Journal of Bangladesh Institute of Planners ISSN 2075-9363
Vol. 6, December 2013, pp. 23-33, © Bangladesh Institute of Planners

Natural Drainage System and Water Logging in Dhaka: Measures to address the Problems

Qazi Azizul Mowla[1]
Mohammed Saiful Islam[2]

Abstract

Dhaka city faces extensive water logging during the monsoon (May to October) as a regular phenomenon due to fast and uncontrolled urbanization. This water logging is a problem creating adverse social, physical, economic and environmental impacts in the life and living in Dhaka. Disruption of traffic movement and normal life, damage of structures and infrastructure, destruction of vegetation and aquatic habitats, loss of income potentials are the prime effects of water logging. This paper focuses on the rainfall induced flooding that is caused by high intensity rainfall runoff in the city area, mainly due to the lack of proper drainage system and inefficient management. Urban design and planning, responsive to the geo-climate and hydrological characteristics of the place will help mitigate water logging problem in the city. A close coordination among urban authorities and collaboration between public and private sectors is needed for sustainable operation of the drainage system to minimize water logging in Dhaka.

Preamble

Bangladesh is located on the extensive floodplains of the Ganges and Brahmaputra river systems. Therefore, flooding is a natural part of the life of its inhabitants. During the last 25 years or so rapid uncontrolled urbanization has taken place in its capital city Dhaka. Substantial increase in built-up areas has taken place due to insensitive developments of areas through private land developers and real estate business (Tawhid, 2004). 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 a result, flooding due to rainfall is a severe problem for Dhaka city that remains inundated after each severe shower mainly due to the drainage congestion (Huq and Alam, 2003). The city has experienced water logging for last couple of years 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, ecological balance of the city is also disrupted and diseases spread which is gross inconvenience to its inhabitants (Mowla, 2005). On the other hand, the city is protected from river flooding by an encircled embankment called Buckland bund and the western Flood Protection Embankment, further obstructing the natural drainage. During the monsoon (May to October), the water level of the surrounding rivers remains higher than the internal drainage level, that is, when the water level in the river increases the drainage capacity to the river is reduced. It naturally demands adequate retention and detention capacity of rainwater and development of a drainage system during urban planning and design.

The study, to find out corrective measures of water logging problems through natural drainage system and man-made network analysis in Dhaka city, is primarily based on secondary data and information. Some information has also been collected from primary sources through informal

[1]Professor, Department of Architecture, Bangladesh University of Engineering and Technology (BUET), Dhaka. Email: qmowla@yahoo.co.uk
[2]Town Planner, Sreemangal Pourashava, Planning Ministry of Local Government, Rural Development and Cooperatives, Email: saifulurp29@gmail.com

interviews of experts of different development agencies. Rainfall data and the storm water drainage system data were needed for the study. The rainfall data has been collected from the Bangladesh Meteorological Department (BMD) 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.

Contextual Brief

In Dhaka, flooding may be classified into two types. One results from overflow of the surrounding river systems, thus rendering any natural drainage ineffective. The other type is caused by high intensity rainfall runoff in the city area, which causes flooding also in situations where natural drainage might be possible. River floods generally take place in the low laying fringe areas outside the protective embankments. On the other hand, Rainfall induced flooding occurs in the built-up areas of the inner city on various scales (Mark and Chusit, 2002). Inadequate drainage channels and their improper operation and management mainly cause these floods. The present study would be focused mainly on the rainfall induced flooding termed as water logging.

Existing Natural Drainage System of Dhaka City

The natural drainage system in the Dhaka city comprises of several retention and detention areas including khals (canals), which are linked to the surrounding rivers. The city rainfall-runoff is accumulated in the retention and detention areas and discharged to the surrounding rivers through the khals.

The Dhaka West has 13 khals having a total length of more than 31 km while the Dhaka East has 27 khals of total length of about 60 kilometer. Approximately 80% of the city area is drained through these channels to the surrounding rivers. The catchments area of the khals in the Dhaka West varies from 6 to 40 sq. km (Chowdhury, 2000). On the other hand, the greater Dhaka city area is divided into 12 drainage zones (JICA, 1991) (Figure 01) on the basis of topographic conditions, khal systems and outfall to the surrounding rivers. There are also many water storage areas such as lakes and low laying lands which function as retention areas. Among the city canals, the Dholai Khal which once used to be the artery of an important navigational route for country boats to and from destinations within the metropolis, has almost disappeared due to four decades of wrong policies of the city administration to construct roads by closing the canal (Huq and Alam, 2003). The canals had their outlets to the Buriganga, the Sitalakkhya, the Balu and the

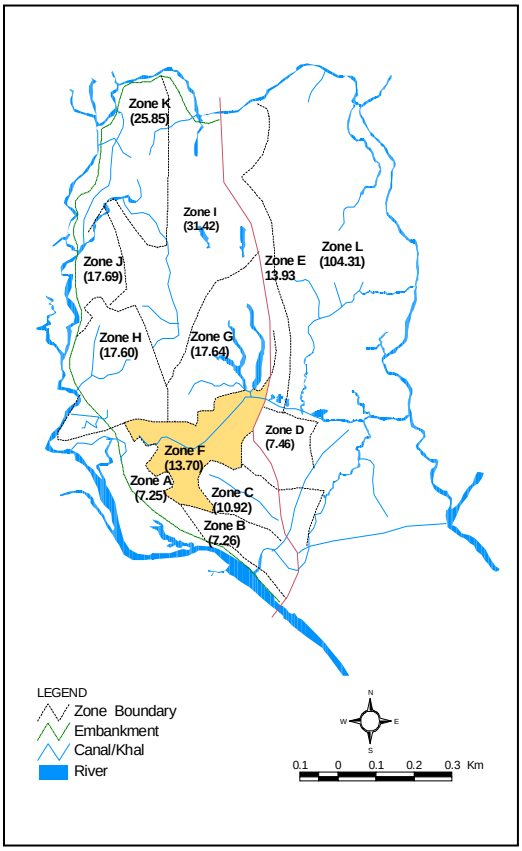

Figure 01: Drainage Zones of Dhaka City.
Source: Das, 2010

Turag rivers, which were inter-connected. An ancient canal, the Dholai Khal used to encircle the oldest part of old Dhaka joining the Buriganga near Mitford Hospital and the Mill Barracks. The closing of the Khal had far-reaching impact on the natural drainage system of the city.

The Segunbagicha Khal that extended from Shahbagh to the Jirani Khal via the Manda Bridge used to from the main drainage channel of central Dhaka. A major part of it is under illegal encroachment by influential people in the Segunbagicha, Purana Paltan and Naya Paltan areas. Under the Asian Development Bank funded '*Dhaka Integrated Flood Control Project*', WASA managed to acquire a narrow strip of the canal and construct box culvert through which storm sewer now empties. Begunbari Khal extending from Dhanmondi Lake to Trimuhani via Rampura before emptying into the Balu River, the Ibrahimpur canal, the Khathalbagan-Rajarbagh canal, the Gopibagh canal together with other minor canals of the city are all victims of either illegal encroachment or acquisition for the construction of roads, box culvert or underground drain. All these projects have changed the original purpose which the old network of canals was meant to serve (Tawhid, 2004). The changes have drastically reduced the carrying capacity of these canals.

Storm Sewer Network

The study is focused on the storm water drainage system of Dhaka. Operation and maintenance of the storm water drainage system is organized by the Drainage Circle of Dhaka WASA. The present storm water drainage network under Dhaka WASA covers area of approximately 140 sq. km (Tawhid, 2004). 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 (Tawhid, 2004).

ii) 185 km of underground pipes having diameter ranging between 450 to 3000 mm (Rahman, 2004).

iii) 6.5 km of box culvert of sizes between 2.5 m * 3.4 m to 6 m * 4.1 m. (Rahman, 2004).

iv) 2 storm water-pumping stations, of capacity of 9.6 m3/s and 10 m3/s at Narinda and Kallyanpur respectively (Rahman, 2004).

v) Recently DCC has constructed one storm water pumping station, having capacity of 22 m3/s at the confluence of river Buriganga and Dholai khal, which is taken over by Dhaka WASA for operation and maintenance (Rabbi, et al., 2001).

Bangladesh Water Development Board (BWDB) has also constructed one pumping station (capacity 22 m3/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 cusec, installed temporarily by Dhaka WASA to drain out storm water from various locations (Tawhid, 2004). 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 (Tawhid, 2004). The responsibility of development, operation and maintenance of drainage system in Dhaka city lies with the Dhaka WASA. But several other agencies are working for development of the city drainage system, with little or no coordination among them.

Natural Drainage System and Manmade Network-An Analysis

Historically Dhaka's urban life and living was interwoven with the system of rivers, canals, lakes and ponds scattered and crisscrossing the city (Mowla, 2008). Water channels like the Dholai Khal, the Gerani Khal, the Segunbagicha Khal or the Begun Bari Khal played an important role in the indigenous city life. Most of these Khals lie east-west, that used to serve an important purpose

of intra city communication, besides drainage and other needs. Before the contemporary era network of natural canals within the city served as the means of drainage of the rain runoff and water during the events of flood, besides these canals served as good means of transportation.

At the time of partition of Bengal in 1947, about 50% of present Dhaka was low laying flood plain and water bodies (Mowla, 2010). Dhaka relied on the gravity drainage system based on 'khals' and 'wetlands'. Traditionally, wetlands and water bodies in Dhaka were the main source of water. Water bodies also offered highly valuable environmental and recreational asset for the area. But in course of time this natural water supply and drainage system is being almost destroyed. Due to the urban development pressure in the city, there is a tendency of filling up of water bodies and flood plains resulting in the reduction of water retention capacity, diminishing public spaces and increasing water logging. Man made drainage and sewerage systems are not sufficient enough for this growing metropolis. Many of the roads in Dhaka are developed by filling the water bodies or by making box culverts, thus shrinking the water carrying capacity as well as reducing ground water replenishment (e.g. Dholai Khal and Panthapath) (Mowla, 2005).

It is said that Dhaka must have at least 20 retention ponds of Hatirjheel size to tackle the storm water (Bangladeshnews, 2009a). Dhaka Metropolitan Development Plan (DMDP, 1995) considered retaining at least eight flood-flow zones undisturbed–Dhaka West; DND Triangle; Eastern Fringe; Narayanganj West; Dhaka NW; and Narayanganj East (Nagario Prokoton, 1995). Transparency International Bangladesh (TIB) informed that around 1,000 ponds, which were in the city, have now been totally destroyed (Bangladesh news, 2009b). TIB reports that 800 acres of land in 5 rivers including Buriganga and Sitalakkhya were illegally grabbed violating the Wetland Protection Act, 2000. The fact is that the contemporary planning process never took water systems as the driving force in any physical planning in this delta.

If the current rate of loss of wetland continues, before the year 2031 all temporary wetlands of Dhaka will disappear (Chowdhooree, 2010). This is alarming for earthquake scenario, all these lands are continuously being converted into urban land through landfill and these filled lands are vulnerable to liquefaction effect. The land filling activity of developers became irresistible during the later half of 90s. Even after the enactment of the Water Body Conservation Act 2000, the city has lost huge amount of wetlands (Sultana, 2007). Sultana (2007) found that, the fringe areas are developing according to the 'S' shaped urbanization curve (Figure 02). The beginning of the 'S' curve represents the early stage of urbanization development, which increases gradually through the increase of population and economic activities. Its gradual increase will eliminate all wetlands gradually through continuous filling up for urban development.

When rainfalls on to undeveloped land, most of the water will soak into the topsoil and slowly flow through the soil to the nearest watercourses or groundwater. A small proportion of the rainfall, usually 15 to 20 percent, becomes direct surface run off (Tawhid, 2004) that usually drains into watercourses slowly because the ground surface is rough (e.g. because of vegetation). On the other hand, 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 (Figure 03). 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. The flow rates in the receiving waters are therefore much more sensitive to rainfall intensity and volume than those in undeveloped catchments and result is the water logging in the city.

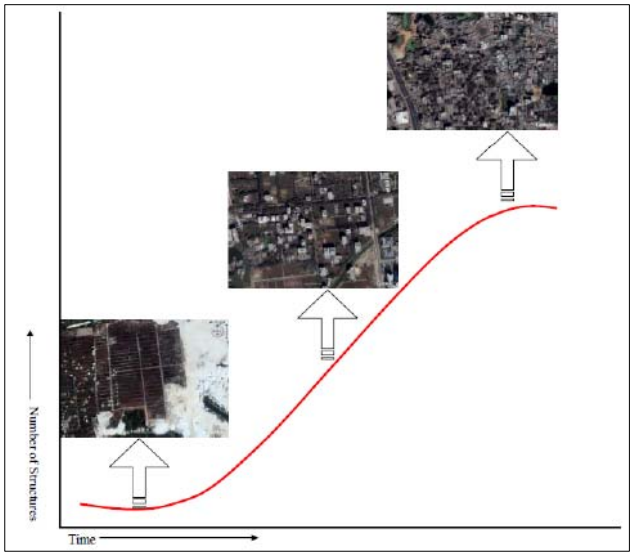

Figure 02: The 'S' shaped Urbanization Curve; Source: Sultana, 2007

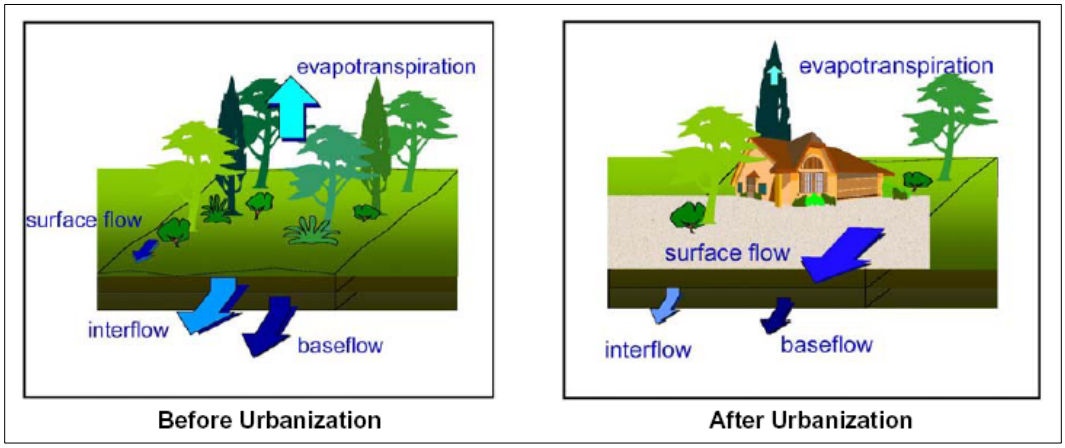

Figure 03: Characteristics of Runoff in Urban Area; Source: Tawhid, 2004

Many ponds that worked as runoff reservoir and met the domestic water needs besides being used as community space are filled up to create space for housing and roads. Being one of the largest mega cities in the world and without any hydrological planning, remaining surface water is being excessively polluted or destroyed. Ground water extraction poses a great threat to the sustainability of the city itself. Dhaka Water and Sewerage Authority (DWASA) mainly depend on ground water extraction and currently it is producing around 1200 Ml/day for the urban water supply from about 423 deep tube wells (Mowla, 2010). Due to over extraction and reduced percolation, water table in Dhaka has currently dropped to below 1200 feet, which was about 10 to 20 feet (Mowla, 2010). On the other hand, the sewerage system of Dhaka city covers only one third of total urban area. Dhaka WASA utilizes the existing canals and sewerage pipes to collect the waste water from different areas, carry the effluent to dispose, most of it, into surrounding

river systems (or even lakes and water bodies in the city) without any treatment. Many canals are cut off and transformed into lakes e.g. Dhanmondi, Gulshan, Banani or Baridhara Lakes.

DMDP' 95 tried to take care of the Dhaka's hydrological systems in the land use planning but never pursued seriously. Even, DAP (2007) that covers the area of DMDP, 1995 did not follow the planning guidelines provided in it. Against the 40% requirement, DAP, 2007 recommends 21% of Dhaka's land as water bodies where no development would be permitted. DAP recommends 50 meter land from riverbanks to be earmarked for walkway or driveway; enlisting parks, playgrounds and open spaces; and making existing canals in the CS and RS maps (DAP, 2007). But no basis of these recommendations is given.

Effects of Water Logging

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, leading to water logging and creating adverse social, physical, economical as well as environmental impacts.

a) Social Problem

Disruption of Traffic Movement

Disruption to traffic movement is an important impact which arises during the water logging. It is observed that normal traffic movement is hampered during rainfall of over 25 mm (Tawhid, 2004), 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 inconvenient for the pedestrians but also dangerous for road and road users.

Figure 04: Disruption of Traffic Movement
Source: Sultana, 2004

Figure 05: Disruption of Normal Life
Source: Sultana, 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-laying and flood prone or steep, and unstable sites, have high-density housing, poor urban planning and control and lack of investment in urban infrastructure. The more affluent members of society have the option to move to less flood prone areas. 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.

b) Physical Problem

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 during the rainy season leading to the movement problem.

Figure 06: Damage of Road; Source: Tawhid, 2004

Figure 07: Damage of Structure; Source: Tawhid, 2004

Damage of Structures

The substructure of the buildings 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 dampness is the after effect. In slums and low income areas, most of the people live in temporary (kutcha) and vulnerable buildings. These buildings become badly damaged during the period of water logging. Sometimes the occupants cannot use the buildings and have to move to other areas, which create psychological and economic stress for the poor people.

c) 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 sewer 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. 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.

Increase of Water Born Diseases

In urban areas, the most adverse impact of water logging is the incidence and prevalence of various diseases. 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 have to rely on surface or shallow groundwater sources that are polluted, as they do not have access to portable water during the period of monsoon. Malaria, respiratory problems, eye and skin disease are also common in water logged areas.

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 the 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.

d) Economic Problem

Increase of Construction and Maintenance Cost

Natural 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 because it reduces the life span and damage to roads 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.

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. This has not only environmental impact but also economic impacts, as it contributes to water shortage, and may 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. 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 hampers traffic movements; therefore, creates an obstacle for communication and timely supply of goods, which means the loss of time, reduced production and economic losses.

Figure 08: Hamper the Income Potential, Source: Sultana 2014

Remedial Measures to tackle the Problems

Rapid population growth and unplanned development, uncontrolled 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, in nutshell, the general man made physical and social activities related to the disappearance of natural drainage system resulting in the water logging in Dhaka city. Under the present situation, revitalization of the natural water bodies of the city to tackle the existing problems will need a combination of approaches of management and restoration. Constant monitoring and management process, either singly or in combination, may include:

i. Stewardship of the Natural Water bodies;

ii. Management of the Natural Water bodies i.e. Quick-fix approach and Long term management;

iii. Natural Water bodies Restoration i.e. Water bodies Treatment Technique (Physical, Chemical and or Biological) and watershed management technique.

Direct actions that are needed at the moment are a combination of socio-economic, physical and biological approaches that fall into one or more of the mentioning processes. The remedial measures should be as follows:

a) Socio-economic Measures: Considering the geo-morphology of Dhaka, it seems essential that if and when needed the earth cutting to fill/raise lands must be judiciously planned and invariably done on the channel ward side that would get rapidly filled up by the natural process of sedimentation/accretion. For the sake of ecological, hydrological integrity and development sustainability, natural systems must be protected. Sub-system of development likes housing, traffic and transportation, land-use etc. are all dependent on environmental systems for their sustainability. Therefore, socio-economic success can be achieved through designing with ecological principles in mind than without it. Urban design and Planning must be holistic in nature and piecemeal solutions are to be avoided. Mass housing and mass transit with ecological imperatives should get priority in the Dhaka's development process. To minimize socio-economic impact, natural drainage system based on gravity flow should be encouraged – man made system when needed should also follow the natural trend. Finger shaped open ended dykes may be constructed for settlements, particularly in the fringe areas to allow free flow of water in and out of the urban areas. Encroachment on the rivers, Khals/drains and wetland of the city through unauthorized construction and development of the developers must be prevented to minimize the water logging problem and also to ensure stable socio-economic condition of the city. Development works like construction of roads, sewerage, underground telephone and electricity lines etc. needs to be coordinated.

b) Physical Measures: Direct measures for the restoration and revitalization of the natural water bodies should be to reroute the surface drainage discharging storm water into the khals/canals and lakes to the nearest storm drainage system of the city, however that should follow the topography. Domestic and clinical garbage disposal needs strict monitoring and management. Non-point contamination sources nearby drainage system and surface runoffs should be properly taken care of. Extensive dredging of surrounding river system as well as the water channels in the city is needed. Dredged contaminated soil must not be deposited in the bank or locations from where pollutants may flow back into the natural water bodies of the city.

c) Vegetation: Thick vegetation along major roads and water channels may be grown especially with the pollution resistant or hardy species to reduce atmospheric, hydrological and noise

pollution in the city. Local varieties of fruit bearing trees may also be planted in the peripheral locations and along the residential plots but away from the water body. Hijal, Keora, Ashoke, Mahua, Krishnachura, Jarul, Kadam, Shiuli etc. may also be planted to attract birds and help revive the lost ecosystem (Mowla, 2008). Most of the above trees also prevent soil erosion and therefore prevent sedimentation and eutrophication. It is observed that palm varieties survived better during 1998 floods, therefore, these species may also be recommended. Lower plains/ flood plains may be used as vegetated public areas (parks or open spaces) during lean seasons (Mowla, 2005).

d) Aquaculture: Restoration of natural drainage system and creation of adequate water bodies is needed for a sustainable ecosystem in Dhaka. Ipil-ipil, water lily, lotus are aquatic species of plant that may be recommended in the city water bodies, because these plants have extensive root system with rapid growth rate and very good capacity for nutrient absorption (Mowla, 2008). This will protect the water bodies from eutrophication. Besides this Ipil-ipil is a good fish feed. Among the fish varieties, Rui, Silver Curp, Grass Curp eats upper level food and purifies water. Sarputi and Rajputi are environment friendly species because they eat wastage in water like rotten leaves, insects and organic materials.

e) Urban Design and Planning Measures: Planning and design, sympathetic to many forces of nature and human activity pattern, result in a sustainable development. Water bodies of the city must be recognized as a valuable natural resources requiring protection, conservation and recycling and the water resources of the city needs to be incorporated in the physical planning process, the early the better. Considering the geomorphology and hydrological profile of Dhaka, contrary to the embankment and pump-oriented flood control and drainage management approach of DAP, 2007, flood management and a detention reservoir-based gravity drainage system is expected to be more reliable and appropriate for storm water drainage system in a floodplain landscape like Dhaka with rivers encircling the city (Mowla, 2010).

Water channels in and around the city if revived and dredged adequately, it will be able to tackle the surface runoff drainage (preventing water logging). If this water system is developed for navigation and hooked up with the city's traffic and transportation system than the urban traffic and transportation system will have marked improvement.

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 devastating impact of the downpours that paralyze Dhaka is a salutary reminder of the severity of problems, and the necessity for the government to take corrective measures on a priority basis. Dhaka city is hurtling towards an ecological disaster due to the gradual destruction of the natural drainage and water bodies and negligence to establish an effective management of urban hydraulic system. Sustainable drainage system can form a key part of sustainable development by reducing the impacts that might otherwise occur to surface water runoff and water resources. If the drainage network can work properly, the other utility service can also run smoothly since they are interrelated and dependent on each other. A close coordination among urban authorities and agencies and collaboration between public and private sectors is needed for effective management

and sustainable development/restoration and operation of the natural drainage system to improve water logging situation.

Reference

Chowdhooree, I. 2010. "Policies and Legislations for the Built Environment in Earthquake Mitigation Planning: A Case-Study of Dhaka", an unpublished Area of Concentration (AOC) Paper, Summer 2010, Department of Urban and Regional Planning, University of Hawaii at Manoa, Honolulu, Hawaii, USA.

Chowdhury, J. U. 2000. Features of Dhaka City and its Vulnerability to Flooding", in A.R. Khan, I. Inun, M. Reazuddin, and R. Amin (eds), *An Assessment of Environmental Impacts of Flood 1998 on Dhaka City*, the 1998 Flood: Impact on Environment of Dhaka City, DoE and IUCN, pp. 1-8, Dhaka.

DAP.2007. *Detailed Area Plan for Dhaka Metropolitan Development Plan (DMD-Draft Final Plan)*, prepared by GBL & DDC for GOB/Moll & PW/RAJUK, September, 2007.

Das, B. 2010. "Effects of Land use Change on Drainage and Retention Ponds in the Western Part of Dhaka city", unpublished MURP Thesis, Department of Urban and Regional Planning, BUET, Dhaka.

Huq, S. and Alam, M. 2003. *Flood Management and Vulnerability of Dhaka City*, Bangladesh Center of Advance Studies (BCAS), Dhaka.

JICA (Japan International Cooperation Agency). 1991. *Master Plan for Greater Dhaka Flood Protection Project, FAB 8A.*, Main Report and Supporting Report-II, Flood Plan Coordination Organization (recently WARPO), Dhaka.

Mark, O. and Chusit, A. 2002. *Modeling of Urban Runoff in Dhaka City*, Asian Institute of Technology (AIT), Thailand.

Mowla, Q.A. 2005. 'Eco-systems and Sustainable Urban Design Nexus: A Borderless Concept', paper presented in the International Alumni Conference on Technology without Borders, organized by the Global IIT, Bethesda, Washington DC, USA, 20-22 May, 2005.

Mowla, Q. A. 2008. 'Eco-Sustainability of Urban Environment: The Case of Dhaka', paper presented in the International Continuing Education Meeting on Sustainable Communities Bridging the Gap between Research and Action, jointly organized by TKK-Finland, AIT-Thailand, UN-HABITAT and UNEP,AIT Bangkok, 11-22 August, 2008.

Mowla, Q. A. 2010. 'Role of Water Bodies in Dhaka for Sustainable Urban Design', *Jahangirnagar Planning Review*, **Vol. 08**, pp. 1-10.

Nagario Prokoton. 1995. 'Nagario Prokotom: An Urban Affairs Quarterly', *DMDP Seminar Special*, year-2, Vol. II (3), Sept-Nov' 1995, Dhaka.

Sultana, N. 2007. "Impact of Urbanization on Wetlands: A Case study of Dhaka City", an unpublished Area of Concentration (AOC) Dissertation, Department of Urban and Regional Planning, University of Hawaii at Manoa, Honolulu, Hawaii, USA.

Internet Source

Bangladeshnews, 2009a. http://www.bangladeshnews.com.bd/2009/07/30/restore-canals-wetlands-to-stop-waterlogging/, (accessed on 30 June, 2009)

Bangladeshnews, 2009b. http://www.bangladeshnews.com.bd/2009/03/28/800-acres-grabbed-from-6-rivers/ , (accessed on 24 March, 2009)

Rahman, Sultana. 2004. *Clogged up Canals Keep City Waterlogged*, URL: http://www.thedailystar.net/2004/09/22/d4092225011l6p. htm, retrieved on 17 December, 2011.

Tawhid, K.G. 2004. "Causes and Effects of Water Logging in Dhaka City, Bangladesh", TRITA-LWR unpublished Master Thesis, Royal Institute of Technology, Stockholm, URL: http://www2.lwr.kth.se/Publikationer/PDFFiles/LWREX0445, retrieved on 14 January, 2012.