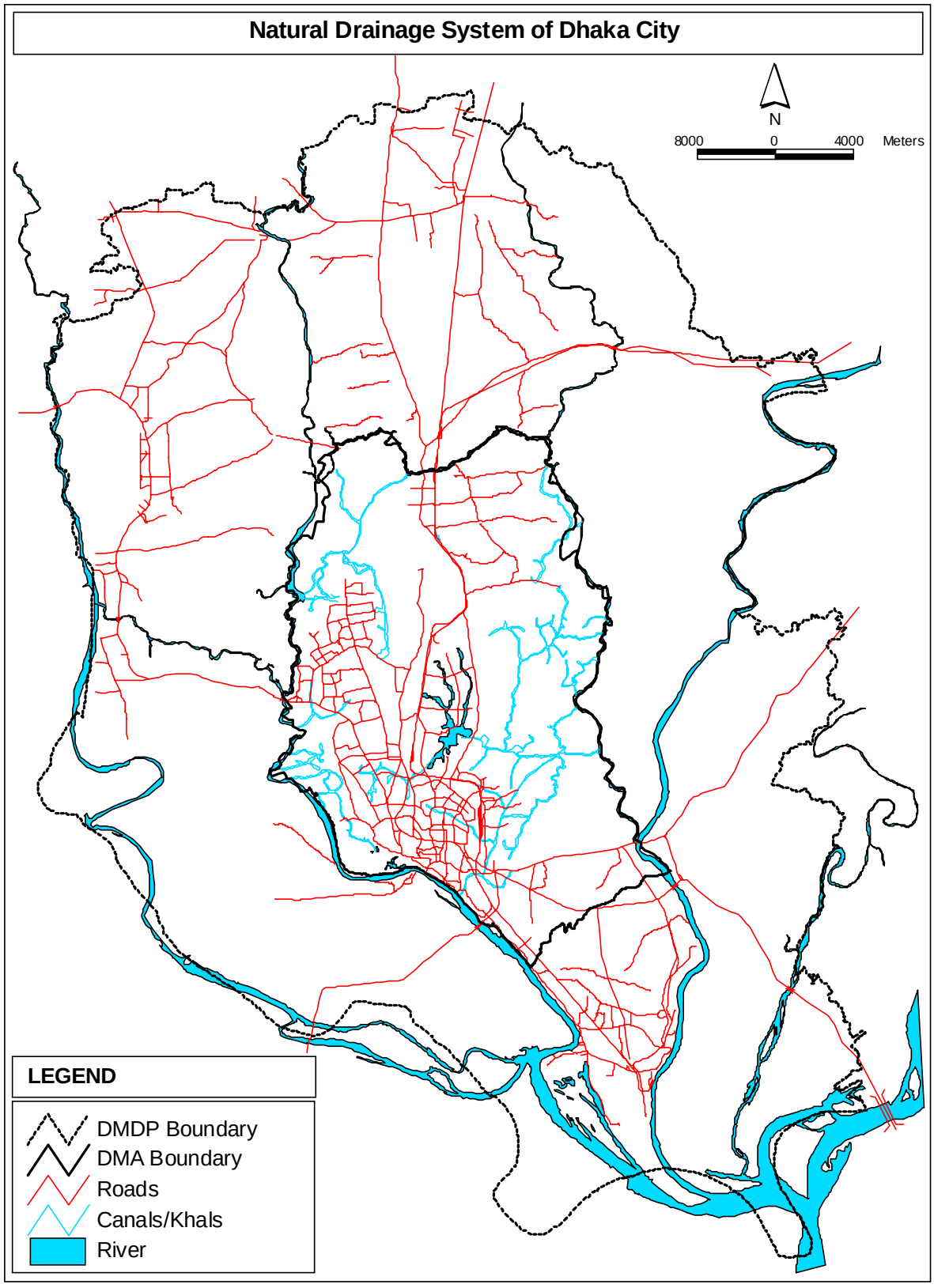
Table-3.2 Characteristics of major khals in Dhaka City

Name of the khals	Length (Km)	Catchments Area (Sq. km)
Dholai khal	4.0	16.8
Gerani khal	3.4	6.7
Segunbagicha khal	3.5	8.3
Begunbari khal	6.5	37.7

Source: JICA, 1991

3.1.3 Backwater effect and retention by storage areas:

The storm runoff from Dhaka city is discharged to the surrounding rivers, which are distributaries from the river Brahmputra River (**Fig.-3.1**). The stage of these rivers generally remains high during monsoon. As a result, the drainage system of Dhaka city is under the influence of backwater effect from surrounding rivers. Consequently the flow velocity in storm sewers and drainage channels remain very slow for several days when flood wave passes through the surrounding rivers. Fortunately, the lakes and low-lying areas provide storage space for storm water. These large retention areas save Dhaka city from flooding during heavy storms. Gradual reduction in retention areas because of human activities, I one of the causes of increasing flood problem in Dhaka city.



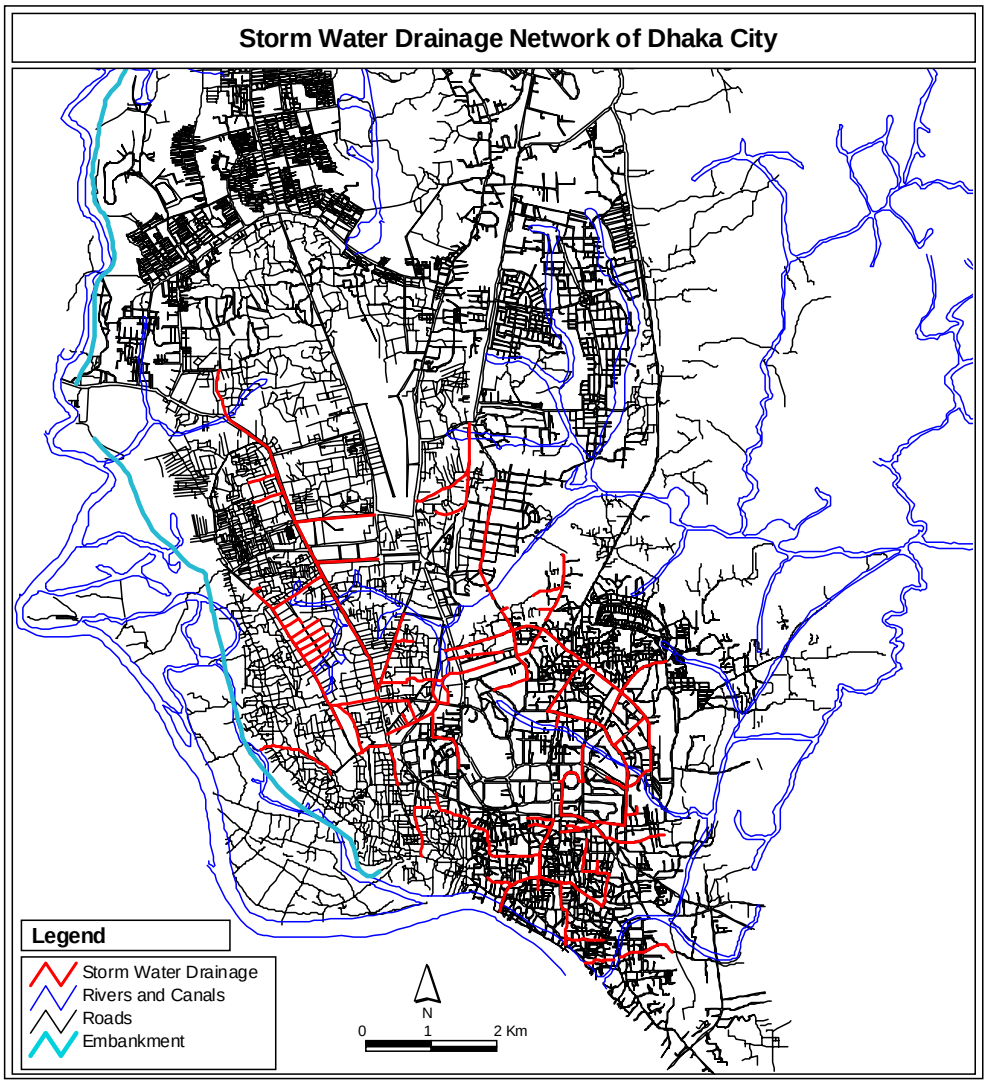
Source: DMDP, 1995; Reconstructed by the Author

Figure-3.1 Natural Drainage System of Dhaka City

3.2 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 organised by the Drainage Circle of Dhaka WASA.

The 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 networks are shown in **Figure-3.2**.



Source: Dhaka WASA, 2003; Reconstructed by the Author

Figure-3.2 Storm Water Drainage 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.

i) 22 open canals having width of 10 to 30 m and total length of approximately 65 km.

ii) 185 km. of underground pipes having diameter ranging between 450 to 3000 mm.

iii) 6.5 km. of box culvert of sizes between 2.5 m * 3.4 m to 6 m * 4.1 m.

iv) 2 storm water-pumping stations, of capacity of 9.6 m^3/s and 10 m^3/s at Narinda and Kallyanpur respectively.

v) 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 cumec, installed temporarily by Dhaka WASA to drain out storm water from various locations.

Moreover, DCC have constructed and maintains at least 130 km small diameter underground drains and approximately 1200 km surface drains, which carry 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 the Dhaka WASA. But several agencies are working for development of the city drainage system, with little or no coordination among them.

3.3 Hydrologic Design Criteria in Master Plan

In response to the request of the Government of Bangladesh (GoB), the Government of Japan agreed to conduct a study on greater Dhaka Flood Protection within the framework of technical cooperation between Japan and Bangladesh. Need for this study was felt when Dhaka City suffered from an unprecedented flood in 1988, which was caused by floodwater carried by surrounding rivers. The Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation program, was assigned to undertake the study. The JICA study team commenced this study in 1990. One of the objectives was to carry out a Master Plan study on comprehensive flood control and storm water drainage for Dhaka Metropolitan area. Some of the hydrologic design criteria adopted in the storm water drainage master plan (JICA, 1991) are briefly mentioned below.

3.3.1 Design Rainfall

For channel and trunk drain:

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

$i = 9005/(t+50)$ $(t \leq 120)$

$i = 12437/(t+115)$ $(120 < t < 1440)$

Where, i is the rainfall intensity (mm/h) and t is the duration (min)

For pumping station and retarding pond:

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

3.3.3 Runoff Coefficient and Runoff Ratio

The runoffs coefficients by land use are shown in table have been proposed for the calculation of design discharge by the Rational Formula. The runoff ratio (total runoff/total rainfall) of 0.8 is employed for the estimation of required pump and retarding pond capacities.

Table-3.3 Runoff Coefficient used in SWD Master plan prepared by JICA (1991)

Land use	Proposed runoff coefficient
Commercial Area	0.65
Industrial Area	0.55
High Class Residential Area	0.30
Middle and Low Class Residential Area	0.50
Green Zone and Others	0.20
Water Bodies	0.10

Source: JICA, 1991

3.3.4 Time of Concentration

Time of concentration (Tc) was calculated by

$$Tc = Ti + L/V$$

Where,
Ti = Inflow time of rain water;
L = Length of the khal; and
V = Average velocity in the khal
Values of **Ti** and **V** were taken equal to 20 minutes and 0.8 m/s respectively

Chapter 04

Water Logging Situation in Dhaka City

4.1 Introduction

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 1996 when residences experienced ankle to knee-deep water on the streets. Daily activities in parts of the city were nearly paralysed and heavy traffic jams occurred due to stagnant water on the streets.

In 1997, the Surface Water Modeling Center (SWMC) presently called Institute of Water Modeling (IWM) carried out a pilot study about Storm Water Drainage Modeling for Dhaka City. Department of Water Engineering & Management (DWEM), Asian Institute of Technology (AIT), Thailand again performed a study named “Modeling of Urban Flooding in Dhaka City”. The study was an extension and improvement of the pilot study in terms of updating and analyzing drainage system together with suggestion of alleviation scenarios to relieve flood problems, i.e. feasibility study of applying real time control to urban drainage system to reduce flood problem. This water logging situation is totally based on the information and reference of the two studies mentioned above.

4.2 The Study Area

The study area was Segunbagicha khal catchments, which is one of the major drainage channels in the city. The khal includes the most important commercial areas and the government offices of Dhaka City, hence most of areas are impervious due to commercial and mixed (residential and commercial) land uses. The khal drains storm water from an upstream drainage catchments area of 4.54 km^2. The elevation of the area is 2 to 13 meters above the mean sea level (msl)

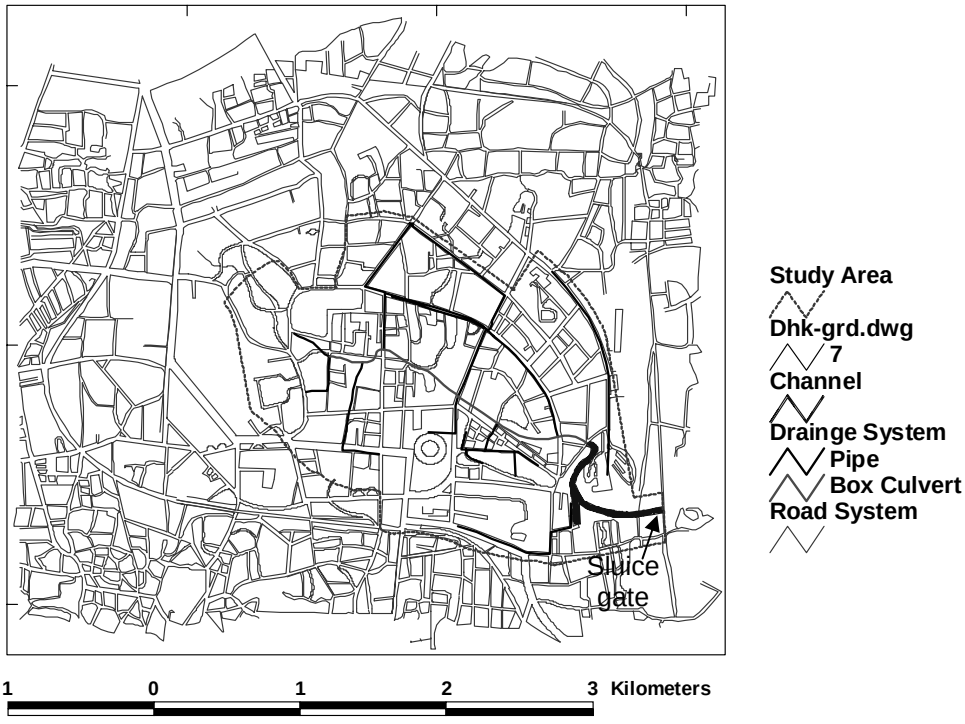


Figure-4.1 Study Areas with Drainage System

4.3 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.

Segunbagicha Khal originates from the Ramna Park area and flows through the areas of Segunbagicha, Paltan, Matijheel and Gopibag. A distance of 3.4 km further downstream, it crosses Janapath and then meets with Gerani Khal before draining finally into the Balu River. Previously drainage from the Segunbagicha 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.

As a part of the Dhaka Integrated Flood Protection Project a four-vent sluice gate has been constructed on the Segunbagicha Khal at the intersection with Janapath. The Collected stormwater from each sub-catchments 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.

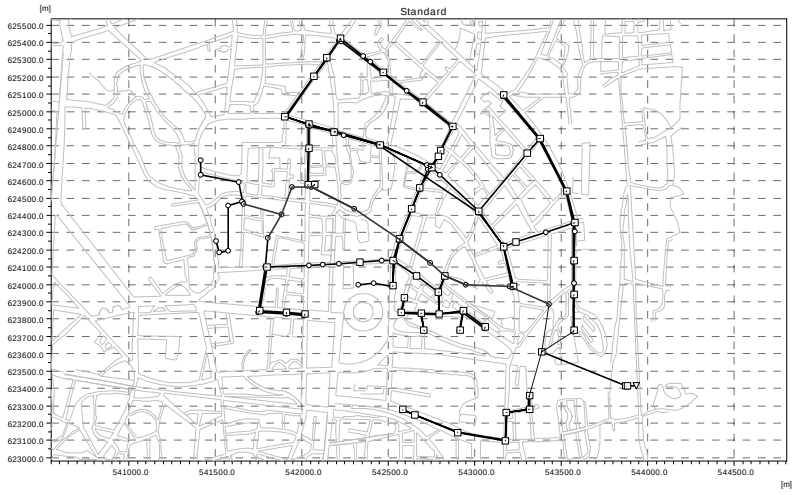


Figure-4.2 Storm Water Drainage Network in the Catchments Area in 1996

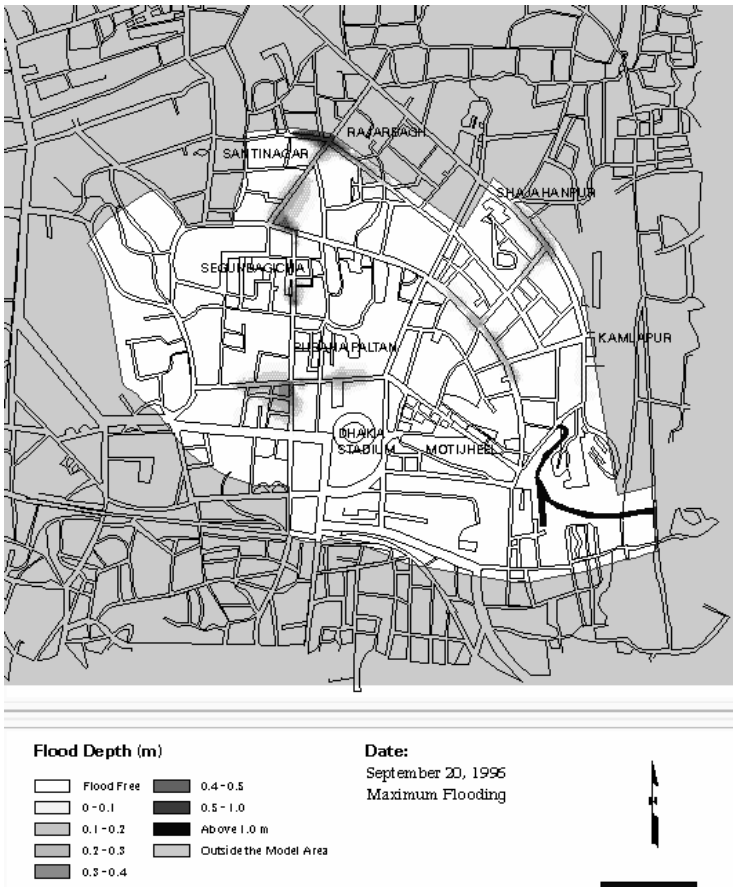
4.4 Water Logging in 1996

As it is mentioned earlier (Chapter One) that the main causes of water logging in Dhaka City can be classified into two types. The first one results from high water level of Peripheral River system and the other caused by rainfall in the city. In 1996, water logging in Dhaka City caused by local high rainfall occurred in the built-up areas of the city.

Table- 4.1 Hourly Recorded Rainfall Data during 16-19 September 1996

Date	Rainfall (mm)	Duration (hours)	Remarks
September 16, 1996	62	2	37 mm in the first hour
September 17, 1996	29	2	28 mm in the first hour
September 18, 1996	0.5	1	-
September 19, 1996	85	4	41.5 mm in the third hour

Source: SWMC, 1997



The severe water logging in September 1996 in Segunbagicha khal catchments is believed to originate from insufficient drainage capacity and blockages of the drainage system due to huge volumes of garbage and polyethylene bags. The areas of Shantinagar, Kakrail, Paltan, Matijheel and Pirjangi Mazar, which include many of the important business and Government offices of the country, suffered most. Important street intersections were inundated for four days during 16-19 September 1996. The water depth in some areas was as much as 40-60 cm, which created large infrastructure problems for the area and a huge economical loss in production together with large damages of existing property and goods.

Figure-4.3 Inundated locations in Study Area

Table- 4.2 Maximum Depth and Duration of Storm Water in the Area in 1996

Sub-catchments	Maximum depth (cm)	Duration (hours)
Shantinagar Crossing	55	16
Kakrail Crossing	19	6
Topkhana Road	25	12
Pirjangi Mazar	18	9

Source: DWEM, AIT, 1997

As an immediate measure it has been suggested to install pumps at a few selected critical locations. During the water logging problems in 1996, the DWASA arranged 19 pumps of 5 Cusec capacities each at four locations to pump out the stagnant water from the area. Besides, DCC also arranged 15 pumps of same capacity in different parts of the city.

The situation was severely aggravated because the only natural drainage system called Segunbagicha Khal, which conveys storm runoff from the areas to the receiving rivers, was not fully operational. As a part of the drainage improvement plan of the Dhaka Metropolitan City, DWASA has been started to rehabilitating the natural channel section of the Segunbagicha Khal by replacing it with a concrete box culvert having length of 2.1 km. After completion of 85% of the total works the construction has been stopped by court order due to land dispute with the owners.

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 toconstruct buildings, with no or little provision for drainage
the main drainage systems of the urban area 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.

4.5 Profile of Water Logging in September 2004

In September 11th to 16th, 2004 heaviest ever rainfall (341 mm) occurred in Dhaka City and its devastating impact paralyzed the city life. Following pictures illustrates the water logging situation due to the rainfall and its impacts in Motijheel, the commercial hub of Dhaka City.

Picture-4.1 Pictures Illustrates the Water Logging Situation in Dhaka City, September 2004

Chapter 05
Causes of Water Logging

5.1 Introduction

The capital city of Bangladesh has become one of the populous Mega City in the world, in recent years facing extensive water logging during the monsoon (May to October) as a common problem of the city like water pollution, traffic congestion, air and noise pollution, solid waste disposal, black smoke etc.

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 care of 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 over and above 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 area also causing water logging.

To find out inherent causes of water logging in Dhaka City, a field survey as a questionnaire survey, informal interviews and open discussion has been conducted with the authorities of different concerned organizations, experts and people living in different parts of Dhaka City. The total numbers of respondent were 100 and following table **(Table- 5.1)** shows their summarized opinions about the prime causes for water logging in the city.

Table- 5.1 Causes of Water Logging in Dhaka City

Causes	Percentage
Excessive rainfall	74
Population growth and unplanned development	95
Waste management system	82
Encroachment	76
Topography	46
Capacity and gravity of drainage system	67
Drainage management system	83
Development works during rainy season	40
Storage of construction materials	37
Lack of public awareness	60
Lack of regulations and its implementation	45

Source: Field survey (Interview and Open Discussion), 2003-2004

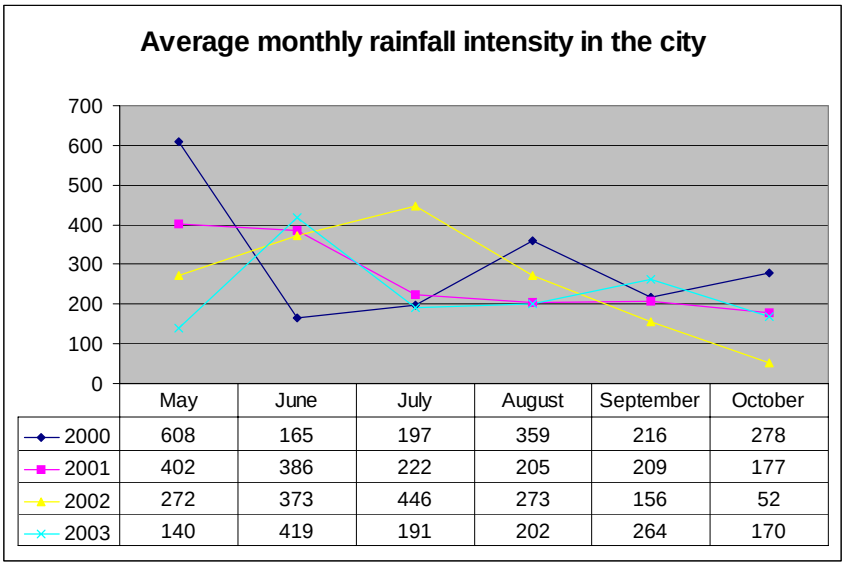
5.2 Excessive Rainfall

Bangladesh is a tropical country and is located on the extensive floodplains of the Ganges and Brahmaputra. The Himalayas stands to the northeast of the country and the Bay of Bengal lies on the south of the country. As a result heavy downpour occurs on the country, especially in the

monsoon season (May to October). In recent years the Dhaka Metropolitan area has been exposed to water logging due to heavy rainfall. During the 1996, 1998 and 1999, excessive rainfall occurred in Dhaka caused short duration flooding in different areas of the City namely Shantinagar, Nayapaltan, Rajarbag, Dhanmodi, Azimpur and Green Road (S. Huq and M. Alam, 2003**)**.

The most recent downpour occurred from September 11th to 16th 2004 in Dhaka forced the City life standstill. 341 mm. of rain in 24 hours between September 14th and 15th is the heaviest ever rainfall. Dhaka's previous record of 274 mm of rain on September 16, 1966. "During the monsoon, the intensity of rainfall is high and in September, it is relatively low. Therefore, it use to occur average 300 to 325 mm of rainfall in the whole month but in this year it occurred average 300 mm in 3 days of the week", said Professor Nazrul Islam at Dhaka University's Geography and Environment Department. Dumped with average 300 mm of rain in that week (MDB, September 2004), Dhaka was sloshing with floodwaters that sent many places, including Motijheel commercial heart, under chest-deep water. The devastating impact of the downpour that paralyzed Dhaka City is a salutary reminder of the severity of the problem.

According to survey, 74 percent of the respondent has been mentioned that heavy rainfall is one of the main reasons for water logging in Dhaka City. Relatively low intensity of rainfall causes serious water logging problems for certain areas of the City that are inundated for several days mainly due to the drainage congestion.



	May	June	July	August	September	October
2000	608	165	197	359	216	278
2001	402	386	222	205	209	177
2002	272	373	446	273	156	52
2003	140	419	191	202	264	170

Rainfall data collected from MDB for last four years shows **(Figure-5.1)** that the average monthly rainfall during monsoon (May to October) are 304 mm, 267 mm, 262 mm, and 231 mm for the year 2000, 2001, 2002, and 2003 respectively.

Figure-5.1 Average Monthly Rainfall in Dhaka City (mm)

Table: 5.2 Highest and Lowest Rainfall Intensity in Dhaka City during Monsoon (in mm)

Month/Year	2000		2001		2002		2003	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
May	152	01	52	01	88	01	52	01
June	28	01	61	01	59	01	93	01
July	47	01	40	01	73	01	30	01
August	133	01	58	01	46	01	67	01
September	73	01	54	01	42	01	61	01
October	158	01	54	01	17	01	73	01

Source: Meteorological Department of Bangladesh, 2004

5.3 Disappearance of Natural Drainage System

The disappearance of the natural drainage system is one of 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, and encroachment on lakes, khals/canals and rivers with unauthorized construction are the summarized general man made physical and social activities related to the disappearance of natural drainage system. 95 per cent of the respondent claimed these activities for prime causes of water logging in Dhaka City.

5.3.1 Population Growth and Unplanned Development

Dhaka City, being the administrative, commercial and cultural capital of Bangladesh has now turned into 26th Mega City and 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 (Census 2001). It is growing at an alarming rate (5.6% during 1991-2001 inter-casual periods). As per future prediction, this population will further grow to about 20 million by the year 2020 and to 25 million by 2025 (DMDP, 1997). Dhaka city is projected to be one of the four largest mega cities in the world by next 10 years. A principal reason of such a rapid growth is over concentration of maximum activities and development works 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 of searching employment and better quality of life. High-density population as well as shortage of land causes intense densification in the existing built up areas.

Table- 5.3 Population Growth of Dhaka City

Year	Dhaka City Corporation			DMDP Area (RAJUK Area)		
	Population (000)	Growth (% per year)	Pop. Density (Person/ha)	Population (000)	Growth (% per year)	Pop. Density (Person/ha)
1991	6100	--	169	7300	--	48
1995	6900	3.0	192	9100	4.2	59
2000	8000	3.0	222	10900	3.6	71
2005	9000	2.5	251	12600	3.0	83
2010	9900	1.5	169	14200	2.4	93
2015	10200	1.0	283	15700	1.9	103

Source: Dhaka Metropolitan Development Plan (DMDP), 1997

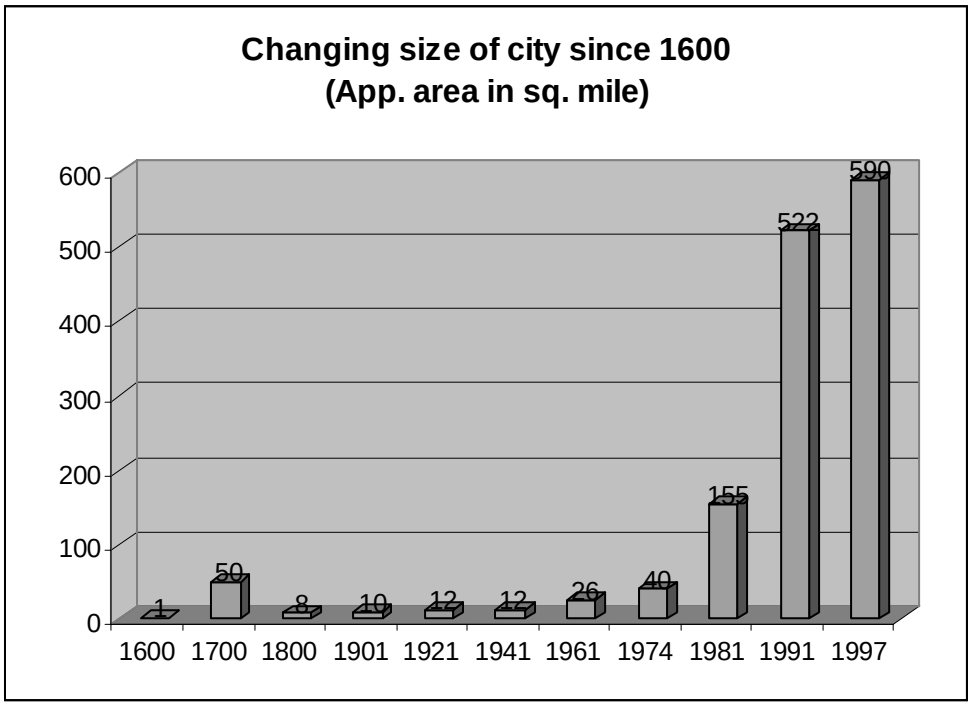
Table- 5.4 Growth of Dhaka City Corporation (DCC) Area

Year	Area (sq. km.)	Population
1906	6.1	--
1951	15.5	276,o33
1961	40.1	368,575
1974	--	1,403,259
1981	131.6	2,475,710
1991	153.8	3,612,850
1997	360.0	6,000,000

Source: BBS, 1997; Islam, 1999; Miah, 1999

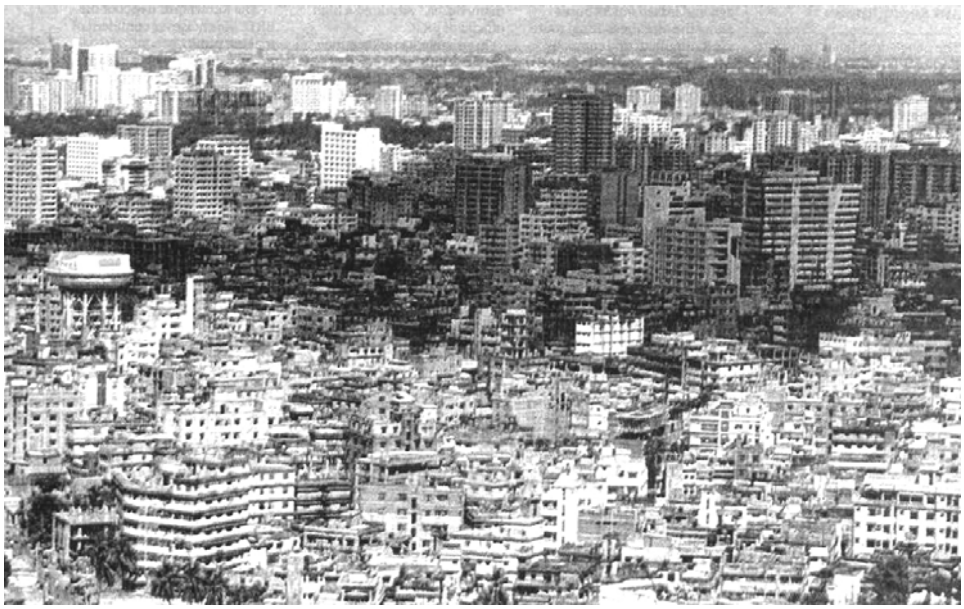
Rapid population growth and so rapid urbanization during the last three decades has taken place, which creates extra pressure on the land of already overcrowded Dhaka City. The size of Dhaka City has grown from 1 sq. mile in 1600 to 590 sq. mile in 1997 (Islam, 1974; DMDP, 1997). At the same time, the size of

Dhaka Municipality, which has been upgraded to DCC, has grown from 6.1 sq. km. in 1906 to 360 sq. km. in 1997 having population from 276033 in 1951 to 6000,000 in 1997 (Islam, 1999; BBS, 1997). 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. Agricultural lands, low lands, wet lands; water bodies and natural drainage give way to housing developments and roads. This urbanization and unplanned development activities resulted in substantial increase in impervious area, created obstruction to natural drainage pattern, and reduced detention basins, which has almost undoubtedly must have aggravated the water logging problem in Dhaka City. **Picture-5.1** illustrates that the increased built-up area in Dhaka City.



Source: Islam, 1966, 1974, 1991; BBS, 1974, 1981, 1991,

Figure-5.2 Growth of Dhaka City Since 1600



Picture-5.1 The Fast Growing "Concrete Jungle" tells the Tale of and Unplanned City

Unplanned urbanisation can adversely impact flooding situation in a watershed. Prior to urbanisation there exists a greater lag time between intense rainfall and peak stream flow. After urbanisation 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% of the land surface is covered by roads and buildings (like Dhaka City), floods are almost six times more numerous than before urbanisation (Khalequzzaman, 2001).

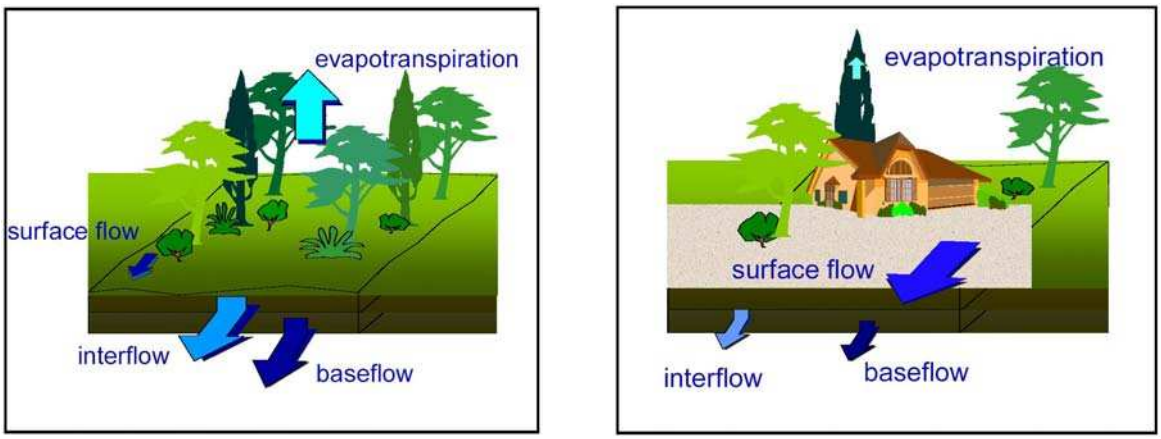
The concrete covering 90 per cent of Dhaka City's land area hampers the absorption of rain water, said Masroor-ul-Haq Siddiqi, a former official of BWDB. He also indicated the city's immense population density contributes indirectly to water logging. "Where will the waste and sewage of so many people go?" he asked.

Why are urban areas drained?

(Extracted from Sustainable Urban Drainage System- best management practice for England, Scotland, Wales and Northern Ireland)

When rainfalls on to undeveloped land, most of the water will soak into the topsoil and slowly migrate through the soil to the nearest watercourses or groundwater. A small proportion of the rainfall – usually 15 to 20 per cent – becomes direct surface runoff that usually drains into watercourses slowly because the ground surface is rough (e.g. because of vegetation). This means that the effects of rainfall are spread out over a period of several hours. Even short, heavy storms may have little on flow rates in the receiving waters because much of rainwater may be absorbed into the ground.

When catchments are developed, the proportion of the land covered by impervious surface (roads, parking areas, roofs, driveways and pavements) will increase, preventing the natural infiltration of rainfall into the ground. Often the remaining open ground cannot accept water as rapidly as it did in its natural state, because during construction topsoil is removed, compacted or mixed with low-permeability subsoil. In developed catchments, direct runoff can increase to more than 80 percent of the rainfall volume. At the same time, because paved surfaces may be less rough than natural surfaces, water may travel over them faster and as a result runoff will reach the receiving watercourses more quickly. The flow rates in the receiving waters are therefore much more sensitive to rainfall intensity and volume than those in undeveloped catchments.



Before Urbanization **After Urbanization**

Figure-5.3 Characteristics of Runoff in Urban Area

Volume and rates of runoff both increase significantly after development. Peak flow rates can increase by a factor of up to ten, which means that streams and rivers have to cope with larger and

often sudden runoff flows. It also means that drainage is needed to reduce flood risk within the developed areas.

5.2.2 Waste Management System

"Waste management system is one of the important factors for water logging in Dhaka City," said 82 per cent of the interviewers from different development organisations and inhabitants. The increased congestion of the city area, the high population density and the rapid growth all around it has made it impossible to clean the street and drains as fast as the waste thrown onto them.

Dhaka, with a population about 10 million, generates a massive quantity of waste everyday from various sources. The major sources of solid waste in Dhaka are residences, streets, market places, commercial establishment, and hospitals. Sources and characteristics of urban wastes in Bangladesh are shown in **Table- 5.5**.

Table- 5.5 Sources and Characteristics of Urban Waste in Dhaka

Types of Solid waste	Quantity (%)
Domestic	40-60
Commercial	5-2
Street Sweeping	20-30
Combustible	20-30
Non-combustible	30-40
Moisture	45-50

Source: Bangladesh Centre for Advanced Studies (BCAS), 2002.

Due to urban development, population growth, and consumption increase, the volume of solid waste generation in Dhaka City increases every year. At present Dhaka City generates 3500-4000 tons solid waste per day, with a per capita generation of about 0.5 kg per day (N. M. Kazi, 2002). The composition of solid waste varies according to location, standard of living, energy sources and season. The quantity of waste generation increases during rainy season when many vegetables and fruits, especially mango and jackfruit, are available. Solid waste in Dhaka mainly consists of food, grass and plants, brick, dirt, paper and polythene materials **(Table- 6.6)**.

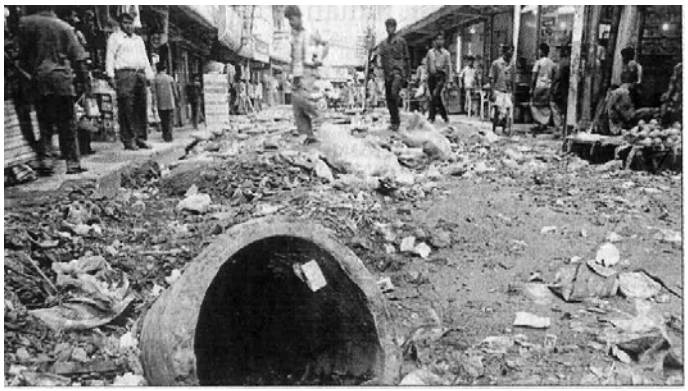
Table- 5.6 Composition of Solid Waste in Dhaka City

Materials	Quantity (%)	
	Residential Areas	Commercial Areas
Food Waste (Organic)	84.37	79.49
Paper/cardboard	5.68	7.22
Textiles	1.83	1.59
Plastics	1.74	1.48
Glass/metals and construction debris	6.38	10.22

Source: Bangladesh Center for Advanced Studies (BCAS), 2002.

The density of solid waste depends on its organic and inorganic content. Density values in India and other developing countries range from 300 to 600 kg/m3. In Singapore it is as low as 175 kg/m3, while in Katmandu and Dhaka measurements of 600 kg/m3 have been reported. The worldwide range of solid waste generation is 250 to 1000 grams per capita per day and the density varies from 100 to 600 kg/m3 (N. M. Kazi, 2002).

In Bangladesh, solid waste management is entrusted with the local government bodies. The responsibility of removing Municipal Solid Waste (MSW) and disposing of it lies with the City Corporation. According to the Dhaka City Corporation Ordinance 1983, collection and disposal of solid waste in the DCC area of 360 sq. km is the responsibility of the conservancy department headed by Chief Conservancy Officer. The Ordinance has a provision for removal of refuses from all public streets, public latrines, urinal drains, and dustbins and for collection, transportation, disposal and treatment of such refuse. Among the 12 executive department of DCC, Conservancy is responsible for solid waste management including cleaning of streets and drains. **Picture-5.2** illustrates that liter covers a stretch of Fakirapool Bazar Road, threatening to chock the sewerage system. But DCC appears indifferent to lax cleanliness.



Picture-5.2 Disposal of Garbage on to Streets that is threatened to Drainage Systems

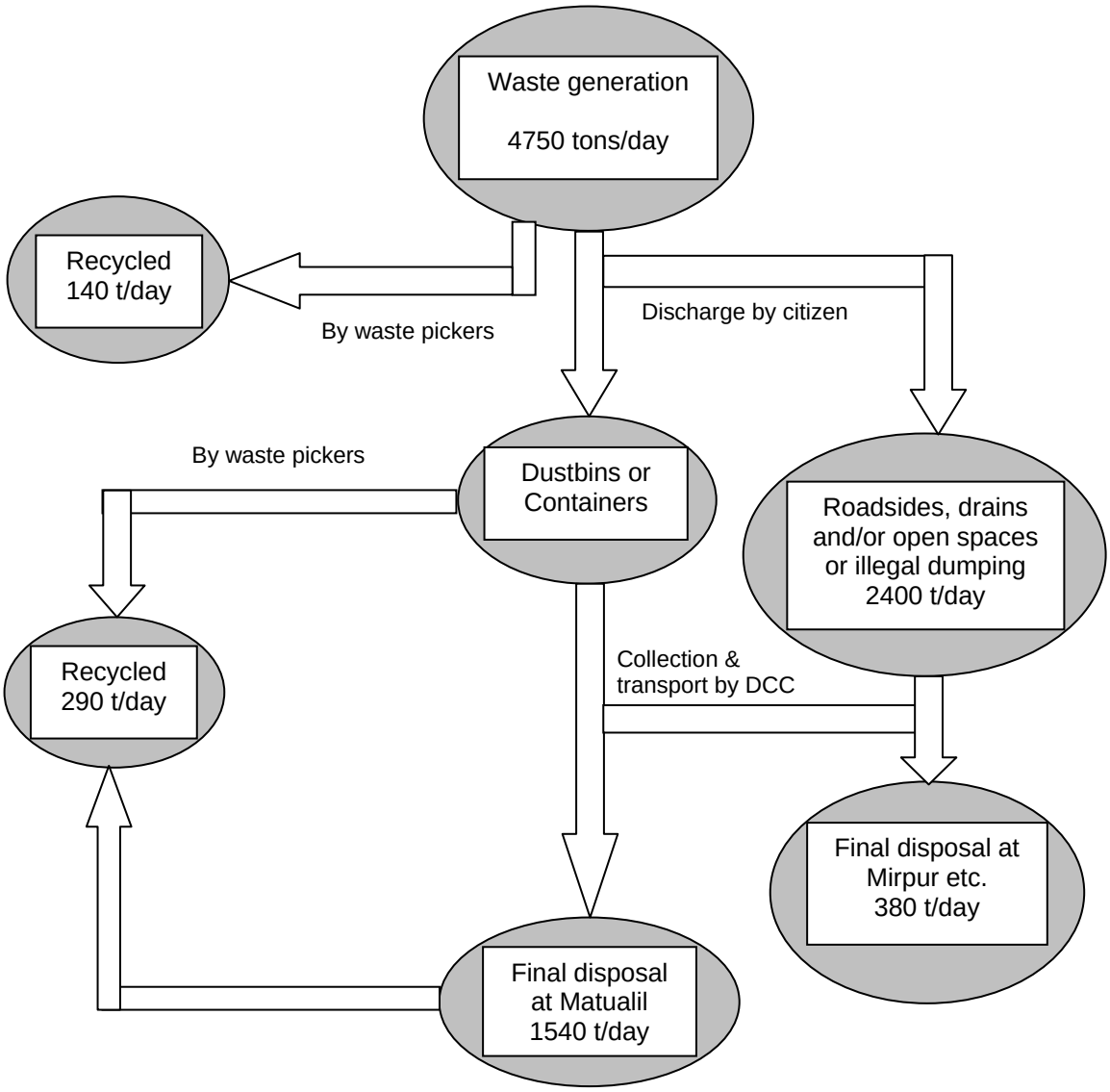


Figure: 5.4 Solid Waste Streams in Dhaka City (*Source: DCC, 2002*)

Moreover, due to resource constraints, lack of available dustbins, shortage of funding, due to almost no direct user charges as well as in sufficient subsidies, and other institutional constrains, DCC in general has not been able to effectively collect and dispose off the waste properly. Most of the waste is visible on the streets and in the drains and there is almost no sanitary landfill or any other facilities like incineration. About 400 tons out of average 3,500 tons of solid waste, generated in the city everyday, remains on the roads, open spaces and in drains (Raziur Rahman, 2003). So the streets remain unclean after daily sweeping and the drainage ditches and channels get blocked due to unwanted waste throwing. Rainwater also washed away these wastes and blockage the surface drains which hampers the natural flow of storm water and creates water logging in different place of the city. Therefore, in most of the area in Dhaka City, solid waste has become a serious problem with health and hygiene consequences for city dwellers. **Picture-5.3** illustrates that people are used to dispose off solid waste on to the road that remains for a long time due to lack of dustbins.

Picture-5.3 Disposal of Solid Waste on to the Roads due to Resource Constraints

The nature of solid waste is changing over time and with development. Of the solid wastes plastic and polyethylene goods also causes problems towards human health, environment and drainage system. These goods are cheaply and easily available in the markets. The users do not care to reuse them. They rather throw these things out of the door and window. An Inception Report on Control and Management of Polyethylene bags in Bangladesh shows that people of Dhaka City alone used 600 million bags a day. During rain, the storm water did not drain quickly, as one of the major reasons was due to polyethylene in the draining system.

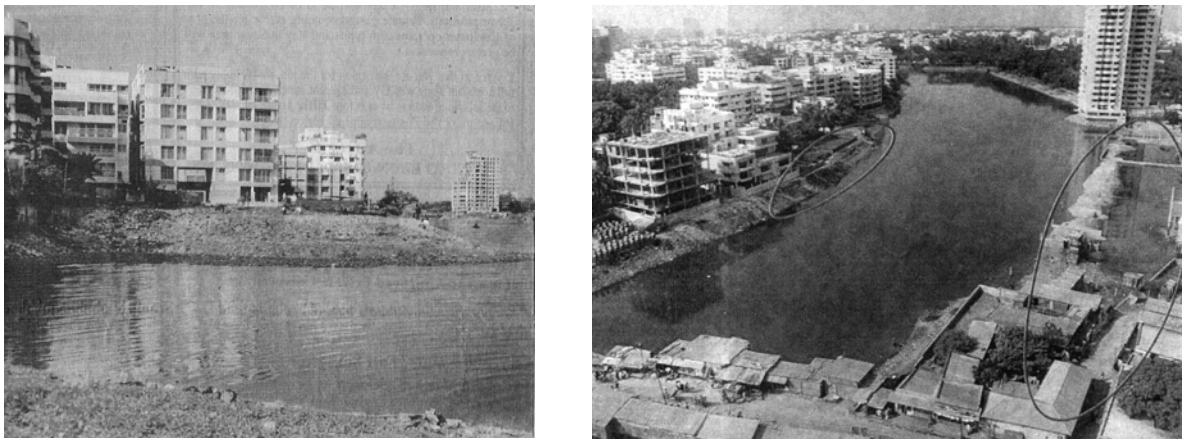
A report named “Environment-Bangladesh: Polybags Add to Flood Woes” shows that water logging persists over a 70 sq. km area in the eastern and southern part of Dhaka City in September 2002. Mohammad Hanif, former City Mayor said, “Indiscriminate dumping of polythene bags has been creating serious environmental hazards and water logging because this insoluble object is choking the drainage system and causing overflow of filthy sewerage water” (Tabibul Islam, 2003).

Considering the water logging and its consequences, there was a growing demand for a total ban on the manufacture of polyethylene bags already under attack for being environmentally hazardous. However, due to effective regulation for banning the polyethylene bags in 2002, this problem has been overcome. But some industries are still manufacturing polyethylene bags and it is still one of the problems for water logging in Dhaka City as it is not biodegradable, natural process cannot decompose it, and remains intact in soil.

5.2.3. Encroachment

Encroachment of natural drainage system is a common practice in Bangladesh. Most of the natural drainages of Dhaka City disappeared or are in way to lose their existence due to illegal encroachment. According to 76 per cent of respondents, encroachment on the rivers and khals/drains through unauthorized construction and solid waste, and the lack of regulations to prevent encroachments making the drain ineffective to drain out the run off.

Dhaka Metropolitan City is bounded by Tongi Khal on the North, the Turag and the Buriganga rivers on the West and as the Balu River on the East (**Figure-3.1**). A good number of Khals criss-crossing 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. During 60s, there were around 50 khals in Dhaka City and their length was 256 km. But due to the encroachment, presently there are only 26 and their length is 125 (The Daily Inqilab, August 9 2004) (**Figure-2.5 and 2.6**). **Picture-5.4** shows the sign of illegal encroachment on Gulshan Lake. Thus the natural drainage system of Dhaka City is losing their existence.

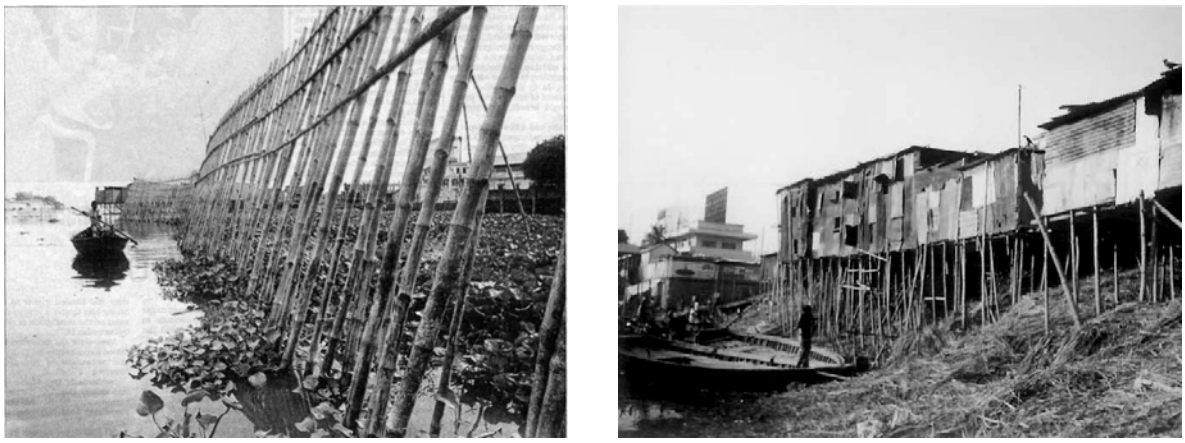


Picture-5.4 Illegal Encroachment on Lake and Khals in Dhaka City

The filling-up of vast areas in Ashulia, Banashree, Aftabnagar, Meradia, Baunia, Badda, Amin Bazar and Hatirjheel, known as water catchments, 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. **Picture-5.5** illustrates that a developer filled-up the low land for the development of housing that is clearly marked as flood flow zone in DMDP

Picture-5.5 Low Lands and Flood Flow Zones are Filling-up rapidly for Housing Development

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. Due to rapid urbanization with unplanned construction, most of these khals have been encroached, filled up, diverted and caused obstruction to the smooth flow of water to the out fall rivers. The Bangladesh Inland Water Transport Authority (BIWTA) identified in May 2001, 204 illegal structures built on both banks of the river. In July 2001, BIWTA prepared a new list of 309 illegal establishments. However, environmental activists assert that the illegal structures may be as high as 5,000. **Picture-5.6** illustrates some illegal encroachment on Buriganga River that is reducing carrying capacity of natural drainage system in Dhaka City.



Picture-5.6 Encroachment on Natural Drainage System through Illegal Activities

However, no attempts have been taken to increase the carrying capacity of these rivers to accommodate for the Basin Development Factor (BDF). On the contrary, the internal drainage system consisting of tributaries to Buriganga and Sitalakha Rivers has been diminished due to encroachment and unplanned land use practices. For instance, it is apparent from topographic maps that Dhanmondi Lake and Baridhara Lake are remnants of tributaries of Buriganga-Sitalakha Rivers. Also, filling up of Dholaikhal channel has reduced the runoff capacity from Dhaka City. Consequently, the lack of an efficient storm sewer system in Dhaka City contributes to the reduction of water carrying capacity, creating severe water-logging in the city every year during monsoon incurring huge loss in terms of damage to roads, business, etc.

Vehicles of DCC remove around 3000 tons of solid waste everyday and carry those to its dumping grounds. These dumping grounds are located in open spaces, low-lands and river banks creating encroachment to the rivers and drainage systems contributing to air and water pollution in the areas in the immediate vicinity of Dhaka city. **Picture-5.7** illustrates that DCC used to dump waste on the bank of Buriganga River that is also encroaching the natural drainage system a polluting the water.

Picture-7.7 Encroachment on Natural Drainage System through Waste Dumping

5.3 Topography

According to the discussion with experts and local people, 46 per cent blamed the topographic condition of Dhaka City is responsible for water logging. The elevation of Greater Dhaka is 2 to 13 meters above the mean sea level (msl) and most of the urbanized areas are at elevation of 6 to 8 meters above the msl. The land area above 8 meters msl covers about 20 square kilometers. The land ranging from 6 to 8 meters msl covers 75 square kilometers while 170 square kilometers of Greater Dhaka is below 6 meters (JICA, 1991). **Figure-5.4** shows the typical digital elevation model in Shegunbagicha khal catchments that is very much responsible for water logging Dhaka City.

Due to such topographic condition, the rainwater cannot smoothly discharge to the lakes, khals, retention areas and surrounding rivers and the accumulated runoff remains stagnant in low laying areas inside the city and creates severe water logging problem. Beside, people have a tendency to develop the residential, commercial and industrial areas comparatively in higher ground to save them from water logging or flooding. Therefore, the more affluent members of society flood-proof their development through raising the ground level.

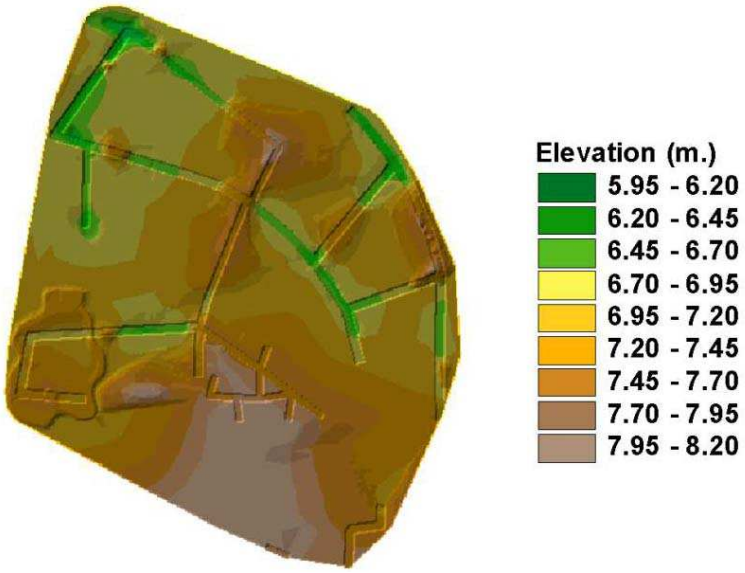


Figure-5.5 Digital Elevation Map of Dhaka City

But the low-income group and the existing road networks remains low in the city, which receives the rainwater from the surrounding areas due to insufficient storm drainage and leads to the water logging problem.

5.4 Capacities and Gravity of Drainage System

The reason of long lasting water logging situation in the city area is owing to inadequate drainage capacity, meaning of small pipe and inappropriate lining of pipe. Absence of adequate roadside drains, lack of enough inlets to the secondary drains to carry storm water and outlet to the receiving water bodies and natural drains (**Figure-3.2**) helps in creating drainage congestion according to 67 per cent respondents.

Dhaka City has an area of 360 square kilometers and storm sewage pipes runs only for 210 kilometers having diameters ranging between 450 to 3000 mm. The city has box culverts running for 7 kilometers with sizes between 2.5 m X 3.4 m to 6 m X 4.1 m. underground and surface drains cover 1100 kilometers and 22 open canals runs for 60 kilometers having width of 10 to 30 m (JICA, 1991; The New Nation).

But the existing drainage system is not capable to drain out the storm water of Dhaka City during the rainy season (May to October) having average rainfall of 304 mm, 267 mm, 262 mm and 231 mm in the year of 2000, 2001, 2002, and 2003 respectively (BMD, 2003). Experts say the city's drains have the capacity of draining out 10 to 15 mm of rain water per hour and that's why the drains overflow when its rain heavily. A WASA official, speaking on condition of anonymity, admits that underground drainage is far from adequate in the capital city. The network needs to be expanded by another 40 per cent; he says adding that the drains should be properly linked through a scientific networking.

The storm water of Dhaka City is discharged to the surrounding rivers as already mentioned. As the city is protected from river flooding by an encircled embankment, the water level of the surrounding rivers remains higher than internal drainage level during the monsoon (May to October). As a result, the drainage system of the city is under the influence of backwater effect and depends very much on the water levels of the peripheral river system. Consequently, the flow velocity in storm water sewers and drainage channels remains very slow for several days when a flood wave passes through the surrounding rivers.

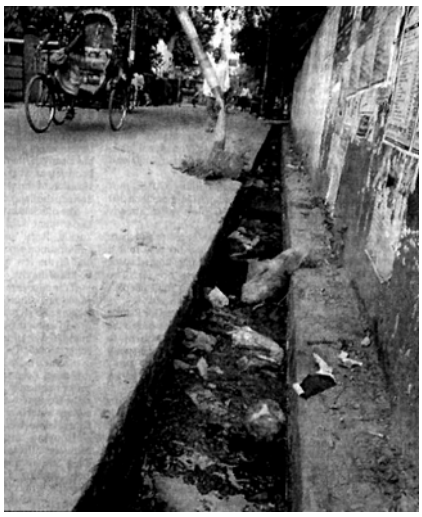
Excessive rainfall during the 1998 caused short duration flooding in different areas of Dhaka City. The runoff generated by rainfall could not flow to the surrounding rivers since the river stage was higher than the inside flowing therefore the accumulated runoff in low-lying areas remained stagnant until the river stage receded. Extensive water logging occurred in Dhaka West during the flood due to a higher river water stage in the surrounding rivers.

As the answer on question about the causes of devastating water logging in Dhaka City in September 2004, S.M. Wahed, a former Chairman of DWASA, said the flood protection embankment from Sadarghat to Gabtoli blocks the cities drainage system, obstructing the normal of storm water and sewage line in the city. “While rain water has already receded from almost all the parts of the country, some areas of Dhaka City still remain inundated, which proves that this water has no outlet”, pointed out Professor Firoz Ahmed, Acting Chairman of Dhaka WASA.

5.5 Operational Performance and Maintenance of Drainage Systems

“Poor performance of operation and maintenance of drainage system is responsible for water logging,” blamed 80 per cent of the sufferers. Many problems associated with the operation of storm water drainage systems are linked to water logging in Dhaka City. Iinadequate maintenance of existing natural drains due to lack of comprehensive and planned maintenance program, equipments, adequate budget, staffing, proper monitoring program and institutional set up to effectively operate and maintain the drainage network. Poor solid waste management is the main problem to maintain the storm water drainage. Municipal agencies (DCC in Dhaka City area) responsible for solid waste management lack sufficient resources and equipment for drain cleaning. “The existing manpower in not sufficient for the DCC to conduct the cleaning drive at a faster pace as four-day downpour in September, 2004 threatened prolong the misery of Dhaka residents as the heaviest rain in more than half a century,” said Shah Alam, Deputy Chief Conservancy Officer of DCC. “The Corporation has 7156 cleaners for its 82 wards. Each cleaner has to work overtime as tons of dirt and garbage is found with the recession of rain water”, he added. Says Prof. Nazrul Islam at Dhaka University’s Geography and Environment Department: “The drains are too narrow to allow workers to go inside.” There is often poor communication and co-ordination between the different urban authorities responsible for operating and maintaining the various components of the drainage network.

Usually, pumping stations are used to pump out the storm water from inner side of the encircle embankment of Dhaka City. But there are only two storm water pumping stations, of capacity of 9.6 m^3/s and 10 m^3/s located 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 the responsibility for operation and maintenance of these pumping stations. These are very much in sufficient in respect of demand for timely pumping out the storm water. Therefore, WASA has to installed lot of temporary pumping station during the monsoon. To drain out the stagnant water inside the embankment due to the heaviest rainfall in September 2004, DWASA has installed more than 100 small pumps temporarily with individual capacities of 0.142 cubic meters per second. But it took more than two weeks to make Dhaka City free from water logging (The Daily Star, September 30, 2004). **Picture-7.8** shows the storm water drain transformed virtually a garbage dump in Banani. Lack of cleanliness is the major causes for water logging in this area.



Picture-5.8 Inefficient Drainage Management System in Dhaka City

5.6 Development Work during Rainy Season

Development works like construction of roads, sewerage, underground telephone and electricity lines etc. during rainy season are very common practice in Dhaka City as well as in Bangladesh. Some officials of DWASA and DCC says that the development budget is the main reason for such tendency as it is passed in June month and the authorities has to start the development works depending on the budget. “But without putting a dependable drainage network and co-ordination with the concerned authorities, they go for frequent digging and sometimes are forced to cut roads and drains,” says the officials. These activities create unwanted obstacles into the drainage networks and hamper the smooth flow of storm water, therefore create water logging in the city area. 40 per cent respondent agreed that it is possible to reduce the water logging situation, if the development works during rainy season can be stopped. **Picture-5.9** illustrates that a development authority of Dhaka City constructing sewerage line during rainy season that creates obstacle to drain out storm water.

Picture-5.9 Development Work during Rainy Season Leads to Water Logging

The population growth of over crowded Dhaka City divides the limited land into very small plots. Most of the people are bound to construct the buildings covering the whole plots and sometimes without following the building by-laws. Therefore, they used to storage the building construction materials like bricks, rods, sands, stones etc. beside the nearby roads due to lack of enough space in and around the plots. This construction materials blockage the surface drains directly and or sometimes washed out by the rainfall. 37 per cent respondents mentioned this causes, which contributes to the water logging in Dhaka City. **Picture-5.10** illustrates that the workers of DCC are cleaning up the surface storm water drains that was blocked due to storage of construction materials.

Picture-5.10 Blockage of Surface Drainage through Storage of Construction Materials

5.7 Siltation

57 per cent respondent mentioned siltation in natural drainage system as a problem for water logging. Rain water carry out different construction materials like bricks, sands, and stones; leaves; household wastes; street sweepings etc. therefore increased impervious surface of storm water drainage and created favourable condition for water logging by reducing the runoff capacity of the drainage system. A significant siltation in the khals and rivers in and around Dhaka City has taken place due to expansion of the Dhaka Metropolitan area over the last few decades. The flood control embankment and sluice gate across the rivers and canals has created siltation problem as riverbed has been raised and reduced the carrying capacity. Many residents of old part of the city have blamed

that a number of sluice gates operated by WASA and these gates are causing siltation in rivers and water logging in those areas. Following picture (**Picture-5.11**) illustrates that one of main natural drainage system of Dhaka City (Begunbari Khal) lost its runoff capacity and increased impervious area due to siltation.

Picture-5.11 Siltation in Natural Drainage System

5.8 Lack of Public Awareness and Education

In general, most people of Bangladesh are poor and illiterate. There is serious lacking of public awareness about the necessity of natural drainage. People don't understand the effect of drainage blocking and filling of natural drainage, low lands, wetlands etc. Therefore, they don't hesitate to throw solid waste on to the roads and drains and their poverty encourage them to fill the natural water bodies as well as destroy the ecological habitats. Not only the general people but also the Government Authority sometimes occupies the wet lands, retention areas, khals etc to save the cost of land acquisition for developments works like roads and so on. Thus, lack of public awareness and education contributing the water logging problem in Dhaka City. According to 45 per cent respondents, through public awareness and education programs, it is possible to maintain the drainage systems properly, therefore, reduce the water logging problem and improve the environmental situation.

5.9 Lack of Policy Guidelines and its Implementation

Lack of regulation; weakness in the existing regulations for development control, waste disposal, encroachment; negligence of the authorities for its implementation; and poor motivation and communal awareness to make the users responsible against clogging of the drains and encroachment of low lands, wetlands, khals and rivers by individuals are the major reasons for failure of urban authority to preserve the right of way over the existing natural drainage channels. On the other hand, the laws and regulations for planning and development of Dhaka City are very old and in most cases outdated in terms of present development, control and needs (Islam, 2001). 60 per cent of the respondents blamed to the concerned authorities that are unable to enforce the regulation for development control and illegal activities. For example, The Dhaka Master Plan has clearly marked and reserved 12 per cent of areas for flood retention. According to the Wetland Conservation Act, 2000, 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. Therefore, the environmental situation of Dhaka City is deteriorating day-by-day and becoming threatened for the survival of its habitats.

Chapter 06
Effects of Water Logging

6.1 Introduction

Urban runoff causes problems. These become obvious when a constructed drainage system fails. Urbanization disrupts natural drainage patterns; natural watercourses are destroyed; natural retention of runoff by plants and soil is removed and the creation of impervious surfaces increases the amount of runoff. This runoff becomes polluted as solid waste, silt and contaminants are washed off roads. The increase in volume and rate of runoff causes erosion and siltation. Therefore, it becomes a burden for the inhabitants of the city, leading to water logging and creating adviser social, physical, economical as well as environmental impacts.

A field survey as questionnaire survey, informal interview and open discussion has been conducted with inhabitants of Dhaka City to know the problem faces due to water logging. The total sample was 100 in different parts of the city including authorities of different concerned organizations, experts and general people and their summarized opinions about the problem faces due to water logging are as follows (**Table-6.1**).

Table- 6.1 Types of Problems Faced due to Water Logging in Dhaka City

Problems	Percentage
Disruption of traffic movement	88
Disruption of normal life	93
Damage of roads	70
Damage of katcha houses	77
Damage of substructure of the pucca houses	62
Damage of household goods	65
Damage of underground service lines	56
Water pollution	95
Water born diseases	84
Increase mosquito	88
Damage of trees and vegetation	48
Increase of construction and maintenance cost	58
Death of fish	55

Source: Field survey, 2003-04

6.2 Associated Problems of Water Logging

The associated problems due to water logging and its chain effects on human life are as follows:

6.2.1 Social Problem

Disruption of Traffic Movement

Disruption of traffic movement is an important identified impact according to 88 per cent of interviewers, which arises due to the traditional water logging problem. Normal traffic movement is hampered during rainfall over 25 mm, creating traffic jam in the city area and people lose their valuable time. Where the storm water cannot drain out, puddles will form. This is not just inconvenience for pedestrians but also dangerous for road users. Following pictures (**Picture-6.1**) illustrates that the heavy rainfall in September 2004 disrupted traffic movement in Motijheel area.

Picture-6.1 Disruption of Traffic Movement due to Water Logging in September 2004

Disruption of Normal Life

Water logging seriously disrupts normal life and it has direct impacts on the poor, as they often live on unsuitable, low-lying and flood prone or steep, and unstable sites, have high-density housing (increasing the impermeability of the ground), poor urban planning and control and lack of investment in urban infrastructure. 93 per cent inhabitants (according to field survey) mentioned that water logging hamper daily life of the city dwellers. The more affluent members of society have the option to move to less flood prone or less polluted areas or flood-proof their homes, e.g. through raising the ground level. But the poor bear the brunt of bad drainage, through direct flood damage, pollution of water supplies and the aquatic environment, the breeding of vectors and soil erosion, leading to direct financial costs, loss of income potential, as the home may also be the workplace, and adverse health impacts. Sometimes, they don't have access to potable water and so had to rely on surface or shallow groundwater sources that are polluted. **Picture-6.2** illustrates an example that the heavy down pour disrupt the daily life of the city in different places in Dhaka.

Picture-6.2 Stagnant Water due to Heavy Down Pour Disrupt the Normal Life of Dhaka City

An article named "**Water logging in city**" by Shaila Yeasmin published on August 14, 2002 in reader's forum of The New Nation (Bangladesh's Independent News Source) can be a practical example for disruption of traffic movement and normal life.

On a rainy day, Molly was riding an auto rickshaw to take part in her Higher Secondary Certificate (HSC) final exam. Escorted by her mother, she was travelling from her Rampura house to the exam centre Siddhershwari. By the time they reached Malibagh railway crossing and the streets were flooded and clogged with traffic. Their auto rickshaw was negotiating through the flooded streets. Molly and her mother were both worried. Their worst fear came true when the three-wheeler finally lost control and overturned on them. Molly was badly injured before passengers-by rescued them. The injury, a broken hand, confined Molly to bed for nearly a month and she was forced to drop out from the tests.

"All my friends did well in the exam. I was doing fine until the accident," says Molly blaming her plight on the poor conditions of rampura-malibagh road. Molly has no hesitation to say that she would not have suffered the accident had the road not been in such bad shape. Her family also raised the finger of blame at the Dhaka City Corporation that has failed to keep the city roads in good shape.

Thousands of commuters suffer badly because of poor road conditions in the city. Molly has broken her hand. Here is one of the few known cases. Many like her suffered even though they may not have broken their legs or hands. Whenever it rains in this city of more than 10 million people, many streets become ponds and even lakes of water. Mud and trashes compound the miseries of the commuters. Not only the rain water, the streets also get swamped with wasters gushing out from leaked or overflowing gutters and sewage pipes.

6.2.2 Physical Problems

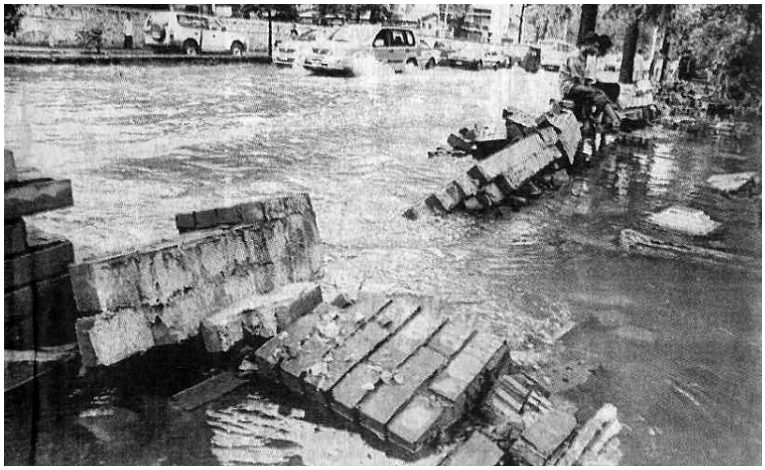
Damage of Infrastructure

Water logging of the ground contributes to ground heave, subsidence, dampness and other damage of property. Water logging causes the damage to roads (both pucca and katcha) in the rainy season every year leading to the movement problem and interrupts the journey and 70 per cent respondents mentioned such problem. On the other hand, 56 per cent mentioned that metalloid pipes of various underground utility services such as water, telephone, sewerage etc. are damaged and they lose their longevity due to water logging. **Picture-6.3** illustrates that traffic negotiates pothole-strew road in Banani area as rainwater have left roads in the capital severely damaged.

Picture-6.3 Damage of Roads in Dhaka City due to Water Logging

Damage of Structures

The substructure of the pucca houses in the low laying areas remains underwater due to water logging. The brick foundations losses its longevity by being affected with corrosive effect of salinity and damping is the aftereffect, said 62 per cent respondents. At the same time 77 per cent people faces the problem of damage of katcha houses. In slums and low income areas, most of the people are used to live in katcha and vulnerable houses. These houses become badly damaged during the period of water logging. Water enters into houses and the floor and walls remain wetted for a long period. Sometimes they can't live in the houses and had to shift their living areas, which again creates an economic burden for the poor people. This water logging decreases the longevity of katcha houses. Following picture (**Picture-6.4**) shows that the wall of Ramna Park in Dhaka City burst in September 2004 as the worst cloudburst in decades continued to wreak havoc for the fifth day.

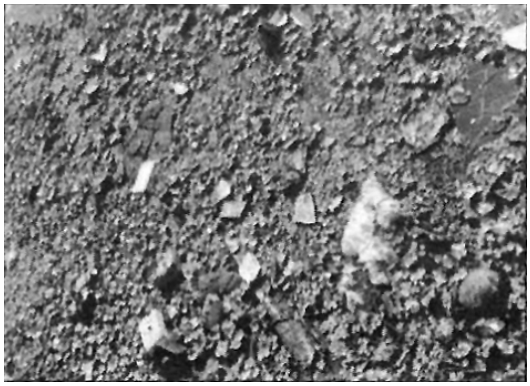


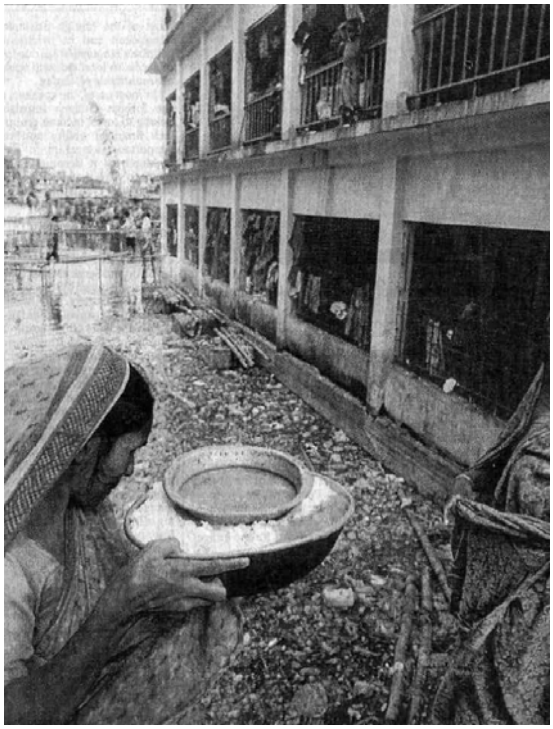
Picture-6.4 Water Logging due to Heavy Rainfall in Dhaka city Damage Structure

6.2.3 Environmental Impact

Water Pollution

Theoretically, Dhaka WASA maintains two separate sewer systems: one for domestic wastewater and another for storm water. However, in reality storm sewers also receive domestic wastewater, which causes unwanted deterioration of the storm water discharges. These discharges in turn pollute the receiving water bodies including the lakes, rivers and detention areas. According to survey, 95 per cent inhabitants said that storm water of Dhaka City becomes polluted as it is mix with solid waste, clinical waste, silt, contaminants, domestic waste water and other human activities, which contaminated ground water as well as the receiving water bodies.





Picture-6.5 Pollution of Water Mixing with Solid Waste, Clinical Waste and Toxic Sewage

Above picture (**Picture-6.5**) illustrates that storm water of Dhanmondi Lake mixed with solid waste, clinical waste, silt contamination etc. (**left**), and a woman balance herself to cross the stagnant water in Mugdapara, where the raw toxic sewage mixed with storm water posses grave health hazard to residence of the neighborhood (**right**). Storm water in Dhaka city is polluted in several ways. One of the major concerns is the contribution of domestic wastewater to the storm flows, and subsequent addition of pollutant loads to the receiving water bodies. Other causes of relatively high level of pollution in storm water include dumping of wastes beside the road, near the receiving water bodies and open surface drains. Apart from hampering the drainage, these wastes cause significant increase in the level of pollution in storm water.

In 1998, Institute of Flood Control and Drainage Research (IFCDR), presently named Institute of Water and Flood Management (IWFM), conducted a study named "Dhaka City Storm Water Quality Assessment". From the laboratory analysis of samples, the pH values found to vary from 7.1 to 7.8. Relatively high BOD5 maximum values during individual storm (96.1 to 142.6 mg/L) were found in the sewer flow in the different locations of Dhaka City. Maximum concentrations of total solids and total dissolved solids were found to be 640 to 3643 mg/L respectively. The nitrate and nitrite maximum concentrations were found to be 6.0 to 12.0 mg/L and 1.1 to 2.1 mg/L respectively. On the basis of water samples collected during several rainfall events, the Event Mean Concentration (MEC) values of BOD5, NO_3 + NO_2 and TS were determined for catchments of commercial land use. Total coliform counts in samples collected from several locations were found to relatively high (1.20×10^4 to 1.96×10^8 per 100 mL). Among different land uses, coliform counts were found to be higher in residential areas.

Deposited sediment contained various materials other than soil. Open surface drains contained higher percentages of deposited materials other than soil. Samples collected from the residential areas had higher percentages of coarser particles compared with the samples from the commercial areas. The D5 values of the samples varied from 0.20 to 0.28 mm in commercial areas and from 0.43 to 0.63 mm in residential areas.

Storm water generated from the catchments areas carry significant amount of pollutants. The level of pollution in the storm water and in the receiving water bodies is generally a matter of concern. Different survey reports in different periods shows that the water of lakes and rivers (Buriganga, Turag, Dhaleshwari, Balu, and Narai rivers-the receiving water bodies of storm water) flowing in and around the greater Dhaka is completely polluted. The reports concluded that the water of these rivers posed a serious threat to public life and is unfit for human use.

Increase of Water Born Diseases

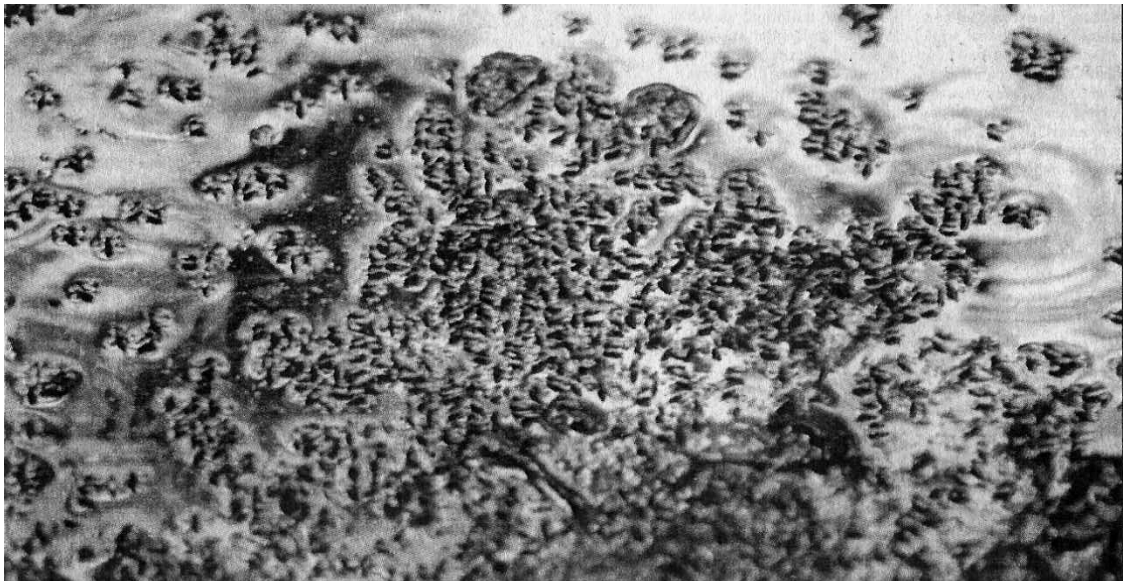
In urban areas, the most adverse impact of water logging is incidents and prevalence of various diseases. 84 per cent of the respondent replied that stagnant storm water increases the diseases as it becomes polluted in different ways. In poorly drained areas, urban runoff mixes with sewage from overflowing latrines and sewers, causing pollution and a wide range of problems associated with waterborne diseases. Sometimes, the poor people had to rely on surface or shallow groundwater sources that are polluted, as they don't have access to portable water during the period of monsoon. Malaria, dhong fever, respiratory problems, eye and skin disease are the worst impacts in Dhaka City. Moreover, contamination of ground water also leads to such adverse health impacts. Says Prof. M. A. Wadud, a skin specialist at Dhaka Medical College Hospital, "Dirty and polluted water causes skin diseases, rashes and sometimes can disrupt blood transmission within the body".

On the other hand, solid waste blocks the drainage system and creates flooding in the streets resulting in increases mosquitoes, bad odor, and inconvenience. Dhaka with its geographical and climatic conditions is prone to flooding; hence solid waste, industrial waste, tanning waste as well as clinical waste in the streets and drains multiplies the health impacts and miseries. Most of the

child mortality is related with this problem, as contaminated ground water and malaria are the major causes for this mortality.

Breeding Site of Mosquito

Poor drainage of rainwater leads to the creation of breeding sites for disease vectors. Where the water forms stagnant pools, it becomes a hazard to health and or breeding site for mosquitoes as well as being unsightly and foul smelling (**Picture-6.6**). Flooded septic tanks and leach pits also provide breeding sites for mosquitoes and faecally contaminated wet soils provide ideal conditions for the spread of intestinal worm infections. “Dhaka City is suffering a lot from tremendous increase of mosquitoes and its associated diseases vectors, which is the ultimate result of water logging” says 88 per cent of the interviewers. Among the diseases associated with mosquito, dengue is the main and it spreads by special mosquitoes named ”Aedes”. Entomologists say the population of aedes mosquito, carrier of dengue virus, increases with excessive rainfall and its result of water logging, which fuels the breeding of aedes. Dengue that breaks out in May and rages full-blown in the rainy season is a major threat to public health. The city has marshy areas measuring over 2000 acres and water logging occurred in these areas, especially in the low-laying localities. The residents of these places are highly vulnerable to the day-and-night incursion of a rapidly growing mosquito infestation (The Daily Star, August 5, 2004). According to the control room at the health department, the deadly out breaks of dengue in August 2002 infected and hospitalized about 12000 people and killed 193 people (Daily Star, April, 2004). Following table shows the prevalence of dengue diseases in Dhaka City, August 2002.



Picture-6.6 Stagnant Storm Water as Breeding Site of Mosquitoes

Table- 6.2 Results of Dengue Diseases from 7 to 13 August 2002 in Dhaka City

Date	Total infection	Death
07 August	1227	16
08 August	1299	17
09 August	1361	18
10 August	1445	22
11 August	1494	23
12 August	1576	23
13 August	1863	25

Source: Daily Star, 14th August, 2002

Apart from the vector of dengue, Aedes mosquito, Culex mosquitoes have also increased because of stagnant rain water occurred in 11th to 15th September, 2004, turned the city into a virtual mosquito-breeding ground. DCC stopped spraying insecticide and a huge volume of rain water forced the DCC to suspend its anti-mosquito drive.

”Mosquitoes bite not only at night, but in the days as well,” said a Basabo resident, adding ”We can’t go out because of filthy rain waters, nor can we stay at home because of the mosquito menace.”

The deadly dengue forced at least 300 people in the city’s hospitals and clinics for treatment and killed 9 between September 16 and 25, 2004. As many as 1540 people got dengue during 2004, according to the Health Directorate Control Room.

Damage of Vegetation and Reduce Aquatic Habitats

Water logging is the after effect of improper drainage management. Stagnant water for a long time and continuous release of wastewater damages the trees and vegetation in and around the city areas. Litter, sediment build-up and oil sheens on the water surface are common visible effects of urban pollution on surface water, which result in a reduction in the numbers of aquatic plants and animals. The increased flows resulted from traditional drainage systems cause streams to scour deeper and wider channels, adversely affecting aquatic habitats. Eroded sediments are deposited downstream in slower moving reaches of the river, damaging aquatic habitats in these areas and increasing sedimentation in wetlands.

The International Center for Diarrhea Disease Research, Bangladesh (ICDDRB) tested a sample of storm water from the natural drainage system. The results show the level of free carbon dioxide at 2.91, up from standard level of 0.6 and conductivity at 259 Micro S/cm, down from the acceptable limit between 800 and 1000 Micro S/cm for fishing water.

High concentration of free carbon dioxide is harmful not only to fish but to flora and fauna as well.

6.2.4 Economic Problem

Increase of Construction and Maintenance Cost

Urban drainage system is decreasing day by day due to uncontrolled rapid urbanization and water logging is the ultimate effect of not only the physical, social and environmental problem, it is an economic burden as well. Water logging increases the construction and maintenance cost, replied 58 per cent of the respondents. As it is mentioned earlier that water logging reduces the life span and damage to roads (both pucca and katcha) and metalloid pipes of various underground utility services such as water, telephone, sewerage etc. It needs a huge cost to replace these facilities and increases the maintenance cost for the authority. According to The Daily Inqilab, August 9, 2004, the City authority had to spend about Taka 7 to 8 billions every year to replace and maintain infrastructures damaged by water logging. DCC, the city father estimated that they need 160 billion Taka need to repair the roads and intersections damaged by the recent flood and deadly rainfall in September 2004 (DCC, 2004). Damage to substructure, brick foundations, katcha houses in slums and low-income areas due to water logging means the huge economic losses for the inhabitants.

Shortage of Water

Water logging due to the increase of impermeable urban areas also leads to a lowering of the ground water table under a construction site by reducing the surface water recharged to the ground. This has not only environmental impact but also economic impacts, as it contributes to water shortage, and cause soil subsidence and consolidation problems.

Loss of Income Potential

Sometimes, water enters into houses and the floor and wall remains wetted for a long period and it damages the household goods, stored food grains etc. and 65 per cent respondents mentioned such impact of water logging. The effects of water logging also leads to direct financial costs, loss of income potential, as the poor people may use their home for workplace. Water logging hamper traffic movements; therefore, creates an obstacle for communication and timely supply of goods, which means the loss of time, reduced production and economic losses. **Picture-6.7** shows that a fish trader pushing from the back to help the van-puller as the water logging make him delayed to reach the market.

When a constructed drainage system fails to evacuate the surface runoff, urban runoff causes economic problems. Therefore drainage overflow is common phenomena during rainy season. Usually the ponds, ditch, lakes, rivers in the city area are used for fish culture. The toxic storm water due to mix up with sewerage, solid waste, oils and trace metals associated with motor vehicles submerge the receiving water bodies and cause a huge death of fish and the owners lose incomes.

Picture-6.7 Water Logging Creates obstacle to Timely Supply of Goods

Due the heavy rainfall in September 2004, business and economic activities virtually came to a standstill in Dhaka as most of the business centers including Motijheel commercial hub were inundated by incessant rains in 12th and 13th of the month (**Picture-6.8**). Meteorological department measured a record 315mm rainfall in Dhaka city in these 48 hours. The overnight downpour forced trade suspension at Dhaka Stock Exchange (DSE). The non-stop rain also dampened banking activities especially in Motijheel where rain water entered many ground floor bank branches. An official of the prime bank said most of the client could not come to Motijheel due to knee-deep water that swamped the entire commercial areas. Sources said that staff turnout in private banks was good in contrast with the public banks where attendance was very thin and transaction was low.

Picture-6.8 Stagnant Water in Commercial Area Hampers the Income Potential

The swampy weather also disrupted production in garment factories as many workers could not come to the factories wading through the inundated roads from their houses mostly located in the city's low lying areas. The torrential rains affected transactions in the wholesale and retail markets

in Dhaka. Shops on Nababpur road, the country's largest machinery market, witnessed dull sales with rainwater submerging the road. Sales in shopping malls and activities in other business houses unusually low as people preferred staying home unless there were emergencies. The inclement weather also affected aviation business as many flights especially in domestic routes were delayed by one hour to two hours. Talking to the Daily star, Vice president of the federation of Bangladesh chamber of commerce and industry Abul Kashem Haider said the incessant rain disrupted business and manufacturing activities all over the country.

A report of Dhaka WASA shows that the water logging in September 2004, 250 schools and 681 garments were affected in Dhaka City and garments sector loss Taka 632 Billions. The damaged road sector need Taka 12.8 Billions for reconstruction and Telephone sector need Taka 175 Millions to replace.

Chapter 07
Recommendations

7.1 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. 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.

7.1.1 Save Natural Drainage System and Water Bodies through Development Control

The chief of the Biodiversity Unit of the World Conservation Union (IUCN), Anisuzzaman Khan, observes, “A densely populated city like Dhaka requires 25 per cent wetland for ecological balance and sustainability of habitats. But Dhaka has less than 10 per cent wetland, which too is threatened. He believes this is not only endangers the survival of the city, but also threatens the livelihood of millions, especially the poor that depends on environment for survival. A wetland is not a wasteland. A wetland gives us much more than money can buy.

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.

- 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 be followed for the development activities to take place.
- The flood retention areas, which are clearly marked in DMDP, should leave for its respective uses.
- Many khals and lakes are still being retained with strict measure taken to maintain the natural drainage system regularly to keep theme useable for drainage.
- The authority can 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.

7.1.2 Waste Management System

Local governments of both the developed and developing countries are concerned with the environmental consequences of waste disposal. Until recently in the developing country like Bangladesh the collection and disposal of solid waste was taken as one sided responsibility on the part of the municipal authorities burdened with financial and management problems. The increased congestion of the city area, the high population density and the rapid growth all around it has made it impossible to clean the street and drains as fast as the waste thrown onto them. Away from the other parts of the SWM system like transportation and disposal; the collection system is the primary challenge for conservancy department.

But nowadays a participatory planning approach in a process through consultation, collaboration and coordination among the stakeholders might become a reliable option for waste management to overcome not only the water logging problem but also relieve from serious problem with health and hygiene consequences.

Laws and Regulations Related to Waste Management:

There is no independent law in Bangladesh to address the problem of solid waste. The Municipal Ordinance 1983 (amended in 1999) and the Bangladesh Environmental Conservation Act 1995 are the legal foundations on solid waste management. This Ordinance is the only local law that gives some idea on disposal of municipal waste. These foundations, however, do not cover the solid waste operation comprehensively.

Therefore, a comprehensive new legislation for solid waste management is urgently needed, which should cover,

- Collection and disposal of all categories of waste.
- Categorize all wastes in terms of danger to environment.
- Correct procedure in SWM, its enforcement and to ensure proper management.

Major Gaps and Barriers for Efficient Solid Waste Management:

- **Institutional:**

  All activities of DCC are carried out under the appropriate Ordinance. Near about 3000 temporary cleaners have been appointed on daily basis. They do not have job security. They work on the “no work – no pay basis”. This situation causes problems in the efficiency of solid waste management. Cleaners’ should have job security with increased remuneration. They should be given proper medical facilities and be provided with protective measures like masks and gloves. Proper training is essential for the cleaners. There should be strict action for negligence of duties by cleaners and sweepers.

  The ordinance does not provide enough legal action against violators. As a result city dwellers do not dispose of waste in designated places and even do not carry out the timely disposal of waste in nearby bins. This area must be strengthened. For this purpose the relevant sections or provisions of Ordinance should be amended. Stringent laws should be enacted locally so that people are constrained from throwing solid waste here and there.

- **Political:**

  No amendment in the ordinance is possible without passing it through the National Parliament. The process of submitting this to the parliament is lengthy and difficult. It involves a large number of ministries and departments. However, it is not impossible. If problems in the ordinance can be put forward with sufficient logical arguments, the government would help solve them as quickly as possible.

- **Practical:**

  Dhaka is already a large city and expanding rapidly. Therefore, the massive quantity of waste generation everyday is already threatened to the environment. But there is no scientific and technological method for disposal of solid waste applied today. As a result, large pieces of low land and water bodies are used for solid waste disposal, which encroaching the natural water bodies and causing pressure as well as having a negative impact on the environment. There should be consistent forward plan to manage solid waste for the future. The solid waste management system of different countries, which are successful in the world, can be followed.

- **Financial:**

  DCC has very much shortfalls in SWM logistics and finance. So it needs financial and logistic support from Government of Bangladesh and as well as from donor countries and agencies.

Community Based Waste Management

As mentioned earlier, DCC is entrusted with solid waste management in Dhaka City. But it is clear that due to limited resources and organizational capacity, DCC is unable to ensure efficient and appropriate delivery of solid waste collection and disposal services to the entire city population. Therefore, community based waste management system can be a better alternative solution to cope with the situation. People have started local initiatives on solid waste management in area like Kalabagan, Kathalbagan, Shaymoli, Mirpur, Banani, and Uttara and they are very much a success (N. M. Kazi). DCC should encourage community-based organizations and local Non Government Organizations (NGOs) to organize and carry out community waste management programs (mainly house to house collection and disposal at roadside bins) in all areas of the city. Moreover,

- Convenient local collection points and more efficient removal services should be provided.
- New dwelling should have at least one garbage collection room.
- DCC should remove solid waste from demountable containers regularly.
- Different waste disposal system like incineration should be introduced instead of covering wetland and encroachment of water bodies as disposal areas.
- As the capacity of landfill area is coming to a saturation point in the near future, the materials should be separated for recycling, thereby relieving the pressure on the landfill.
- A separate management system should be introduced for toxic and hazardous wastes.
- Existing community projects should be given a legal status.
- Public awareness should be raised. This could be done by DCC in collaboration with ward commissioners and NGOs through local meetings, group discussion, and the mass media.
- DCC should concentrate on formulating policies for overall solid waste management, which requires substantial funding and legislation.
- Coordination and cooperation among different divisions of DCC involved with the waste management should be improved.

7.1.3 Drainage Capacity Adjustment

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 of the amount of impervious surface by 10% in a watershed, a 23% increase in the drainage capacity by dredging or deepening of streams is suggested by Sauer et al. (1983).

7.1.4 Comprehensive Drainage Development Plan

It clear from previous chapters that, the existing storm water drainage is not sufficient for Dhaka City to drain out the excessive rainfall during the monsoon in the region. On the other hand, storm sewers also receive domestic wastewater, which causes unwanted overflow and deterioration of the storm water discharges. Besides, the conventional or traditional drainage system leads to increased water logging, erosion and pollution at the eventual outfall as it is designed to remove water from one area as rapidly as possible.

Therefore, there should be a comprehensive storm water drainage improvement plan to overcome the water logging problem as well as its environmental consequences. Experts say the entire drainage system of the city will have to be overhauled to mitigate the plight of the residents and should be properly linked through a scientific network. DCC should execute the comprehensive drainage improvement project as implementing agency. If DCC is lacking in planning and detailed design works for implementation and management of this project, it will need the assistance and supports of local consultants. With the involvement of professional development organizations, it can be managed in a more sustainable fashion. This will develop the skill of manpower of DCC through transfer of technology and training.

The proposed comprehensive drainage improvement plan should be exchanged with other utility organization to avoid overlapping and duplication. As such, a high degree of close coordination with WASA, DPHE, BWDB, LGED and other utility organization should be maintained during the project implementation stage.

7.1.5 Establish “Right-of Way”

Reckless encroachments of the city’s water bodies like lakes, khals and rivers by land developers as well as individuals for so called development, illegal structures and waste disposal have already affected city life in many ways. The natural drainage system of the city is losing their actual width and existence due to such encroachment and reducing the water carrying capacity day by day with the results of water logging during monsoon period within the city area and polluting the water of these water bodies.

Therefore, to get rid of the water logging problem, the original width and alignment of the lakes, khals and rivers has to be re-established in proper shape and ensure easy drainage flow through these natural channels.

- The concerned authority like DCC, RAJUK, BWDB and BIWTA will have to establish “right-of-way” right over the natural drainage system and ensure that the drainage system is free from any obstruction, blocking, or encroachment.
- On the basis of the Drainage Improvement Plan, all areas where existing main drains are located or will be required in future will have to be identified and enforced existing legislation to prevent unauthorized development or encroachment on the drain alignments.
- Immediate action and steps will have to be taken by the concerned authority to remove all blocking and unauthorized constructions, encroachments etc. from the existing natural drainage system by enforcing necessary regulations.
- DCC should stop encroachments of the low lands, water bodies and riverbanks using them as dumping sites.
- Proposed channel geometry will have to be ensured by the authority to keep waterway free from all unwanted intrusion, encroachment etc.

7.1.6 Improvement of Drainage Management System

Adequate management of drainage system is essential to ensure the natural and smooth flow of storm water. The management system will be the composition of operation; maintenance; rehabilitation and replacement.

- Operation – related to drains involved in carrying out activities in the field of conservancy, collection and disposal of solid wastes from drains.
- Maintenance – related to maintenance of drains as well as equipment.
- Rehabilitation and replacement – related to provision of rehabilitation drainage work and replacement of equipment.

The responsibility for management of drainage system is rest with DCC. The authority should develop a routine preventative maintenance program for the drainage systems so that the structural improvements will provide a lasting benefit. It is, therefore, recommended that DCC should develop a comprehensive conservancy program for maintenance of drainage system, which is maintenance activities and scheduling of these activities, methods and equipment, staffing needs and any appropriate re-organization, which may be necessary. To make the conservancy program effective,

- Adequate funds in all annual budgets for carrying out routine maintenance program should be provided.
- Institutional set up for effective operation and maintenance of drains should be strengthened.
- The concerned authority should be ensured regular and careful maintenance of all the interconnected secondary and tertiary drains through proper monitoring program to secure its efficient operation.
- Inspection at regular interval should be made on storage of construction materials and any sort of illegal affairs causing blockage of drains to protect and conserve them.
- 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.
- The inhabitants should be motivated for cooperation for maintenance of drainage system.

7.1.7 Improvement of Environmental Situation through Drainage Management System

Water logging and its environmental consequences are the result of insufficient storm water drainage and lack of proper drainage management system. Storm water becomes polluted as solid waste, silt and contaminants are washed off roads. The runoff mixes with domestic wastewater and dumping of wastes beside the road, near the receiving water bodies and open surface drain causes significant increase in the level of pollution in storm water.

Improvement in the drainage system will improve the environmental situation in the water logged areas by eliminating stagnant water and associated problems like odors from decaying solid wastes, insects, scams and disease vectors as well as the incidence of local flooding due to rainfall. Therefore, especial emphasis on drainage development works will have to be considered and undertaken in the severely waterlogged areas to reduce the spreading of diseases and damage to public and private properties.

- The schemes and programs proposed in the DMDP to reduce the incidences of drainage blocking and water logging through provision of improved drainage system, environmental

measures and services including sanitation, drainage and solid waste disposal will have to be implemented with prior consideration.

- Faulty sewerage networks will have to be identified and repair it to protect the contamination of domestic wastewater with storm water.
- Direct septic tank connections to the drainage system will have to be prohibited by enforcing regulations to prevent this.
- A long range program to reduce the "source" of intrusion of sludge, silt, garbage, effluent into the drainage system, thereby reducing the cost of the long term maintenance operation will have to be undertaken.
- Due to lack of toilet facilities, people living in slum areas use the surface drains. Therefore, better sanitation will have to be provided for low-income group and town centre areas through construction of pit latrines and public toilets respectively.
- Public information campaign will have to be introduced to make people more aware of the problems, hazards and unacceptable practices.
- The outlet of drains will have to be protected by providing oil and silt traps as necessary and trash racks and sumps in the drainage system to facilitate collection of silts and floating garbage's therefore, to reduce cost of routine cleaning and maintenance work.
- The city generates about 120000 cubic meters of sewage everyday but the inadequate and faulty sewerage network in the city is unable to carry about half of the total sewage to the only sewage treatment plant at Pagla in Narayanganj (R. Rahman, 2003). Therefore, more sewage as well as storm water treatment plant will have to be established to ensure the water quality of receiving water bodies.

7.1.8 Awareness Development against Closing of Drains

The natural drainage and water bodies and its surrounded lands are day by day occupied by the people living nearby. Most people of our country are illiterate and they even don't know the after-effect of the filling of natural drainage and water bodies. Therefore, 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.

7.1.9 Legal Instruments

Legal instruments play a vital role towards the changes in behavioral attitude of the people in a democratic society. There are a set of acts, rules, and policies in the country to deal with the problems of environment. Some laws are century-old and cannot cater to the need of the day. Some are new that need amendment to accommodate the existing environmental scenario. Though a single issue, environment encompasses different ministries in respect of preventing pollution. 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.

7.2 Conclusion

Water logging in Dhaka City is the consequence of unplanned development. Due to rapid urbanization with unplanned construction, most of the storm water drainage have been encroached, filled up, diverted and caused obstruction to the smooth flow of water to the outfall-rivers, creating severe water-logging in the city every year during monsoon incurring huge loss in terms of adverse social, physical, economic and environmental costs.

The most recent heavy rainfall that brought Dhaka to a virtual standstill demanded the urgent need for long term planning to overcome water logging problem. We understand the exceptionality of the

deluge and that the government and development authorities have no control over the weather. Nevertheless, the devastating impact of the downpour that paralyzed Dhaka is a salutary reminder of the severity of the problem, and the necessity for the government to take counteractive measures on a priority basis. Dhaka City could hurtle towards an ecological disaster if destruction of the natural drainage and water bodies isn't stopped and an effective management of urban drainage system isn't set up.

Planning, design, operation and maintenance of urban drainage systems is a challenge for urban authorities because of unplanned development activities, and the effectiveness of storm water management systems can be directly linked to the efficacy of urban management. Therefore, for urban drainage systems to be managed effectively and operationally sustainable, greater emphasis needs to be placed upon:

- Co-ordination between urban authorities and agencies those are responsible for different aspects of urban infrastructure provision and management;
- Collaboration between government and non-governmental organizations and promotion of effective partnership with civil society and the private sector;
- Training and human resource development for improved planning, design, and operation of urban drainage systems.

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Appendix A: Questionnaires

Causes and Effects of Water Logging in Dhaka City, Bangladesh

Appendix A1: Questionnaire for Field Survey

1. Name of the respondent
2. Profession of the respondent
3. Area of living in Dhaka City
4. Do you face any water logging in your area of living?
   i) If yes, when (period/season of the year)?
   ii) How long the water remains stagnant in the catchments area?
5. According you, what are the main reasons for such water logging in your area?
6. What type of problems you used to face during the period of water logging?
7. Do you think the water logging problem in your area can be solved?
   i) If yes, how?

Appendix A2: Questionnaire for the concerned development organizations

1. Name of the organization:
2. Name of the respondent:
3. Designation of the respondent:
4. What are role of your organization for the management of Dhaka City?
5. What are the main reasons for water logging in Dhaka City?
6. Does your organization have any activities related to water logging?
   i) If yes, which activities?
7. Is your organization able to perform/manage all these activities properly?
8. What is the lacking of your organization to manage the activities related to water logging?
9. What is your suggestion to enhance the management system of water logging related activities that can help to reduce the problem?

Appendix A3: Questionnaire for Informal discussion with the experts in different field

1. Name:
2. Expertise Field:
3. Working Place:
4. What are the main reasons for water logging in Dhaka City?
5. What are the effects of water logging on city life?
6. What type of measures/actions are needs that can help to solve or reduce the water logging problem for long term?

Appendix B: Interviews and Meetings

Appendix B1: Informal Interviews with the Officials of Different Development Organizations

Sl. No.	Name	Designation	Organization	Survey Date
1	Prof. Firoz Ahmed	Acting Chairman	DWASA	20/09/2004
2	S.M. Wahed	Former Chairman	DWASA	22/09/2004
3	A.N.H. Akhter Hossian	Managing Director	DWASA	27/09/2004
4	Dr. Azam	Dy. Managing Director	DWASA	27/09/2004
5	Mr. Emdadul Islam	Chief Engineer	RAJUK	09/10/2004
6	Mr. Zahurul Haque	Town Planner	RAJUK	10/10/2004
7	Shah Alam	Dy. Chief Conservancy Officer	DCC	12/05/2004
8	Masroor-ul-Haq Siddiqui	Former Engineer	BWDB	15/10/2004
9	Md. Kamrul Islam	Superintend Engineer, Drainage Circle	DWASA	20/10/2004
10	Mr. Abu Sufian	Chairman, Land Development Staring Committee	REHAB	25/10/2004

Appendix B2: Meetings for Informal Discussion with the Experts in Different Filed

Sl. No.	Name	Expertise Field	Working Place	Survey Date
1	Prof. Nazrul Islam	Urban Researcher	Dhaka University Geography and Environment Department	22/04/2004
2	Ataur Rahman	Water Management	Design and Development Consultant (DDC)	29/04/2004
2	Anisuzzaman Khan	Biodiversity	World Conservation Union (IUCN),	04/05/2004
3	Dr. Golam Rahman	Urban Planner	Professor, BUET	07/05/2004
4	Mr. Mujibor Rahman	Environmentalist	Department of Civil Engineering, BUET	21/09/2004
5	Prof. M. A. Wadud,	Skin specialist	Dhaka Medical College Hospital	23/09/2004

Appendix B3: Interviews with the Inhabitants of Different Parts of the City

Sl. No.	Name	Profession	Area of Living	Survey Date
1	Md. Asaduzzaman	Business	Malibagh	21/04/2004
2	Abdur Rauf Sheik	Business	Malibagh	21/04/2004
3	Ezaz Ahmed	Teaching	Malibagh	21/04/2004
4	Md. Moin Udding	Engineer	Malibagh	21/04/2004
5	Sabina Akter	Banking	Malibagh	21/04/2004
6	Mujibor Rahman	Govt. Job	Malibagh	21/04/2004
7	Shamsul Alam	Govt. Job	Malibagh	21/04/2004
8	Aminul Islam	Doctor	Malibagh	21/04/2004
9	Mozammel haque	Teaching	Motijheel	02/05/2004
10	Rowshan Ara	Social Worker	Motijheel	02/05/2004
11	Din Mohammad	Self Employed	Motijheel	02/05/2004
12	Aminur Rahman	Business	Motijheel	02/05/2004
13	Mizanur Rahman	Govt. Job	Motijheel	02/05/2004
14	Ishtar Jahan	House Wife	Shantinagar	18/05/2004
15	Khurshid Alam	Business	Shantinagar	18/05/2004
16	Rakibul Hasan	Govt. Job	Shantinagar	18/05/2004
17	Anisur Rahman	Govt. Job	Shantinagar	18/05/2004
18	Sirajul Islam	Business	Shantinagar	18/05/2004
19	Istiak Ahmed	Business	Shantinagar	18/05/2004
20	Khurshida Haque	Business	Shantinagar	18/05/2004
21	Fatema Akter	NGO Worker	Shantinagar	18/05/2004
22	Kamal Hossain	Private Job	Basabo	04/06/2004
23	Md. Alimuzzaman	Private Job	Basabo	04/06/2004
24	Md. Alamgir Hossain	Doctor	Basabo	04/06/2004
25	Kazi Anwar Ali	Govt. Job	Basabo	04/06/2004
26	Ferdous Hasan Khan	Engineer	Basabo	04/06/2004
27	Md. Moshiur Rahman	NGO Worker	Khilgaon	10/06/2004
28	Kader Hossain Bhuyan	Govt. Job	Khilgaon	10/06/2004
29	Md. Hafizur Rahman	Private Job	Khilgaon	10/06/2004
30	Jahid Hassan	Business	Nababpur	12/06/2004
31	Harez Chaowdhury	Business	Nababpur	12/06/2004
32	Nigar Sultana	NGO Worker	Nababpur	12/06/2004
33	Rabindranath Saha	Govt. Job	Nababpur	12/06/2004
34	Sheikh Md. Ezaz	Business	Nababpur	12/06/2004
35	Enamul Haque	Self Employed	Azimpur	26/06/2004
36	Md. Makbul Hossain	Private Job	Azimpur	26/06/2004
37	Khadiza Begum	Teaching	Azimpur	26/06/2004
38	Jahangir Hossain Khan	Business	Azimpur	26/06/2004
39	Md. Rafiqul Islam	Govt. Job	Azimpur	26/06/2004
40	Shafiqur Rahman	NGO Worker	Azimpur	26/06/2004
41	Nahid Chowdhury	Business	Azimpur	26/06/2004
42	Monwara Khanom	Private Job	Azimpur	26/06/2004
43	Jahidul Islam	Private Job	Banani	05/07/2004
44	Golam Mustafa	Doctor	Banani	05/07/2004

45	Rubina khatun	Architect	Banani	05/07/2004
46	Md. Tariqul Islam	Private Job	Banani	05/07/2004
47	Rezaur Rahman	Private Job	Banani	05/07/2004
48	Md Delwar Hossain	Govt. Job	Banani	05/07/2004
49	Narayan Chandra Biswash	Private Job	Banani	05/07/2004
50	Afsana Sultana	NGO Worker	Banani	05/07/2004
51	Wahidur Rahman Mridha	Private Job	Mirpur	12/07/2004
52	Jalal Uddind Sikdar	Private Job	Mirpur	12/07/2004
53	Abdul Kader	Self Employed	Mirpur	12/07/2004
54	Helal Uddin	Private Job	Mirpur	12/07/2004
55	Asifuzzam Khan	Private Job	Mirpur	12/07/2004
56	Ferdous Ara	Engineer	Mirpur	12/07/2004
57	Md. Razob Ali	Business	Mirpur	12/07/2004
58	Mir Md. Taukir	Private Job	Mirpur	12/07/2004
59	Khalequzzama Sheik	Govt. Job	Mirpur	12/07/2004
60	Farhana Rahman	Student	Mirpur	12/07/2004
61	Sonjoy Kumar	Banking	Kallyanpur	24/07/2004
62	Ariful Islam	Private Job	Kallyanpur	24/07/2004
63	Dolly Chowdhury	Private Job	Kallyanpur	24/07/2004
64	Aminur Rashid	Private Job	Kallyanpur	24/07/2004
65	Mostofa Anwar	Govt. Job	Kallyanpur	24/07/2004
66	Abdul Jalil Mollah	Private Job	Badda	28/07/2004
67	Bikash Kumar Sarkar	Engineer	Badda	28/07/2004
68	Md. Ashraf Ali	Student	Badda	28/07/2004
69	Jmilur Rahman	Business	Badda	28/07/2004
70	Md. Anisur Rahman	Private Job	Badda	28/07/2004
71	Kawsar Ahmed	Business	Bakshi Bazar	07/08/2004
72	Syed Nazrul Islam	Doctor	Bakshi Bazar	07/08/2004
73	Chayonika Karmakar	Business	Bakshi Bazar	07/08/2004
74	Md Wahidul Islam	Private Job	Bakshi Bazar	07/08/2004
75	Obaydur Rahman	Private Job	Bakshi Bazar	07/08/2004
76	Rabiul Alam	Doctor	Hatirpull	12/08/2004
77	Golam Kibria	Business	Hatirpull	12/08/2004
78	Ahsanul Habib	Govt. Job	Hatirpull	12/08/2004
79	Suranjit Bissash	Business	Hatirpull	12/08/2004
80	Nur-E-Fatema	Teaching	Hatirpull	12/08/2004
81	Mostafizur Rahman	Private Job	Kathal Bagan	15/08/2004
82	Md. Sadiar Rahman	Private Job	Kathal Bagan	15/08/2004
83	Laila banu	Teaching	Kathal Bagan	15/08/2004
84	Keramot Ali	Doctor	Kathal Bagan	15/08/2004
85	Md. Shamimuzzaman	Student	Kathal Bagan	15/08/2004

Appendix C: Rainfall Intensity of Dhaka City

Appendix C1: Rainfall Intensity of Dhaka City, 2000

Date	Month					
	May	June	July	August	September	October
1	0	1	0	4	73	5
2	58	0	0	133	0	9
3	1	0	0	126	1	0
4	0	0	0	3	0	0
5	0	0	0	10	0	2
6	11	1	0	2	1	0
7	0	12	1	0	0	0
8	0	0	27	0	4	15
9	0	17	6	0	5	0
10	0	4	25	1	12	18
11	0	23	0	0	12	5
12	0	8	0	5	0	0
13	0	0	7	4	0	0
14	0	0	6	23	0	0
15	0	0	7	24	5	0
16	0	1	3	0	18	0
17	0	28	0	3	0	0
18	7	2	1	0	3	0
19	0	4	18	1	16	0
20	65	11	10	0	30	0
21	152	4	11	5	24	5
22	2	7	47	0	0	0
23	49	7	6	0	0	0
24	1	4	11	0	12	0
25	6	20	3	0	0	0
26	43	0	0	5	0	0
27	52	0	8	0	0	5
28	90	0	0	5	0	55
29	23	0	0	0	0	158
30	0	11	0	2	0	1
31	48		0	3		0
Total	**608**	**165**	**197**	**359**	**216**	**278**

Source: Meteorological Department of Bangladesh, 2004

Appendix C2: Rainfall Intensity of Dhaka City, 2001

Date	Month					
	May	June	July	August	September	October
1	18	17	40	45	13	7
2	0	0	0	0	6	3
3	48	5	1	13	0	14
4	10	20	0	0	0	13
5	6	16	0	12	0	10
6	4	61	0	9	0	6

7	0	10	0	0	15	0
8	71	23	1	5	0	0
9	52	0	0	58	19	11
10	8	7	1	0	10	6
11	32	0	3	4	2	0
12	0	18	8	5	11	0
13	0	4	11	1	1	0
14	0	6	15	5	23	8
15	0	49	0	0	0	10
16	0	6	0	5	0	1
17	0	59	0	2	2	1
18	0	6	2	6	54	21
19	0	16	0	0	7	54
20	6	29	20	10	0	0
21	40	11	21	1	0	0
22	0	1	4	0	0	0
23	27	0	12	4	0	0
24	7	0	1	1	19	0
25	0	0	12	3	25	0
26	0	0	26	10	0	0
27	23	3	5	1	0	0
28	0	9	4	1	0	1
29	0	1	10	0	0	0
30	49	9	23	4	2	11
31	1		2	0		0
Total	**402**	**386**	**222**	**205**	**209**	**177**

Source: Meteorological Department of Bangladesh, 2004

Appendix C3: Rainfall Intensity of Dhaka City, 2002

Date	Month					
	May	**June**	**July**	**August**	**September**	**October**
1	8	0	26	1	0	3
2	0	31	62	18	0	0
3	2	47	0	20	0	0
4	4	0	42	4	16	0
5	0	30	73	2	0	0
6	18	0	4	0	0	0
7	62	0	7	2	42	0
8	1	12	12	1	0	0
9	1	0	0	1	1	1
10	3	5	0	3	1	4
11	16	21	15	46	2	1
12	18	1	0	14	0	6
13	0	33	0	2	0	0
14	0	59	14	43	0	0
15	1	33	0	3	0	7
16	0	0	9	16	9	0
17	0	5	5	4	0	0
18	7	8	6	17	0	0
19	0	0	18	5	0	17
20	0	0	9	2	0	13

21	0	1	12	0	0	0
22	3	18	71	13	11	0
23	18	41	1	2	1	0
24	0	7	0	1	2	0
25	0	1	21	0	7	0
26	6	3	0	1	26	0
27	88	7	0	9	2	0
28	10	0	1	6	35	0
29	1	10	37	37	0	0
30	0	0	0	0	1	0
31	5		1	0		0
Total	**272**	**373**	**446**	**273**	**156**	**52**

Source: Meteorological Department of Bangladesh, 2004

Appendix C4: Rainfall Intensity of Dhaka City, 2003

Date	Month					
	May	**June**	**July**	**August**	**September**	**October**
1	0	0	22	2	3	0
2	0	0	0	5	19	0
3	52	0	0	0	7	15
4	0	0	5	0	5	1
5	0	6	12	0	0	0
6	0	93	3	0	0	0
7	18	0	8	0	8	16
8	0	45	3	0	4	16
9	17	0	14	0	0	73
10	2	8	0	4	2	15
11	0	0	3	22	2	4
12	0	10	15	23	11	0
13	2	0	7	67	29	0
14	0	0	0	8	15	0
15	0	66	2	3	0	0
16	1	0	1	0	8	0
17	0	0	2	0	1	0
18	0	3	0	0	3	0
19	0	6	0	18	2	4
20	0	2	0	4	4	0
21	25	13	0	0	4	0
22	0	86	0	9	11	0
23	1	11	0	7	6	0
24	0	14	5	6	1	0
25	14	0	8	1	3	0
26	0	0	30	0	50	1
27	0	1	0	0	61	11
28	8	1	4	0	0	14
29	0	17	23	7	0	0
30	0	37	20	13	5	0
31	0		4	3		0
Total	**140**	**419**	**191**	**202**	**264**	**170**

Source: Meteorological Department of Bangladesh, 2004