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Towards a disaster free India

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Editorial Note

One of the main challenges posed by global and local environmental changes is the In spite of step-up efforts at reducing the risks of flood, the frequency and magnitude of the floods have more than doubled in recent years. One disturbing phenomenon that is recurring on a large scale all over the world, particularly in the developing countries, is the emergence of urban flood as a major issue of disaster management. A survey of the causal factors for failure of flood control structures in mitigating urban flood, illustrated with examples from cities across the world, identified four broad categories to be very important. These are: (a) rapid unplanned urban growth with scant regard to land use and physical development regulations, (b) inadequate observation network to record and analyze hydrological and meteorological data, (c) suboptimal design and implementation of structural mitigation measures and (d) poor enforcement and governance system. A number of policy issues have emerged that concern (a) early warning of flood, b) flood modeling scenarios, (c) validity of design concepts and criteria and (d) flood regulations and management

One of the main challenges posed by global and local environmental changes is the need to integrate research and assessment into decision-making processes. When dealing with issues involving uncertainty and high risks, such as natural disasters and climate change, this integration is particularly difficult but necessary. Drainage management is the key issue in urban flood risk reduction that involve the multi-sectoral issues of irrigation, flood panes, wetlands, rainwater harvesting, waste disposal, transport, slum, housing etc.

Sewer and drainage systems require large investments. Investments and maintenance costs can be reduced by planning and operating the systems more efficiently and incorporating innovative solutions. Master plans with direct and indirect provisions provide opportunities for risk based land-use planning and orienting the entire urban governance system in a risk sensitive manner. Most of the Indian cities and towns are facing challenges of seasonal flood which pose serious issues for research and planning.

National Institute of Disaster Management conducted a coordinated study by involving 8 city teams to capture various aspects of urban floods challenges and mitigation in the past recent past. The present issue of our journal 'Disaster and Development' presents four studies of the research outcome and the remaining studies shall be released in the following issue.

Urban Floods and Case Studies Project: An Overview

Anil K. Gupta and P.G. Dhar Chakrabarti

Prologue

Urbanization in developing countries doubled from less than 25% in 1970 to more than 50% in 2006. It is widely accepted that proactive disaster management is a necessity for maintaining the environmental integrity and economic functions of the city. Rapid and uncontrolled growth, bloom in number of vehicles, and financial constraints leading to diminishing investment of infrastructure, have worked together to make our cities highly vulnerable to known natural and un-known so-called natural disaster that are actually man-made for their origin and impacts. Flood disasters are now the most frequent and devastating natural disaster in monsoon Asia. Their impacts have grown in spite of the improved ability to monitor and assess the hazards. The expansion of urban areas into flood plains and wetlands is one reason as it places additional people and infrastructure at risk. Besides this, land-use changes have altered the run-off characteristics of watersheds. Diversions, storage dams, irrigation schemes and inter-basin transfers have altered river flows. The onset, duration, distribution, speed and quality of flood waters has already been changed by human activities. Changes in climate is further altering the flood regimes.

By 2020, seven of the world's ten largest economies will be from Asia. At the same time, Asia is one of the fastest urbanizing regions in the world. In 2000, 37% of its population lived in cities and the proportion is projected to reach more than 50% by 2025. Urbanizing societies usually spend increasing amounts to protect or rebuild damaged flood protection structures, and also respond through land-use regulations, early warning system, etc. Structural intervention to protect valuable urban-based assets, like city commerce & business, however, may shift risk of flood disasters onto other people and places. The actions during and immediately after major floods may exacerbate or limit disasters, while inappropriate recovery activities and policies can

recreate the conditions for the next, even worse, flood disaster. Institutional capacities to manage floods and flood-related disasters are major determinants of vulnerabilities and risk of disaster. Changes in the Asian monsoon system compound the challenges of managing floods in urban regions.

Urban Floods

Recent phenomenon has highlighted the human-made causes that are responsible for recurring and prolonged nature of floods in South Asian cities like Dhaka, Mumbai, Chennai, Bangalore, Ahmedabad, Surat, Patna, Rawalpindi and Islamabad, etc. Flood hazards result from the overflow of land areas, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions, deposition of materials in stream channels during flood recession, rise of ground water coincident with increased stream flow, and other problems (State of Kentucky, III-4).

Mumbai is the largest and most economically important city in India, contributing annually about 17% to the nation's income tax and 37% in corporate tax. The flood of 2005 was truly a disaster as it receded only after seven weeks and affected 20 million. The floods killed 1,200 people and 26,000 cattle. It destroyed more than 14,000 homes, damaged more than 350,000, and about 200,000 people had to stay in relief camps. The agricultural sector was heavily hit as 20,000 hectares of farmland lost the topsoil and 550,000 hectares of crops were damaged. The damage to roads and bridges was estimated at EUR 214 million. Much of the drainage system collapsed and there was a continued risk from water-borne diseases. It took several weeks before basic services were restored.

Figure 1. Continued water logging in Varachha area of Surat even after eight days of flood.

All cities face risks from a range of natural and human-induced disasters, including disasters arising from extreme weather events, fires and industrial accidents. There can also be very large differences in the capacity of city authorities and of city-based households and organizations to take measures to limit an increase in risk and to ensure rapid and effective responses when flooding or some other disasters occur. Coastal hazards can be most disruptive to settlements on coastal and estuarine areas and this is where a considerable proportion of the world's population lives. One estimate suggested that 60 percent of the world's population live within 60 kilometers of the seacoast (Scott, et al, 1996, cited in Hardoy, et al, 2001). Ports and other settlements on the coast or estuaries are also most at risk from any increase in the severity and frequency of floods and storms induced by global warming.

Several factors have immensely increased the difficulty in designing an effective and sustainable flood mitigation policy for urban areas. Severe flooding occurs in many Indian cities during the monsoons every year. Global climate change is now resulting in changed weather patterns and affecting the monsoons. Increasingly heavy rainfall occurrences are causing larger incidences of flooding in urban areas resulting in severe disruption to the urban infrastructure. Also, the urban drains are increasingly being used for wastewater / sewage disposal and the overflows result in epidemics. Principal phases of urban water cycle are shown in figure 2.

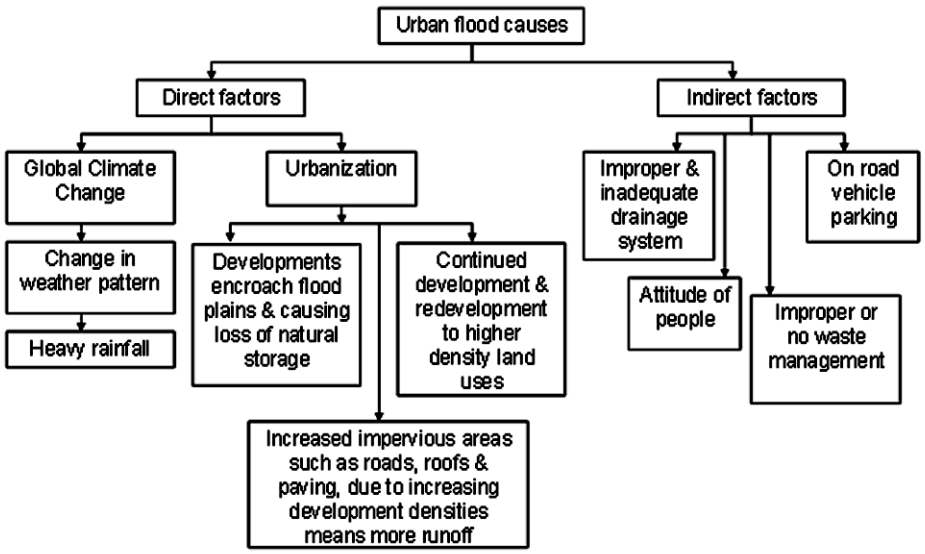

Figure 2. Causes of Urban Flooding.

Flooding in the urban areas may occur when heavy rainfall causes:

a) creeks or channels overtops their banks
b) drainage systems back up because they can not cope with the volume of water or are blocked by rubbish
c) sewers overflow because of illegal connections and the sewer system can not cope with the increased volume

The worst flooding occurs after prolonged rainfall when the soil is saturated and the water levels in creeks elevated. Then, if an intense rainfall burst occurs, causing a large amount of rain within a brief period, flash flooding may occur with little or no warning. Flooding occur because of:

a) developments encroach floodplains, obstructing floodways and causing loss of natural flood storage
b) continued development and redevelopment to higher density land-uses by high costs in major cities
c) increased impervious areas such as roads, roofs and paving, due to increasing development densities means more run-off

Urbanization: Takahashi (1964, 1971) examined flooding events in Japan and showed that floods were not a purely natural phenomenon and that social conditions played an important role that varied from region to region and from time to time. Floods are related to the increase of the impermeable areas and man- made drainage such as conduits and channels. Usually the land use surface in small urban basins are made of roofs, streets and others impervious surfaces. Runoff flows through these surfaces to the storm-sewers. It changes the hydrologic cycle, increasing the overland flow and decreasing the groundwater flow (figure 3). Under these circumstances the peak discharge increases together with the flood frequency.

On-road vehicle parking especially in commercial areas and during night time in residential areas aggravates the blockage of flow of rainfall runoff during heavy rains. With changes in the social structure of post-industrial society, urban space is becoming denser and more complex. The urban facilities, information systems, and networks that are now being built are particularly vulnerable to flood damage. Recent urban floods are examples of a new type of disaster that causes a new type of damage in urban areas. In Chennai City 40 per cent of the population lives in slums - there are 69,000 families who have been identified to be living on government land and they are to be relocated to areas far removed from the city. Delhi, where sub-standard settlements house as much

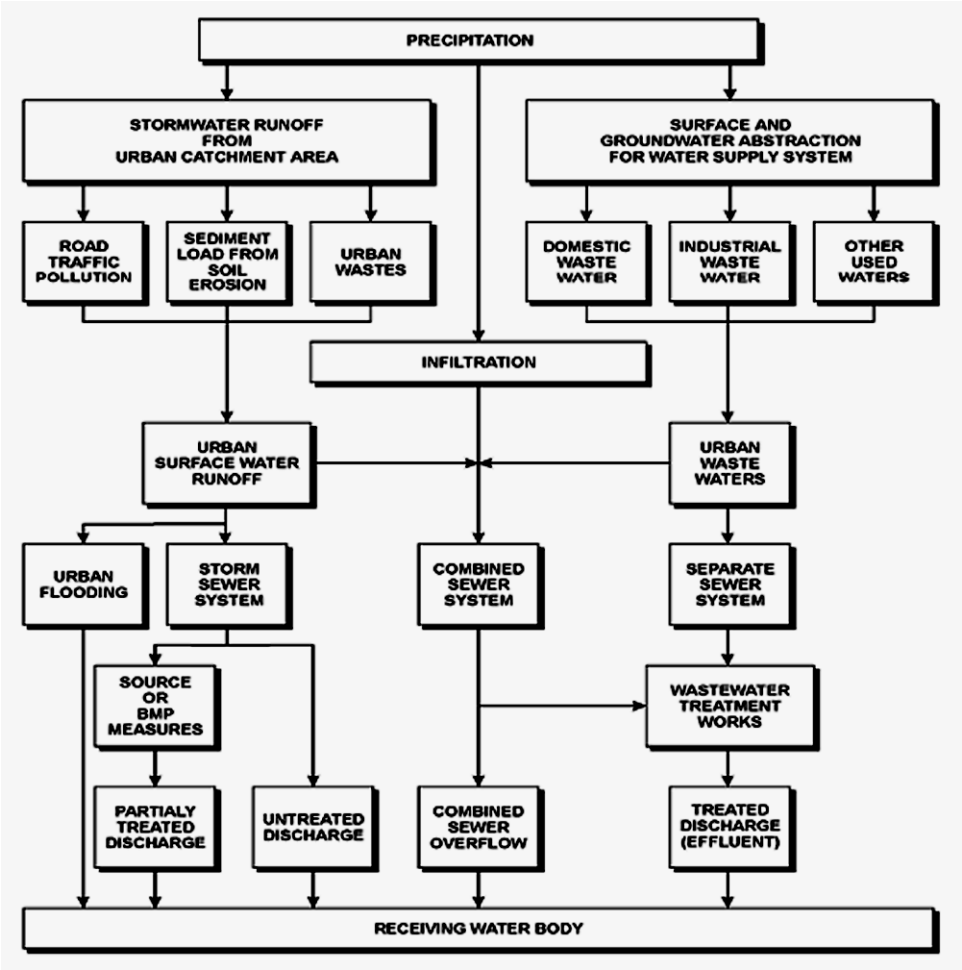

Figure 3. Urban water courses

as 70 per cent of the city's population, leads the way in environmental activism.

In the developed countries the source control of urban drainage has been practiced by detention and retention ponds, permeable surfaces, infiltration trenches and others source control measures. In developing countries usually this type of control does not exist and the impacts are transferred to downstream in the major drainage. The cost to control of this impact is transferred from the individual to the public, since the county has to invest in hydraulics works structures to reduce the downstream floods impacts.

(a) Flood plain occupation: Natural floods mainly occur in medium and large sizes rivers. When no reliable urban plan and regulation exists, the population occupies the flood plain after a sequence of low flood years, because these areas have a flat topography and are near to valuable city land and have a low cost. However, when a larger flood occurs, flood damage increase and the municipality is requested to invest in flood protection in the area.

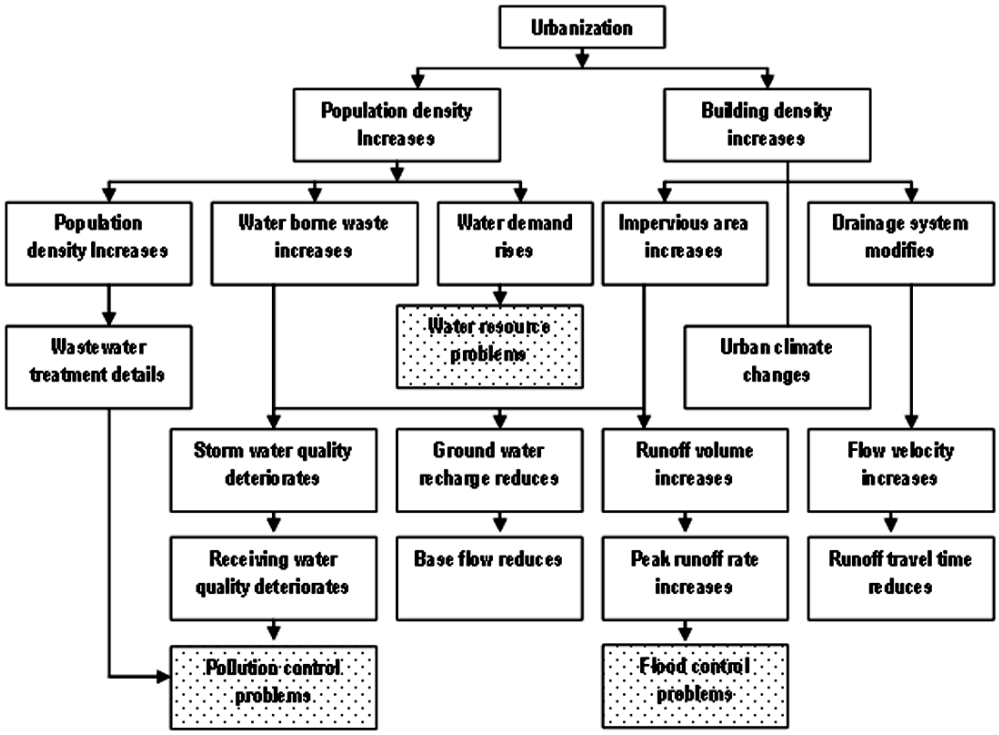

Figure 4. Hydrological impacts of urbanization

Urban flooding is significantly experienced in watersheds of all sizes, wherever the community has occupied locations, which are susceptible to inundation by floodwater. In watersheds which are hydrologically small, it results from cyclonic or storm rainfalls falling on local areas, within or adjacent to urban settlements, where the process of urban development itself has dramatically altered the runoff-producing characteristics of the catchment.

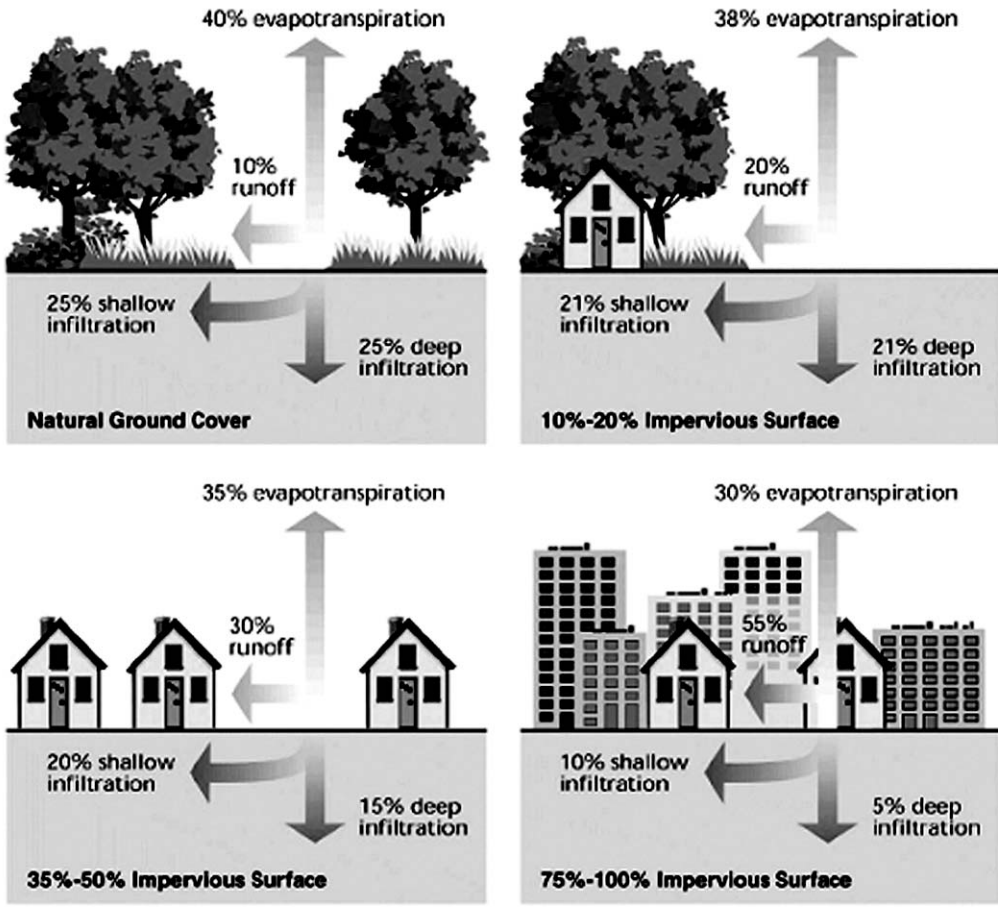

Figure 5. The influence of urbanization on different components of the water cycle

Present Flood-management Practices & Shortcomings

In general, floods cannot be prevented but mitigation and emergency planning can reduce the risk and catastrophic consequences. Flood management is broadly integrated water resource activities aimed at reducing flood impacts on people, infrastructure and economy. It is an irony in the planning that economic considerations and short-term political goals often outweigh long-term but often very serious environmental and social risks. Despite of high impact urban-flood incidence in many cities during recent past, there are still serious flaws in the city planning and governance

in relation to flood risk management.

- The increase in paved ground surfaces, together with the installation of a more efficient drainage system, greatly reduces surface depression and detention storage, reduces the time of concentration and delivers runoff to the nearest watercourse in a fraction of the time that this would have taken prior to urbanization.

  The result is a much sharper rise in the rate of flood runoff, which greatly increases the peak discharge rate from the catchment and substantially increases the subsequent depth and severity of flooding. For these reasons, urbanization can significantly increase the peak discharges in smaller, comparatively frequent storms. Even in larger, rarer storms the peak discharges can be double those of an equivalent rural catchments.
- The current flood management lacks appropriate predictions as the past data for statistical and probabilistic models is often unavailable. The fact that a particular outflow can result from the combinations of hydrologic conditions and is often neglected. Influences of antecedent conditions in the drainage basin are prerequisite considerations and the combination of sound engineering with mathematical modeling can work well.
- An often neglected fact is that change of natural water storage as a consequence of urbanization, also causes significant changes to the temporal characteristics of runoff from an urbanized area, such as shortening the runoff travel time and giving to the event a flashing appearance. Destruction and degradation of urban wetlands has aggravated the risk of urban flooding.
- New buildings on the floodplains are not only at risk of flooding themselves, but also unless care is taken with their design and location, can worsen flooding. Inappropriate new developments can reduce floodwater storage and increase surface runoff.
- Total flood protection is unrealistic and unwise. The ultimate goal of flood loss prevention is the improvement of the quality of life by reducing the impact of flooding and flood liability on individuals, as well as by reducing private and public losses resulting from the flooding. The objectives of the urban flood management are to provide answer to the question of how to deal effectively with the possibility of flooding in urban environment and how to cope with the associated uncertainties.
- An additional present problem of cities is sewerage flooding. Apart from where sewers break, these floods are normally caused by the overflow of 'combined

sewerage overflow' which are common across Indian cities. They carry both sewerage and surface-run-off. The existing capacity is failing to meet growing levels of run-off as discussed above and the increase of sewage as we use more waters.

- Present planning process is weak in addressing on how planning authorities should taken into account the level of flood risk when deciding whether to grant permission for new developments, and to avoid building in flood risk areas, and reduce vulnerability.
- Limited resources for flood mitigation and land-use regulation enforcement in terms of finances and more importantly the staff for field assessments is one of the major problems leading to inefficiency
- Rainwater harvesting structures and facilities, also play significantly additive role in rain-water retention that otherwise shall form the greater amount and velocity of runoff. Insufficient emphasis on promoting such measures has also been a weakness
- Solid waste management in urban areas especially the peri-urban parts is still far from satisfactory, and the garbage including polythene, etc., causes blockage of drains, sewers, and run-off mechanisms, thus aggravating the problem. Incapacities to deal adequately with SWM is additive to urban flooding risk
- Vehicle parking on road is out of proper regulation and enforcement, whereas in case of heavy rainfall resulting in high runoff it leads to retention of greater amounts of water for inundation due to parked vehicles on runoff routes and later floating vehicles create embankments for the flooding waters

Improving and shortening the river channels, constructing high and continuous embankments to keep flood waters in river channels, and expanding storm-water drainage systems, Large-Scale Flood Control Structures (LFCS) have increased a potential of creating new flood hazards. LFCS change the way flood waves propagate in rivers, shortening the time-lag between the rainfall and the peak discharge, thereby increasing the flood discharge flowing down the channels (Takahashi, 1971; Sato, 1998). Moreover, the volume of flood runoff has increased as a result of the loss of water detention capacity of urban catchments. These days, a particular quantity and pattern of rainfall results in a flood discharge of greater volume and with a higher peak discharge than ever before. Moreover, the number of heavy rainfalls, the primary external force of a flood hazard, has been increasing in urban areas in Japan, according to statistics for Japan (JMA, 2005). If this trend continues, it might become a major factor in increasing the flood risk in urban areas.

Framework of City Studies

In order to study the phenomenon of urban floods in India in a comprehensive manner, the National Institute of Disaster Management has taken up a research project, primarily based on case studies on the mega cities of Mumbai, Delhi, Kolkata, Hyderabad, Chennai and Bangalore and two smaller cities of Bhopal and Surat, which have faced floods in the recent years. The basis of selection of above cities is occurrence of regular floods in these cities that caused immediate as well as long after effects like damage to life and property, disturbance in normal routine life through destruction of infrastructures, communication and eclectic facilities etc. Among them five are metro cities so loss due to floods has been on large level that also influenced other parts of the country. For example, the flood incidence of Mumbai 2005 affected all trade activities throughout the country. Other two cities are also important as Bhopal, known as Lake City, is the capital of Madhya Pradesh and Surat is a historically known port and an industrial city. The chapters based on the city-wise studies are organised as per the following structure:

Profile of the City

History – topography – hydrology & water bodies – vegetation - rainfall pattern - demographic and settlement pattern - socio-economic and cultural profile related to flood

City Infrastructure with special reference to drainage

Roads – sewerage – solid waste management – drainage system, Land-use changes

Floods in the City

a) Brief historical account of recurrent and abnormal floods in the city and their impacts, including human dimensions
b) Recent floods in the city – detailed accounts, immediate and long-term impacts
c) Various factors responsible for the floods – natural, physical, environmental, managerial, developmental, etc.

Efforts made to mitigate and manage the floods

a) Master plan provisions in relation to city drainage / sewerage and carrying capacity management – extent of their implementation including regulatory or voluntary efforts
b) Inquiry and faction finding reports – why were the provisions suggested could not been implemented

c) Various structural and non-structural measures for mitigation of flood – achievements and shortcomings
d) What went wrong – critical appraisal of city flood mitigation and management in terms of planning, resources, implementation, capacity, enforcement, participation, etc.
e) Good practices and exemplary lessons

Strategies for the future

What are the strategies of city or state government to mitigate and manage the floods – what are the constraints – what should be done.

Lessons and Concerns

Flood risk depends upon the variety of sources of flooding and layout of the urban environment under concern. It is now well realized that the flood control should not be based on transferring the flood to downstream reaches and must give priority to source control measures. The urban flood mitigation management strategy covers following four components:

- Land-use planning for urban area
- Drainage network management
- Solid waste collection and disposal system
- Building designs and materials

– The *non-structural* measure includes mainly strategic measures: legislature, financing, environmental impact assessment, reconstruction, rehabilitation. Components like flood forewarning, alternative transport, media, alerting, fire service, and environmental control are the emergency issues of consideration.

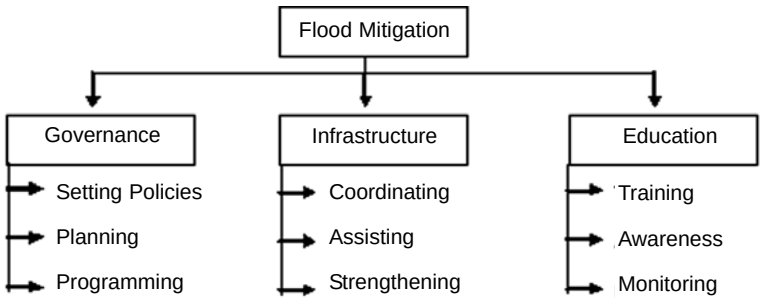

Figure 6. Non-structural strategies of urban flood mitigation

– Structural measures are the imperatives of the integrated strategy for flood mitigation. Following are the non-conventional structural aspects of integrated flood mitigation:
  (a) Improvement and maintenance of the drainage efficiency
  (b) Bulk-water resistant materials in building construction
  (c) The water infiltration process and the creativity
  (d) Restoration of urban wetlands and other natural –water storage sites
  (e) Rainwater harvesting structures promotion

Land use and zoning plans

Land use management employs two principal options: zoning control and development / building control.

Zoning control includes designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area. Most of the physical, social and economic problems associated with flooding, soil erosion and water pollution stormwater are attributable to inappropriate urbanization of the floodplain, unwise land use within the city, insufficient attention to drainage in urban planning, ineffective updating of existing stormwater control facilities and lack of enforcement of zoning ordinances.

Reducing flood damage requires strengthening resilience of low-lying alluvial lands to unexpected scale of flood hazards. People need to understand that low-lying land cannot attaint "zero flood risk", and that they are to be ready for taking an acceptable level of flood risk. It is a myth that people always demand "zero flood risk". A survey taken in a flood prone area showed that 30% of the respondents accept the risk of flooding below the level of the tatami mats (straw floor mats) in their homes in every one to thirty years (Sato, 2006). On the basis of an objective assessment of hazard, economic, social, and environmental factors, the responsible authority should impose appropriate conditions to ensure that the future development is compatible with the prevailing flood situation.

There are three basic types of floodplain development: - preventing development from constricting floodway and allowing the flood fringes to be preserved for agricultural or recreational purpose - preventing development from constricting floodway and allowing the flood fringes to obtain housing, commercial or industrial purpose as long as the encroachment results in only insignificant increase in the water surface elevation - restricting the use of the flood plain and leaving it in its original unoccupied state.

Those types of floodplain development actions are institutionally accompanied by:
- legal measures that enforce zoning, density and pace of development
- taxation measures that may guide development away from hazard areas
- government action that may alter existing land use or require compulsory purchase of the flood-prone land

Building codes generally deal with the following aspects:
- purpose for which the building is constructed
- the criteria for structural strength to withstand water action
- specifications for material
- adequate elevation of basement and first floors

Scope of master planning

The flood management master planning process is a system approach that that is expected to include following:
- documentation of the problem; investigation of the causes of the problems; determination of needs and the planning criteria
- problem inventory; appraisal of feasible solutions; setting up flooding standards based on social, economic, and environmental factors
- collection of all baseline data and identification of baseline conditions, including political, geographic, hydraulic and environmental issues based on systematic interviews and site visits
- description of the existing stormwater practice and its inadequacies
- definition of hydrologic conditions and constraints that proposed changes or development would have on baseline conditions
- definition of interdependencies with neighbouring administrative areas an related municipal infrastructure services
- analytical work that includes hydrologic, hydraulic and water quality analysis
- definition of priorities and alternative solutions (interim solutions, long-range solutions)
- description and cost estimate of proposed facilities and measures
- benefit/cost analysis and comparative evaluation of alternative solutions, including valuation of benefits, damage assessment, cost of traffic disruption, environmental and social factors; other assessment techniques that are more appropriate to urban conditions
- recognition of alternative plans; recognition of emergency plans

- practical financing program; identification of the sources of funds
- drafting legal documents needed to implement the adopted measures

Conclusion

There are varying solutions to the problem of urban flooding and the options must be screened and evaluated in order to facilitate the best practicable options in the planning approach. Besides this an assessment for the "sustainable solutions" of urban flood risk reduction shall help in the long-term basis, as if the risk reductions measures are planned only in view of short-term goals, they themselves may become the factors to aggravate risk in the times. A surface water management plan, based on the inputs from a basin flood management plan and assessment of flood risks due to local floods and coastal floods, if any, is an essential element for a comprehensive and coordinated approach to flood risk management. The planning process should not be unilateral phenomenon but shall involve the stakeholders responsible for implementing the provisions of flood risk reduction plan and allied responsibilities. The proposed case studies for the selected seven Indian cities shall be greatly helpful in identifying the root causes and their sustainable solutions in order to minimize the risk and the loss-free ways to live with the residual risks.

Acknowledgements:

A range of source of information – from published and unpublished literature including web-resources has been utilized in the articles based on appropriate interpretation. Authors acknowledge their original sources and publications.

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Urban Floods: Case Study of Delhi

A.K. Gosain, P.K. Khandelwal and S. Kulshrestha

Profile of the City

History

New Delhi, the capital of India, sprawled over the west bank of the river Yamuna is one of the fastest growing cities in India. It is surrounded on three sides by Haryana and to the east, across the river Yamuna by Uttar Pradesh. It traces its history to Mahabharata, the great epic tale of wars fought between estranged cousins, the Kauravas and the Pandavas for the city of Indraprastha. Historically, the city has long since been the foremost in political importance with successive dynasties choosing it as their seat of power, between the 13th and the 17th centuries. Remnants of the glorious past survive as important monuments in different parts of the city.

Mughals ruled Delhi in succession starting from Qutab-ub-din to Khiljis, Tughlaqs . The city of Delhi passed on to the hands of the British in 1803 AD. It was only in 1911, when the capital of British Empire was shifted from Calcutta to Delhi, that Delhi got its present prestige. After independence also, a kind of autonomy was conferred on the capital but it largely remained a chief commissioner's regime. In 1956 Delhi was converted into a Union Territory and gradually the chief commissioner was replaced by a Lt. Governor. In 1991, the National Capital Territory Act was passed by the parliament and a system of diarchy was introduced under which, the elected Government was given wide powers; except law and order which remained with the Central Government. The actual enforcement of the legislation came in 1993.

The myriad faces of the city are simply fascinating. In some places it remains a garden city, tree lined and with beautiful parks, but in some places it can also be crowded with heavy traffic. Turbaned Sikhs, colourfully dressed Rajasthani and Gujarati women working in offices, Muslim shopkeepers along Chandni Chowk in Old Delhi, Tibetians and Ladakhis in the street stalls along Janpath and Kashmiris in the handicraft emporia around Connaught Place, all add to the cosmopolitan feel of the city. Soaring skyscrapers, posh

* Contributed as Delhi city team under National Coordinated Project of NIDM (Gupta, Anil K. and P.G. Dhar Chakrabarti, *Disaster & Development*, 3 (1):1-14, 2009)

residential colonies and bustling commercial complexes can be seen along with the ancient historical monuments. Its boutiques and shopping arcades offer access to a wealth of traditional and contemporary crafts from all over the country. Old Delhi which looks entirely different from New Delhi area, is about 6 Km north of the city center [1].

Topography

It is located in the North-west portion of the country at latitude 28.68 N and longitude 77.21 E. The eastern portion of the Delhi Union Territory is adjacent to the State of Uttar Pradesh, simultaneously; the northern, southern and western portion is adjacent to the State of Haryana. In the east portion of the Delhi Union Territory, Yamuna River, a tributary of Ganges River flows to the south, and in the west, Aravalli Mountains forms the administrative boundary with the Uttar Pradesh Region.

The Delhi region exhibits a very gentle southerly master slope as indicated by the southerly flow of the Yamuna River, except at some places where the slopes have been locally reversed. The general slope in the region east of the Yamuna River is westerly. Similarly, the change in slope direction is also noticed west of the Yamuna adjoining Okhala Barrage [2].

Vegetation

Delhi geography divides the state into three parts- the Delhi ridge, the Yamuna flood plain and the plains.

The Yamuna river plains are very fertile as they are flooded by the river and is rich in alluvial soil. The Delhi ridge is the most important characteristic of the state and is a part of the Aravalli range that passes through Delhi. It is interesting to note here that each of these regions is marked by distinct type of vegetation. The ridge area of the city offers the right factors that favor the growth of acacias and other cacti [3]. However, during the monsoon, herbaceous plants grow in abundance in the ridge. As far as the plain region of Delhi is concerned, it is characterized by shisham trees. And finally, riverine type of vegetation grows along the plain of Yamuna. Vegetation of Delhi mainly comprise of medium size trees and herbs. However Delhi is known for its varied flowering plants [3]. Weeds and grass grow on the banks of the Yamuna river.

According to the Delhi weather records, extreme temperatures dominate the state capital. Delhi experiences extreme summer and winter seasons. Besides this, winter season also experiences immense fog which covers the city in its blanket.

Climate and Rainfall

About 160 kilometres south of the Himalayas, Delhi feels every chilly blast that lashes

the snowcapped mountains. From December to February temperatures range from 3°C to 21°C. The season is marked with light rainfall, frosty winds and an all-enveloping fog.

But the cold months of December-February soon give way to the balmy month of March. Birds sing out a full-throated welcome to Basant Bahar (the bloom of spring) as fresh grass and blossoms burst forth and trees sprout shiny new coats. Sometimes, when Delhiites are in luck, the spring gets an extra lease of life and tarries till mid-April.

Hot on its heels comes May which turns Delhi into a scalding charcoal tandoor (a large round clay oven). Thanks to its distance from the sea, Delhi bears the brunt of an extreme type of continental climate. The summer consequently is as hot as the winter is cold. The mercury, itself in danger of dehydration, soars to 47°C. One has to be carefully prepared before venturing out as heat strokes and dehydration are the order of the day. Violent dust storms and hot winds – locally dubbed "loo" – are part and parcel of the hot and dry Delhi summer.

The cruel onslaught of summer is cut short with the advent of the monsoon (moisture bearing winds) in early July. The monsoon, of course, is never known to have arrived when it is expected – it's either late, early or whimsically decides to just skip Delhi. It provides the city much-needed succor. The parched ground, plants, animals and people greedily soak up the moisture for the next two months as the temperature dips down to a bearable 30s°C. September though hot, is not dry but humid. In October the days become cooler and with November Delhi is very much in the arms of winter again [3].

Monthly average temperature, precipitation and Humidity of Delhi are shown in Table-1. Distribution of rainfall over entire Delhi with measurements at different rain gauges is shown in Figure-2. Average monthly rainfall is shown in Figure-3.

Table 1: Monthly Average Temperature, Precipitation and Humidity of Delhi

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	14.3	17.3	22.9	29.1	33.5	34.5	31.2	29.9	29.3	25.9	20.2	15.7
Precipitation (mm)	25	22	17	7	8	65	211	173	150	31	1	5
Humidity (%)	62	47	39	25	25	30	67	73	65	49	44	55

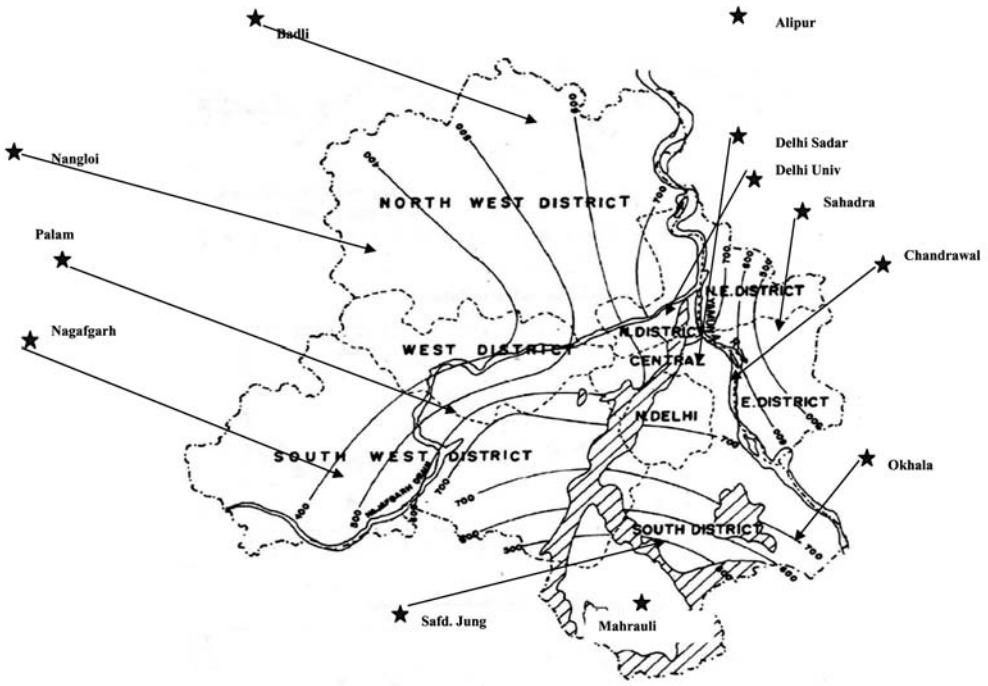

Figure 1. location of rain gauge stations and distribution of rainfall over Delhi

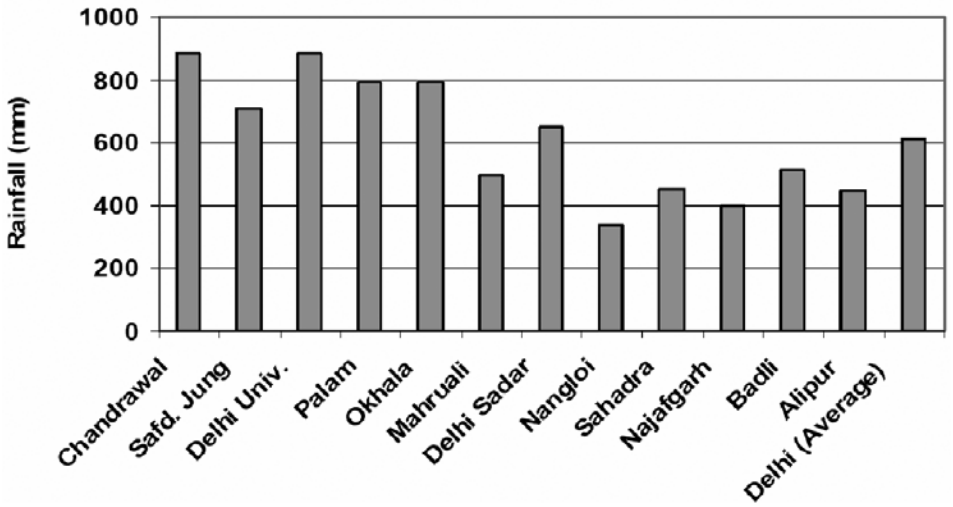

Figure 2 Average Rainfall at different Rain Gauges of Delhi (adapted from [4]).

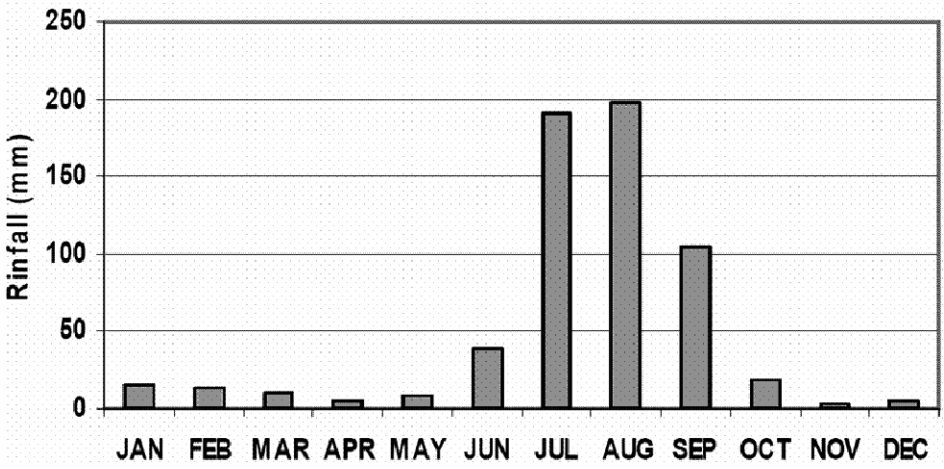

Figure 3 Average Monthly Rainfall of Delhi

Demographic and Settlement Pattern

The present administrative setup of Delhi city consists of Government of Delhi and various Municipal Corporation. The Delhi Union Territory including Delhi City is under jurisdiction of the Government of Delhi.

The Delhi City is divided into the following three municipality areas:

(1) Cantonment area in the western central part of the city where housing area was developed by United Kingdom for the higher military officers.

(2) New Delhi in the eastern central part of the city where the central government offices as well as many cotemporary buildings have been placed since 1911 when the capital of the republic of India has been formulated.

(3) Old Delhi is surrounding the above two municipality areas where the atmospheres of the Mugal Empire era is still heavily remaining and many buildings are disorderly located.

The total area of the Delhi Union Territory is 1,484 Km^2, while the area of Delhi city is 325 Km^2 consisting of 240 Km^2 of Old Delhi, 44Km^2 Cantonment Area and 41Km^2 of New Delhi.

The population of the Delhi Union Territory was 9.4 million in 1991, 89% of its population (8.4 million.) concentrating in Delhi City. The city is thirdly populated in India after Bombay City (12.6 million.) and Calcutta (10.9 million). The growth rate of population in Delhi City in the past 10 years is 3.4% that exceeds the nation wide average of 3.1%. Such relatively high population growth is due to the illegal population inflow to

the city area. According to the Slum & JJ Department, MCD, the number of illegal residents in Delhi City in 1984 was about 260 thousand households (about 1.2 million residents), while it has remarkably increased to about 480 thousand households (about 2.0 million residents) in 1994. Majority of illegal residents settles in Old Delhi, where the present population density is 30,000/Km^2 much higher than that of New Delhi and Cantonment area as shown in Table 2. As shown in figure 4 the population density of North district is 13 thousand/km2: North-East district is 29.5 thousand/km^2: Central district is 25.8 thousand/km2: North district is 5.0 thousand/km^2: South district is 9.1 thousand/km^2: South-West district is 4.2 thousand/km^2: West district is 16.5 thousand/km^2 and North-West district is 6.5 thousand/km^2.

Table 2: Population and Population Density in Delhi City

City	Population	Area (km^2)	Population Density (thousand/km^2)
Old Delhi	7,206,704	240	30.3
New Delhi	301,297	41	7.3
Delhi Cantonment	94,393	44	2.1

Socio-economic profile

Delhi, the capital of Republic of India, acts as the national economic center having its principal basis on service sector that employs about 22% of total working population. Succeeding to the service sector, the industrial sector is the second largest working population sharing 9%, and the agricultural sector is the third sharing 0.4%. Judging from the share of working population of Delhi, the economic structure of the city can be classified as urban type. The city recorded its per capita income of 872 rupees in 196-1961, which is much higher than the national average of about 330 rupees.

Delhi has accentuated its function as a banking wholesale-trade and distributive center. There exist the headquarters of the Reserve Bank of India and the regional offices of the State Banks as well as other banking institutions in Delhi. The city also has the large distributive share in the north-eastern region of India for bicycles, fresh fruits/vegetables, furs, skins, wool, motor parts/machinery and iron/steel. Most of the distributive trades are carried out from the Old – Delhi area, where most of the markets are located in close proximity to each other.

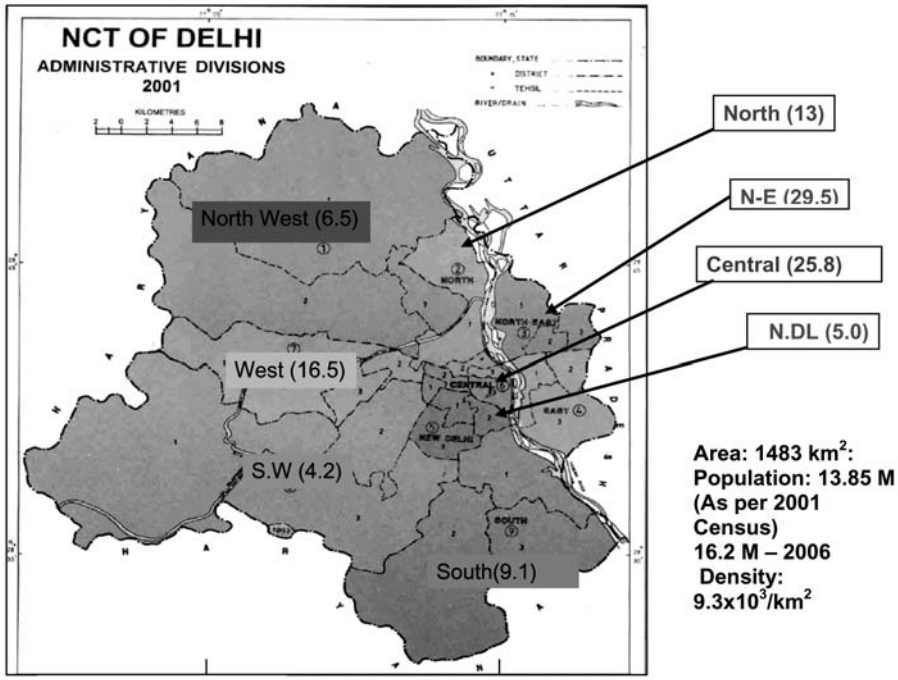

Figure 4: Population Density in various districts of Delhi

Moreover, Delhi has been traditionally famous for its artistic works such as ivory carving and painting, gold and silver embroidery, decorative ware, copper-ware and brass-ware. More recently, it has become important for the manufacture of various sophisticated products in small-scale industry such as electronics, automobile parts, precision instruments, lathes and drilling machine. Delhi has the largest number of establishments for manufacture of electronics goods in the country.

City Infrastructure

The usual city infrastructure involves a very wide spectrum of facilities, however, the present description is confined to only those infrastructure that are connected in some way to the flooding problems.

Roads

There are six different agencies maintaining the roads in the city - NHAI, PWD, MCD, NDMC, DDA and Delhi Containment Boards. The road network in Delhi was 31,183 kms

in March 2006, the number of vehicles has increased from 2.14 lakhs in 1971-72 to 48.30 lakhs (23 times)[5].

The imbalance between growth of vehicles and road network has led to heavy traffic congestion and reduced vehicle speed. A rough network of major roads is shown in Figure 5.

Sewerage

The existing capacity of sewerage system in Delhi is grossly inadequate, as only about 55% of the population is covered under organized conventional sewerage system and about 15% under on-site sanitation systems. Rest of the population does not have proper access to sanitation facilities. The increasing pollution in the river Yamuna is also a major indicator of lack of sewerage treatment facilities.

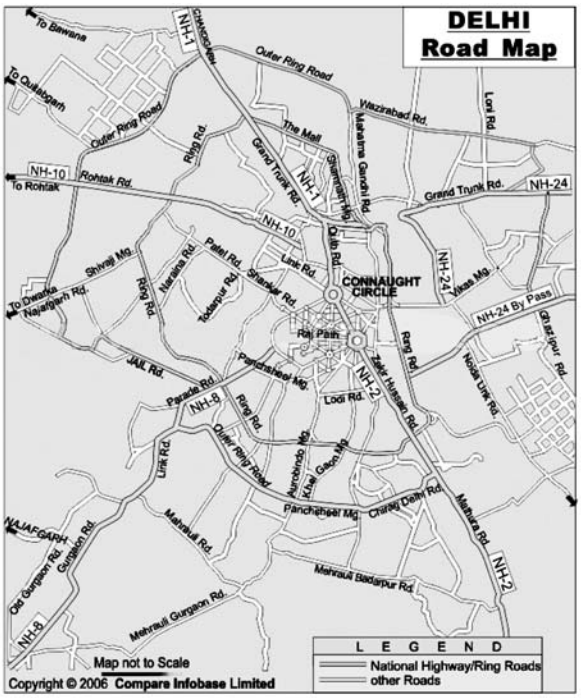

Figure 5: Major Road Network of Delhi [4]

By the year 2021 entire Delhi should be served by regular sewerage system in a phased manner. The areas where immediate regular sewerage system is not available, low cost sanitation system by individual families could be adopted as a short range provision.

These should be planned in such a way that in the long term regular sewerage facilities could be provided. To improve the sewerage and sanitation, the surface drainage and sewerage systems would have to be developed in an integrated manner.

The sewerage system is designed to handle domestic liquid waste @ 80 % of the water supply, which has to cater to 1472 mgd (6625 mld) of waste water by the year 2021. This excludes commercial and industrial waste water handling which needs to be treated separately. The waste water is also generated due to the use of ground water drawn from the bore holes installed by the public which is not included in the above figures.

Drainage System

Drainage has two aspects: flood protection and storm water discharge, which are interrelated. The storm water and flood protection in Delhi are not local but have regional bearing including areas of Haryana and Rajasthan. The main drainage system of Delhi is such that all water collected through main drains, link drains and small rivulets is discharged into Yamuna. On the basis of topographical characteristics and existing drainage network, NCT of Delhi has been divided into five drainage basins namely Najafgarh, Alipur, Shahdara, Khushak nallah and Mehrauli.

At present, rain water in Delhi City is drained through twenty five main drainage channels into Yamuna River. The outlet facilities for these drainage channels are classified into the following three groups; (1) natural drainage without reverse flow water gate, (2) natural drainage with reverse flow water gate and (3) pumping drainage system. The last drainage system is adopted in only three out of twenty five main drains. The pumping drainage channels, having relatively small pumping capacity of less than 1000 cusec (28.3 $m^3/_s$). Consequently, most of rain water in Delhi City could not be drained during a period of high water level of Yamuna River. The major drains out-falling in river Yamuna are shown in Figure 6. The major drainage Basins of Delhi are shown in Table-3

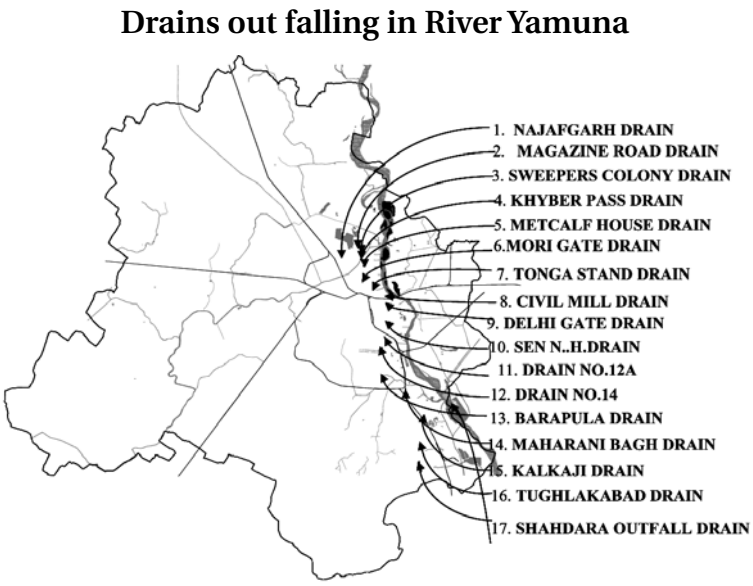

Fig. 6 Major Drains falling in river Yamuna.

Table 3: Drainage Basins

Basin	Location	Length of Drain in Km	Discharge in cumecs
Alipur	North	144	174
Khanjhawala	West	120	52
Najafgarh	Central-North & West &South	105	369
Khushak-Barapulla	Central-South & East		120
Trans-Yamuna	East	45	158
Mehrauli	South	5	86
Trans-Yamuna	East	45	158

Among the main drainage channels, Najafgarh drainage channel which is controlled by Irrigation and Flood Control Department of Delhi Government has the largest flow capacity, covering extensive drainage area. The flow capacity of Najafgarh drainage channel is 20,000 cusec (566 $m^3/_s$), and after the supplementary drainage that is now under construction, is connected to Najafgarh drainage channel, the future flow capacity will increase to 25,000 cusec (708 $m^3/_s$) in all. However, Najafgarh drainage channel naturally drains to Yamuna River without reverse flow water gates. Consequently, the reverse flow in the drainage channel occurs due to backwater effect of Yamuna causing serious damages in the city as experienced in 1995.

Land-Use changes

The Delhi Development Authority's 20-year master plan implemented from 1962-81 broadly divided up the city on the basis of public, semipublic and residential use of land. Public and semipublic land use was concentrated in the Central Secretariat area of New Delhi, the Old Secretariat area in the Civil Lines, Indraprastha Estate, the CGO complex and RK Puram (an office-cum-residence complex).

Small manufacturing units have sprung up in almost every part of Old Delhi, but the main industrial areas are along Najafgarh Road in the west and on Mathura Road in the south, where a large planned industrial estate, Okhla, has been established. Areas for

commercial land use are confined mainly to Chandni Chowk and Khari Baoli (both in the north), the Sadar Bazaar of Old Delhi, the Ajmal Khan Road of Karol Bagh in western Delhi, and the Connaught Place area of New Delhi. A number of district and local shopping centres have also developed in other localities.

The University of Delhi, India's most prestigious university, is located in the north, where a number of educational institutions for college education and for higher studies are located. It attracts students from all over the world and is hotbed of educational, research and cultural activity. Its southern campus is located near Dhaula Kuan. Another educational complex that includes Jawaharlal Nehru University, the Indian Institute of Technology, and other institutions has been developed in southern Delhi. The current land use pattern is shown in Figure

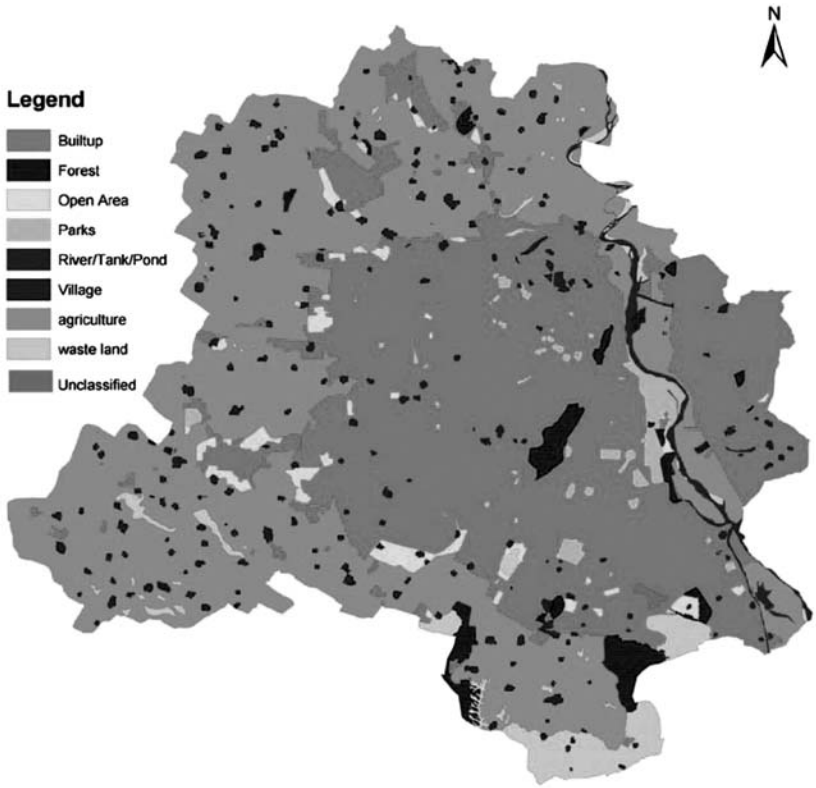

Figure 7: Current Land use of Delhi

The Land Use Plan-2021 has been prepared based on

i) The policies enunciated for different urban activities,
ii) Requirement of additional social and physical infrastructure,
iii) Transportation and work centers,
iv) Restructuring of land uses along the MRTS corridors based on the studies and considering the inter relationship between the urban activities, environment and the image of the city and
v) Already approved Zonal Development Plans and land use modifications.

In order to control the development, the areas have been designated as one of the 27 use zones identified in the Development Code. These use zones have been classified broadly in ten categories of land uses namely Residential, Commercial, Industry, Recreational, Regional Park / Ridge, Transportation, Utility, Government, Public and Semi Public Facilities and Agriculture and Water Body. The development in these use zones would be carried out in accordance with the regulations as given in the Development Code and respective chapters.

Table 4: Zone wise area as given in MPD-2001

Zone	Name of Zone	Area (Ha.)
A	Old City	1159
B	City Extn. (Karol Bagh)	2304
C	Civil Line	3959
D	New Delhi	6855
E	Trans Yamuna	8797
F	South Delhi-I	11958
G	West Delhi-I	11865
H	North West Delhi-I	5677
J	South Delhi-II	15178
K	K-I West Delhi-II K-II Dwarka	5782 6408
L	West Delhi-III	22840
M	North West Delhi-II	5073
N	North West Delhi-III	13975
*O	River Yamuna / River Front	8070
P	P-I Narela P-II North Delhi	9866 8534

Zonal Development Plans

The NCTD has been divided in 15 Zones (Divisions). The Zonal Plans of seven zones have been approved and notified whereas the Zonal Plans for the zones 'G', 'H', 'M' and 'P' (Narela) is at various stages of approval. The boundaries of the zones 'O', 'P' and 'N' as given in the MPD-2001 have been modified and accordingly the areas have been computed approximately as given in the table-4.

The Walled City and its Extensions, Karol Bagh and the area in between with contiguous specific use has been designated as Special Area for the purpose of development since it is not possible to develop the old built up area in accordance with the general use zone regulations given in the Development Code. Land use plan as per Master Plan is shown in Figure 8.

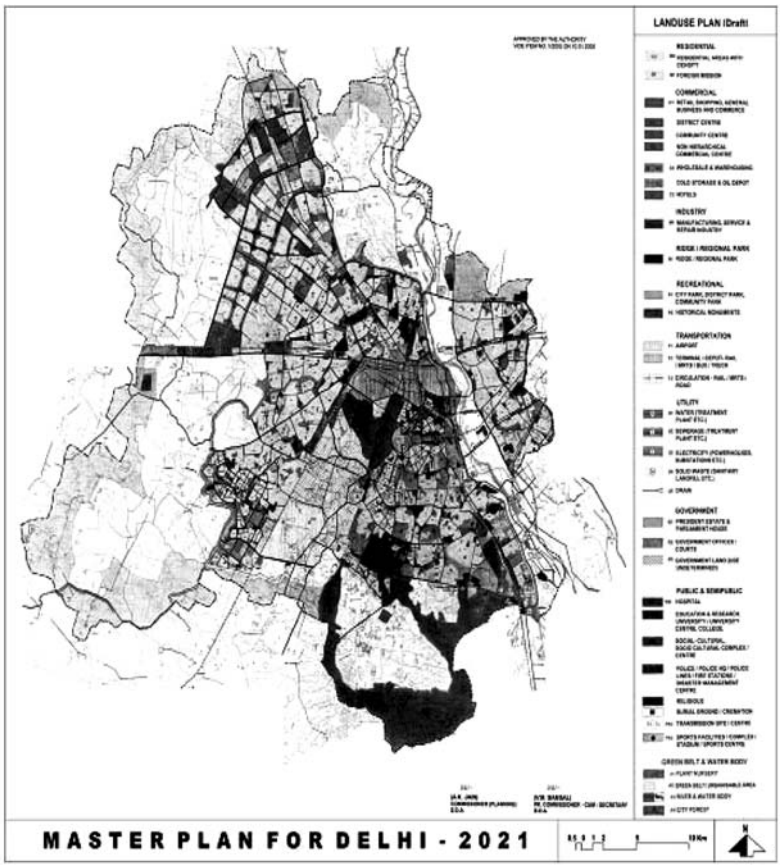

Figure 8. Land use plan as per Master Plan Delhi-2021

Floods in the City

Flood vulnerability

Delhi has a history of floods in river Yamuna. Regular flood monitoring in river Yamuna in Delhi started only in 1958 after the construction of the Yamuna Pushta (Left Marginal Bund) and the 'danger level' was then fixed at the Old Railway cum Road Bridge at 672 ft which on conversion to the metric system became 204.83 m. The 'warning level' has been fixed at 204 m.

The city has been experiencing floods of various magnitudes in the past due to floods in the Yamuna and the Najafgarh Drain system. The Yamuna crossed its danger level (fixed at 204.83m) twenty five times during the last 33 years (table 3.1). Since 1900, Delhi has experienced six major floods in the years 1924, 1947, 1976, 1978, 1988 and 1995 when peak level of Yamuna River was one meter or more above danger level of 204.49m at Old Rail Bridge. The highest recorded level of 2.66m above the danger level occurred on September 6, 1978. The second record peak of 206.92m was on September 27, 1988.

A profile of recently experienced floods indicating the extent of damage caused is as follows[9].

1977: Najafgarh drain experienced heavy floods due to discharge from the Sahibi River. The drain breached at six places between Dhansa and Karkraula, marooning a number of villages in Najafgarh block. Six human lives were lost due to house collapse. 14 persons died in a boat mishap. Crop damage was estimated at Rs 10 million.

September,1978: River Yamuna experienced a devastating flood. Widespread breaches occurred in rural embankments, submerging 43 sq km of agricultural land under 2 meters of water, causing total loss of the kharif crop. In addition to this, colonies of north Delhi, namely, Model town, Mukherjee Nagar, Nirankari Colony etc. suffered heavy flood inundation, causing extensive damage to property. The total damage to crops, houses and public utilities was estimated at Rs 176.1 million.

September, 1988: River Yamuna experienced flood of very high magnitude, flooding many villages and localities like Mukherjee Nagar, Geeta Colony, Shastry Park, Yamuna Bazzar and Red Fort area, affecting approximately 8,000 families.

September, 1995: The Yamuna experienced high magnitude flood following heavy rains in the upper catchment area and resultant release of water from Tajewala water works. Slow release of water from Okhla barrage due to lack of coordination between inter state agencies further accentuated the problem. Fortunately, the flood did not coincide with heavy rains in Delhi, and could be contained within the embankments. Nonetheless, it badly affected the villages and unplanned settlements situated within

the river-bed, rendering approximately 15,000 families homeless. These persons had to be evacuated and temporarily housed on roadsides for about two months, before they went back to living in the river-bed.

The flood situation is projected in the Flood Atlas map prepared by Central Water Commission. As per the map of the flood prone areas, Delhi has been classified into thirteen zones based on the flooding risk in relation to incremental rise in the water level of the Yamuna (DDA, 1993). These zones cover a range from 199m to 212 m level of water in the Yamuna. This zoning map covers part of North Delhi on the West bank of the Yamuna and almost the entire Trans Yamuna Area on the East bank. Besides this, the Delhi Flood Control Order also divides the NCTD into four Flood Sectors, namely Shahadra, Wazirabad - Babrapur, Alipur and Nangloi - Najafgarh sectors.

Although the unprotected flood prone area is only 1.7% or 25km only towards the south east and about 5% or 74 sq km in the north eastern parts which is protected by earthen embankments, every year water level rises in Yamuna above danger level and large population has to be evacuated to the top of the bunds and Delhi highways.

The Environment Status Report of WWF for Nature-India (1995) has pointed out that since 1978 the flood threat to Delhi has increased. In 1980, a discharge of 2.75 lakh causes at Tajewala resulted in flood level of 212.15 meters at the bund near Palla village in Delhi.

August and September 2008[12]: On 16th and 17th August 2008, Delhi was warned of possible flood. The peak of 205.71 m was reached on 20th August 2008 by which time deep flood waters could be seen in areas immediately downstream of the Wazirabad Barrage in east bank with flood waters gradually spreading over the entire available flood plain between the ring road in the west and the Yamuna Pushta (Left Marginal Bund) in the east. Residents of Jhuggi Jhompris all over the flood plain relocated themselves away from menacing flood waters and the villagers of Usmanpur, Garhi Mendu and Bela Estate were specially impacted as flood waters entered their houses and submerged standing crops. Even the residents of Mukherjee nagar were impacted as a result of backflow in the drain which had been closed by the authorities to prevent the flood waters entering the city from the several drains falling from the city into the river.

Again from 20th September 2008 onwards flood warnings for Delhi were given following heavy rains in Himachal, Uttarkhand and Punjab. Close to 3.80 lac cusec water had been released from the Hathnikund Barrage. It was almost double of what had been released in the month of August 2008 but still short of the 5 lacs cusec figure from 1988 and 1995. The peak of the floods was experienced in Delhi on 22nd and 23rd September 2008 and by 24th September the flood waters once again entered the available flood plain in the city and knocking at all the embankments of the river. The authorities had to resort to the use of

physical barrier like sand bags to prevent flood waters spilling on to the ring road near ISBT, while the Tibetan market and the entire Qudsia Ghat area went under deep water.

Once again in a short span of a month the life of people in Usmanpur, Garhi Mendu, Bela Estate and Chilla Saroda Khadar was upturned with most of them finding refuge at high places on the Yamuna Pushta and on the road sides. Farmers, of course, lost all that they had grown in the flood plains. This time around the flood waters which had barely touched the embankment next to the ongoing constructions like the Games Village and the DMRC depot during the August floods saw deep waters standing next to them.

Local Flooding

A significant phenomenon which has been increasing during recent years is that of local flooding. Urban areas are characterized by a high proportion of area under impervious surfaces (Roads, pavements, houses etc). High rates of development along with the resultant loss of soft landscape have led to high surface water runoff rates. This results in floods in the low lying areas even after moderate precipitation. Another factor adding to this effect is that of River Yamuna because the river is normally flowing at a higher level within its embankments during such periods. Thus, the water gets logged in the city areas and it takes several days to mechanically pump it out and bring the situation under control. Similarly, during the past few years, flooding due to the city's 18 major drains has also become a common phenomenon. Already under the pressure of the city's effluent discharge, these drains experience reverse flow from the Yamuna, which is in spate, and as a result they tip their banks, flooding the neighboring colonies.

Recent Floods in Delhi– Detailed account

Flood Problem Due Due To Sahibi Nadi

The Sahibi River originates in Jaipur district of Rajasthan. After passing through Alwar district in Rajasthan and Gurgaon district in Haryana it enters Union Territory of Delhi near Dhansa. Very little quantity of water used to enter Delhi due to interception of Jahajgarh and other jheels and the under ground reservoirs of Rajasthan and Haryana. But due to land developments and improvement in drainage system in Haryana, it is seen that every year, the quantity of water entering Delhi is increasing very fast and the Najafgarh Jheel areas have started remaining under water for full year. To check this entry of water in Delhi, the bund and regulator at Dhansa were constructed in the Year 1964 and the same year there had been an unprecedented heavy flood in Sahibi which caused breach in Dhansa Bund and resulted in submergence of most of areas of Najafgarh Block in deep waters.

Similar instances of heavy flood in Sahibi have been in the years 1967 and 1977. Though the flood of 1967 did not make any damage in Delhi area but 1977 flood created even worse position than 1964, when even the far off colonies of Delhi like Janakpuri, etc. were threatened by the Sahibi floods.

Every time after the flood in Yamuna & Sahibi different experts Committees had been set up who always recommended for increasing the capacity of N.G. Drain and Dhansa Regulator and also the raising of the banks to accumulate higher discharges inside them. Sahibi river belongs to special category of rivers in arid and semi arid areas in Rajasthan.

The flooding and consequent damage is caused mainly in the rural areas of Delhi in and around Najafgarh Jheel. It also causes damage to the urban areas situated along the banks of the Najafgarh Drain. There is no record of flooding and damage in Delhi area prior to 1964, when the capacity of the Najafgarh Drain was only 900 cusecs. Even the Reddy committee which examined the problem of floods and drainage in Delhi in 1957-58 did not mention any damage caused by Sahibi floods in the past. The first major flood of Sahibi as known in the recent past occurred in 1964. The Dhansa bund which was constructed in 1961-62 suffered damage when the level U/s rose considerably. A controlled cut was made through Dhansa bund which later on widened and resulted in a breach and the flood waters could not be contained within the Najafgarh drain, thus caused damage both in the rural and urban areas of Delhi. In the years 1967, 1975 & 1976 the flood was of less magnitude and there was some damage in Haryana, without effecting Delhi as Sahibi water could pass down the Najafgarh drain through Dhansa regulator. The real major flood after 1964 was that of 1977.

During 1977 two major floods were experienced in the Sabhibi catchment, the first storm occured between 29th to 31st July and the second between 4th & 6th of August. The Yamuna was already in spate when the Sahibi level rose. The level of Yamuna on 27th of July at old Railway Bridge in Delhi was 204.85m (672.07ft.) against a danger level of 204.83 m (672 ft.). The maximum level of Yamuna recorded at old railway bridge in 1977 was 205.85m (675.29 ft.) on 7th August 1977.

The Water level U/s of Dhansa was 210 M (688.98 ft.) on 11.7.77 i.e. 2.5 M less than the FRL. It started rising gradually and reached a level of 210.80M (691.58 ft.) on 28.7.77. Thereafter due to floods in the Sahibi, the level started rising rapidly and reached 213.575 M (700.71 ft) on 6th of Aug. 1977 whereas top of the bund at Dhansa is at a level of 214 M (702 ft.). Anticipating such a high rise of water U/s of the bund Delhi Admn., had started from 2nd August, temporarily raising the bund by means of sand bags, and on this account bund remained safe. As the bund is not connected to high ground at its southern

end, considerable flow started through that gap, which got further developed on account of high level on its U/S. During this period both the regulator were kept open and max. discharge of about 6000 cusecs was passing through regulators against the designed capacity of 3000 cusecs. It is roughly estimated that the max. discharge passed through Dhansa bund (Regulator as well as by-pass channel) was of the magnitude of 36,000 cusecs. On account of this heavy flow from Dhansa and also due to inflow from direct catchment of Najafgarh lake, the Jhatikara bund on the left-bank of Najafgarh Drain in Delhi breached on 6.8.77. Consequently the entire Najafgarh Jheel and vast area of Delhi came under submersion. The Najafgarh drain had a designed capacity of 3000 cusecs. Due to such heavy inflow, the Kakraula regulator was also by-passed and lot of water started flowing over-Najafgarh Dhansa road. The Najafgarh drain was carrying a discharge of about 6000-6500 cusecs for number of days against the designed capacity of 3000 cusecs. The excess discharge resulted in overflowing the banks of the drain inspite of the attemps made by Delhi Admn., to temporarily raise the banks by sand bags.

The max. level recorded D/s of Dhansa regulator was 212.80 M (697.98 ft) on 9.8.77 and the max. level recorded at Kakraula was 212.125 M (695.77 ft) on 16.8.77 and the same level was recorded at Basaidara on 17.8.77. The rural area in Delhi remained under water for about 3½ months and was free from submersion only in the second week of November.

Flood Problem Due To River Yamuna

Yamuna is the main river of Union Territory of Delhi which flows in its Easterly direction from North to South. Keeping in view the topography, Yamuna catchments upto Delhi is divided in two parts - (1) The upper catchment from source in Himalayas to Kalanaur in Haryana - which comprises parts of Himachal Pradesh and hills of West Uttar Pradesh and (2) the lower catchment from Kalanaur to Old Delhi rail bridge which consists of West Uttar Pradesh and Haryana.

River Yamuna enters Delhi from the northeast near Palla at an altitude of 210.3 meters and after traverse of about 40km. it leaves Delhi at an altitude of 198.12 m near Jaitpur in the South. The width of the riverbed varied from 1.5 to 2.0km. in its flow from Wazirabad barrage, a network of seventeen drains joins the river on the West bank during its traverse in the northern parts of the city. Najafgarh and Alipur drains, due to heavy discharge from Sahibi river, inundate a number of villages in Nazafargarh block causing heavy damage to life and property. There was, however, little effect of it in Yamuna river flow. Only one drain joins on the East bank near the old rail bridge.

As per available records, during the last 40 years, the years 1967, 1971, 1975, 1976,

1978, 1988, 1995 and 1998 have been the high flood years for River Yamuna, when the water level in the river at old railway bridge was observed to be 206.0m or more.

Various Factors responsible for Floods

The Yamuna River is an alluvial river and hence has got a meandering tendency. In the past this river has caused serious flood problems in U.T. of Delhi by inundating large areas during flood season, and disturbing the normal life of people of Delhi. Prior to construction of Shahdara Marginal Bund and Left Marginal Bund in 1956, this river used to inundate the trans-Yamuna areas very often (nearly every year). In right side also before construction of Right Marginal Bund in 1977-78, most of the areas of Northern Delhi in Alipur block used to be inundated under deep waters. This has been the result of inadequacy of flood protection measures adopted in Delhi area in the past. Even in 1978 floods i.e. after the construction of Right Marginal Embankment upstream of Wazirabad upto Delhi-Haryana border the area of Alipur Block and even Model Town colony of Delhi city area was inundated in deep water due to a breach in this embankment. The main city areas of Delhi and New Delhi and Trans-Yamuna Area of Shahdara Block are although protected by embankments but there also remains a danger of breaches which may endanger the normal life of the residents in these areas. The floods of the years of 1924, 1947, 1955, 1956, 1967, 1971, 1975, 1976, 1978 are the main examples of the flooding in River Yamuna when the normal lives of the residents of Delhi were disrupted. Nearly every year there is flooding in River Yamuna, the intensity of which may be low, medium or high. The general water level of Yamuna at the Old Railway Bridge during dry season is found to be nearly 202.00 m (662 to 663 ft.) The low intensity floods are those which are below warning level i.e. 204.22m (670.00 ft.). During this type of flood, the water generally remains within its regime and no danger is created to life and property. However due care is to be taken by departmental officers to keep a watch on the future discharges, the information for which is to be collected from Tajewala headwork, the controlling point in the upstream. The floods attaining water levels above 204.22m and below 205.44 m (674.00) are called medium floods. In this type of flood, the water spreads out of the regime and touches the embankments constructed on both sides.

At this stage backflow starts in most of the drains out falling in Yamuna and hence their regulators have to be brought in operation. The patrolling for watch & ward of embankments is to be intensified and done during day and night. Proper watch is kept on seepage points already earmarked and proper check is kept for new seepage points also. When the level in river goes above 205.44m (674.00 ft.), the flood is termed as high flood.

Efforts made to mitigate and manage Floods

Master Plan Provisions

The sustainable development of Delhi, and a minimum quality and standard of living pertains to the availability of, and accessibility to basic infrastructure facilities viz. sewerage, drainage and solid waste management. The rapid and almost uncontrolled growth of population has put these facilities under severe pressure, and there are significant deficiencies. Even a cursory analysis of the present state of affairs would reveal that infrastructure problems could become a cause of crisis. Sewerage and solid waste management are State affairs. Thus critical need of advance action and arrangement is required for the adequate provision of physical infrastructure. For each component a broad augmentation plan to meet the projected requirement is essential. GNCTD has prepare a detailed and integrated plan in coordination with concerned authorities, NGOs and community groups.

The Master Plan envisages an integrated approach that packages mutually supportive infrastructure components i.e. water-sewerage- drainage for recycling, harvesting and optimal use of water; solid waste sewerage- power for power generation, etc. The projected requirement of sewerage and solid waste management is listed in Table 4.

Table 4: Projected Requirements for the Year 2021

	Availability	Requirement		
	2001	2001	Projected 2021	Additional 2001-2021
Sewerage (mgd)	512	877	920	408
Solid Waste (tones/day)	5543	7100	15750	10207

Sewerage

Sewerage is the core element of physical infrastructure that determines the environmental status of any city and requires minute planning, development and management. Development of appropriate sewerage system with efficient sewage treatment is vital to facilitate balanced and harmonized development. Augmentation of existing inadequate systems / treatment facilities as well as adoption of new

technologies of waste treatment demands special efforts. Further, it is pertinent to point-out that the existing capacity of sewerage system in Delhi is grossly inadequate, as only about 55% of the population is covered under organized sewerage system and about 15% under on-site sanitation systems. Rest of the population does not have proper access to sanitation facilities. The sewage treatment facility is also inadequate. The increasing pollution in the river Yamuna is a major indicator of lack of sewage treatment facilities.

Delhi has 17 STPs. In east Delhi, Delhi Jal Board has planned to augment the capacity of Sewage Treatment Plant by 45 MGD at Kondli and 25 MGD at Yamuna Vihar.

The existing Sewerage Conveyance System is a large network of branch peripheral and Trunk Sewers. There are 28 main Trunk Sewers with sizes ranging from 700mm dia. to 2400 mm dia. with a total length of about 130 kms. The balance length of sewage conveyance system comprises of peripheral sewers and internal sewers of small sizes and a total length of approximate 6000 kms. The Trunk Sewers have been laid over the years at different stages. Some of these are as old as 40-60 years old. The condition of Trunk Sewers specially the older ones have deteriorated as a result of silting and settlements.

It has been projected by DDA that for 2021 projected population of the city will be 230 Lacs and requirement of potable water shall be 805 MGD and non-potable water shall be 1035 MGD. Total sewage generated has been worked out to be 1012 MGD (DDA) which seems to be on the lower side keeping in view of the requirement of water worked out by DDA to the tune of 1840 MGD (805 MGD + 1035 MGD) whether it is potable or non-potable because both the water will generate the waste water.

Proposed Strategies For Different Aspects Of Sewerage System:

Drawing up a detailed blue print for augmenting sewerage system of Delhi, following key proposals are included.

1. Phasing of new work for total coverage of city with interim arrangements.
2. In the old city and other areas identified in some places, new sewerage lines can not be laid and the existing sewer lines have to be de-silted and rehabilitated.
3. Technological changes: The Delhi Jal Board has switched over to the Design Build & Operate (DBO) Contracts for setting up the STPs. In these cases, availability of land with the DJB is mentioned and the contractor has the option for offering the suitable technology, which can fulfill other specified parameters. Sewerage system in Delhi except NDMC and Cantonment area is being laid and maintained by Delhi Jal Board where as surface drains are being constructed and maintained

by General Wing, MCD, CSE (MCD), DDA, PWD, Irrigation and Flood Department, and Govt. of NCT of Delhi etc. Decentralized STPs with capacity of 3-5 MLD at the sub-city level, (10-15 Lacs population) can be set up keeping in view the techno economically feasibility and viability and availability of land by the DDA.

Drainage

To improve the drainage system of Delhi, effluent treatment plants should be provided at outfall of drains and aeration units at interceptions with advanced techniques for maintenance of drains. A time bound action program for augmentation and capacity revision of existing and new drains (due to increase in run off from urban extensions) is also vital. Check dams and depression/ lakes may be designed for increasing ground water table and as storm water holding points wherever needed. The design shall preserve the natural drainage pattern after the development of an area.

Drainage should be linked with the ecology and green networks, by adopting the concept of "bio-drainage". Regular desilting of drains and control of dumping of solid waste/ malba into the drains should be taken up. Other measures essential for proper drainage are the following:

1) Drainage to be integral part of Road Development Plans/ flyover/ Grade Separators.
2) GIS based drainage mapping and planning.
3) Sub-wells need to be developed under flyover for trapping rainwater. Pump houses in low-lying areas should be operational and given back-up power.
4) Remodeling of selected drains may also be required considering the upstream flow in the region.

Inquiry and fact finding report.

Delhi Jal Board proposed that the capacity of new urban drainage facilities should be designed to cope with the probable rainfall intensity of 5 to 10-year return period. The actual flow capacity of present facilities is, however, far smaller than the proposed design level and, inundation by storm rainfall occurs almost every year, at many parts of Delhi City. The main causes of deterioration in the present drainage system are enumerated as follow:

(1) The solid wastes and sediment have accumulated in the present drainage channels seriously affecting the smooth channel flow. Especially, soil accumulation in the Najafgarh drainage channels is posing serious problem.

(2) Since most of rain water in Delhi City is to be drained without pumping as mentioned above, it is virtually difficult to drain during the high water stage of Yamuna River.
(3) The development of drainage networks does not catch up with the rapid urbanization of Delhi City, and the present drainage channel networks are very insufficient in comparison to the extent of urbanization.

The government of Delhi as well as Delhi Jal Board has carried out cleaning work for the existing drainage channels, but such works have not been satisfactory due to lack of cleaning machinery. The solid wastes are being dumped into the channels in spite of the protective fence constructed around drainage channels. Although the development of various drainage facilities and the network of drainage channels are planned and partially implemented, the development could not cope with the rapid expansion of urbanization of Delhi City.

The local flooding of Delhi can be attributed to following factors:

i) Unlined open sewerage drains have resulted in a number of environmental problems. In the Najafgarh area, in the west and in some areas east of the Yamuna River, these drains have acted as influent seepage channels, and have polluted shallow aquifers through the infiltration of leachate. The drains were initially designed to transport excess storm water and sewerage flow. However, due to poor design and improper maintenance and unsuitable geomorphic conditions, these now form pools of stagnant water in north-west and northern parts of Delhi and are potential sources for groundwater pollution and sites for mosquito breeding. These drains join the Yamuna River at its lowest flow level, thus resulting in back-flow due to the rise in water level in the Yamuna River during monsoon showers. The Najafgarh drain passes through structurally weaker zones that act as channelways in unlined sections of the drain and directly pollute the aquifer system in its area of influence.
ii) The area to the east of Delhi Ridge is one of the heavily populated regions of Delhi and also includes 'Connaught Place', the hub of commercial activity. Unfortunately, it is also the site for heavy water impounding during storm showers causing disruption of traffic and normal life. This may be attributed to providing concrete surface over the entire available surface on the pretext of beautifying the area. The non-availability of sufficient recharge surface has compounded the problem of water impounding. These features were overlooked while developing the area.

iii) In some of the regions of Delhi, the old practice of human fecal disposal into soak-pits/septic tanks is being followed. The influent nature of open drains in these areas has changed the geo-hydrological scenario by lowering the water table and by development of artificial recharge mounds at several locations. This has led to surface inundation/ impoundment on one hand, and pollution of shallow aquifers on the other. The failure of septic tank-soakpit systems, particularly during monsoon, can largely be attributed to water table rise. These problems have arisen by ignoring basic geomorphic parameters like slope-morphometry, groundwater conditions, soil characteristics, subsurface lithology, etc.

iv) Three barrages have been constructed on the Yamuna River in the Delhi region, probably without much morphological considerations. These are either in non-water tight locations or adjoining weak zones. As a result, the Yamuna River has locally developed an influent behaviour in contrast to its general effluent nature, as is seen in Kalindi Kunj area of south of Delhi.

Structural measures for mitigation of Floods.

The National Capital Territory of Delhi has been experiencing floods, mainly from Sahibi Nadi (passing through Najafgarh Drain in Delhi) and Yamuna River. Local drainage system has also been found to be inadequate to meet the requirement whenever there is heavy rainfall in the catchment of these drains or during in flow of flood water from adjoining states in Yamuna river. Several flood mitigating measures like raising and strengthening of Yamuna marginal embankments, remodelling and lining of Najafgarh Drain for a discharge of 10,000 cusecs from Kakraula regulator to its outfall into river Yamuna, strengthening of Dhansa Bund, Construction of Supplementary drain to Najafgarh Drain to cater to excessive in-flow of flood discharge in the Najafgarah Drain have been taken up over the years so that there is no repetition of flood like the one experienced in Najafgarh drainage system in 1997 and in Yamuna river during the year 1997-98.

The marginal embankments along Yamuna River in Delhi can withstand only a discharge upto 2.5 lakh cusecs in the river against the requirement of 3.5 lakh cusescs for a flood frequency of one in hundred year as is suggested by Central Water Commission, Govt. of India. The work relating to construction of Supplementary drain to Najafgarh Drain was supposed to be completed in the 10th Five Year Plan. So far, 82% of the works on this project has been completed. In order to identify the weakness in the flood management system and to suggest remedial measures, the then Chief Minister, Govt. of Delhi constituted an 11 member committee in 1995 headed by Minister of Development

and Education Govt. of Delhi. The committee recommended the following short term and long term measures relating to the works of Irrigation & Flood Control Department.

Short Term Measures

I. Flood Proteaction/Embankment Works

1. Strengthening of right marginal embankment of Yamuna River from Palla to Jagatplur including jagatpur Bund.
2. Raising and strengthening of Yamuna Bazar Wall.
3. Construction of new walls from Metcalf house to Qudsia Ghat drain, Strengthening of river training works along left forward bund near Sonia Vihar
4. Improvement of Shahdara Marginal bund from Loni Road to G.T. Road
5. Improvement and strengthening of river training bund along left forward bund from old Railway bridge to Noida Bund
6. construction of Mundela bund along Delhi-Haryana Border near Mundela Khurd Village.

II. Elaborate desilting of Najafgarh Drain which is lifeline of present drainage system of Delhi by way of deployment of draglines, dredger and pumping of silt in Yamuna. The desilting work is shown in Figure 9.

Figure 9 Desilting work going on at Najafgarh Drain.

III. Making supplementary drain functional by way of excavation lining and improvement of drainage network in Najafgarh and Kanjhawala Block byremodeling various existing drains.

Long Term Measures

1. Flood Protection/Embankment works.
   i. Construction of new embankments from Palla to G.T.Road.
   ii. Raising of right side bund downstream of Okhla Barrage.
   iii. Strengthening of Eastern and Westren marginal bund of Yamuna River downstream of old Railway Bridge after removal of jhuggies.
   iv. Completion of Jahangirpuri Drain and completion of balance work of supplementary drain.
2. Improvement of major drains namely Bawana Escape drain, Palam drain, Pankha Road Drain, Mundella Drain, Karari Suleman Nagar Drain, etc.
3. Apart from remodeling, permanent pumping arrangement with captive power should be made at outfall of some of the drains of Alipur Block like Burari Drain, Burari Creek and in Shahdara Block for drainage of area located between Shahdara Marginal embankment and left Forward Bund in Sonia Vihar & Rajiv nagar, etc.
4. New Trunk Drains in Sarita Vihar and Dwarka residential area are required to be constructed.
5. Alternative ponds are to be developed in place of village ponds which are coming inside village boundary so that new ponds may moderate the flood discharge and help in recharge of ground water. In addition to this a number of water harvesting schemes have also been taken up by deepening of existing drains such as Bawana Escape drain, Najafgarh drain and Mungeshpur drain.

Non Structural Measures

To cope up with monsoon the Irrigation & Flood Control. Department (I&F) undertakes pre-monsoon anti water-logging & flood control measures every year, like desilting of all the Trunk Drains, restoration of anti erosion works like spurs, installation of control rooms and check post at various stations etc.

A **Flood Control Order**, giving contingencies plans to meet any serious floods in river Yamuna, is issued every year prior to onset of monsoon.

The Divisional Commissioner who is incharge of Flood Control and Relief Measures functions as Convenor Secretary of the Committee. He is assisted by Deputy Commissioner (East) in discharging his functions.

The Apex Committee under the chairmanship of Hon'ble Lieutenant Governor of Delhi meet on the last week of June every year to take the stock of preparations. The committee also meets during the monsoon depending on the exigencies assessed by the

Central Flood Control Room (vested with the responsibility). A brief account of the Central Flood Control Room and its functionality is described below.

A Central Flood Control Room is established to assist the Apex committee and functions round the clock in Room No. 13, A Block Office of the Deputy Commissioner (East) L.M. Bund, Shastri Nagar, Delhi w.e.f. 15th June to 15th Oct. every year or till monsoon withdraws, whichever is later. The S.D.M. Vivek Vihar is the Officer-in-charge of the Central Flood Control Room. Contact Telephone No. of this Control Room are 22444254 & 222444255.

The organizations/offices which depute a Liaison Officer (of a fairly senior level) to be available in this control Room in each shift are shown in Table 5 [8]:-

Table 5: Departments/organizations which Liaison with the Central Flood Control Room

• **MCD and NDMC**
• **Police**
• **Transport**
• **Health**
• **Home Guards & Civil Defence**
• **Food & Civil Supplies**
• **Flood Control Deptt.**
• **Delhi Development Authority**
• **Education Department**
• **P.W.D., Govt. of Delhi**
• **Delhi Vidyut Board**
• **Delhi Jal Board**

The deputed officers are present in the Flood Control Room after receipt of the first warning signal. Liaison Officers from Army/Air Force are also posted to the Central Flood Control Room when the Army /Air Force help is requisitioned by the Government of Delhi.

Following are the major functions of Central Flood Control Room:-

1. Receive flood warnings and other related information.
2. Submit Flood situation reports to the Chief Minister, Chief Secretary, Divisional Commissioner and Secretary (I&F) every evening, or as and when the circumstances may require.
3. Convey Flood situation reports and orders relating to flood control measures to the Sector Officers/Sector Control Rooms and the concerned Organisations/Departments of the Administration (through their Liaison Officers).
4. Issue necessary Flood warnings and directions for evacuation.
5. Arrange necessary food articles and relief supplies.
6. Maintain Liaison with Upper Yamuna Division of C.W.C., R.K. Puram, New Delhi and Army/Air Force, when ever required.
7. Maintain a fleet of vehicles needed for mobility of staff and the relief measures.

The control Room maintains a log-book of the messages received and dispatched by it. The directions received from the senior officers and transmitted are also recorded in the log-book under the initials of the Officer Incharge.

Flood Control Room of Irrigation & Flood Control Department is also set up at Inter State Bus Terminal, Kashmirigate in the office of the Chief Engineer (I&F), Govt. of Delhi. The Control Room remains in constant touch with wireless station at R.K. Puram-Central water Commission; Room No. 13 Office of the D.C. (East), L.M. Bund, Shastri Nagar. Delhi, and Coordinates the activities of the Flood Control Deptt.

In addition to the above, a number of regional posts and wireless stations of Flood Control Department are also set up at the important locations along River Yamuna, Najafgarh Drain, Supplementary Drain, Jahangir Puri Outfall Drain and Trunk Drain No. 1 to monitor the situation regarding floods or drainage congestion and handle any eventuality, effectively.

What went wrong?

Being the capital of India, the land–water system in this region has been under tremendous stress to accommodate a growing population and rapid urban industrialization of the region.

To accommodate heavy urbanization and population rise, the area has undergone tremendous environmental degradation resulting from a mismatch between adopted land use and drainage plan. The Delhi region is an example of regrettably ignored geomorphic inputs though essential in planning and urban development.

Delhi state has flat land, however there is a big depression in the southwest known as the Najafgarh jheel area, which receives the drainage from the adjoining states of Haryana and Rajasthan. The only outlet for these waters is the Yamuna.

The Sahib river that flows through Rajasthan and Haryana used to be absorbed in the sandy areas of Haryana and has no definite course downstream of Masani in Haryana. The waters of the Sahibi flow into Delhi through the Dhansa bund. The waters find a final outlet in to the Yamuna (throught eh Najafgarh nala) below wazirabad. There are barrages across the Yamuna in Delhi at Wazirabad, Indraprastha and Okhla. There are also some 18 drains that join the Yamuna in Delhi. Delhi's flooding is due to

- Spills from the Yamuna
- Drainage congestion due to intense rainfall
- Flooding from various drains of Haryana and the Sahibi nadi.

The Delhi region exhibits a very gentle southerly master slope as indicated by the southerly flow of the Yamuna River, except at some places where the slopes have been locally reversed. The general slope in the region east of the Yamuna River is westerly. Similarly, the change in slope direction is also noticed west of the Yamuna adjoining Okhla Barrage.The southerly and westerly flowing drainages change to the north easterly direction in the western part of area and join the north easterly flowing Najafgarh drain.

But what of course is surprising is the spread and damage experienced in the flood plain from a rather 'medium level' flood of 205.71 m as against all previous 'high' floods of 206 m and above. Clearly the observations made in the NEERI 2005 report that "the river has lost its carrying capacity and hence its remaining flood plains should not be compromised in any manner" are proving to be prophetic [12].

Strategies For The Future

Some of the popular non structural measures that can be adopted are discussed in brief here under:

Flood forecasting: Flood forecasting enables forewarning as to when the river is going to use its floodplains, to what extent and for how long. With reliable advance information/warning about impending floods, loss of human lives and moveable properties and human miseries can be reduced to a considerable extent. Flood forecasting and flood warning in India was commenced in a small way in the year 1958 with the establishment of a unit in the Central Water Commission (CWC), New Delhi, which is now responsible for issuing forecasts at 157 stations, of which 132 are for water level forecasting and 25 for inflow forecasting, used for optimum operation of certain major reservoirs. These stations are located in 11 flood prone states and two union-

territories. The accuracy of the forecast made by the Central Water Commission is increasing with time(CWC 1996) To improve the quality of forecasts further, the modernization of existing networks has been undertaken with international agencies, developed nations and national institutions such as UNDP, USAID, World Bank, IIT etc.

Dam break flood wave simulation: Worldwide many types of dam break models exist ranging from simple computations based on historical dam failure data that can be analyzed to complex models that require computer analysis. These models simulate the breach on the dam, and route the flood through the downstream terrain of the valley. Such information is very useful for planning purposes.

Flood inundation mapping: For flood mitigation measures and land use planning, flood inundation mapping is an important activity. Mathematical models are available that can predict the inundation knowing the forecasted flood. The Satellite remote sensing technology is also extremely useful in monitoring the dynamics of water spreads during the floods. Analysis of remotely sensed data gives a reasonable accurate assessment of water spread directly from the satellite images as a just processed information.

Flood plain zoning: A flood plain zoning means categorizing various zones based on administrative legislations for planning and development of the flood plains for various purposes such as agricultural activities, play fields, industrial areas and residential areas etc. Preparation of flood plain zoning maps takes into consideration the inputs from flood inundation, flood hazard and flood risk zone maps (NIH, 1988-89). The important aspect of zoning is that it can be used to regulate what uses the land can be put to and what kind of construction can be carried out on such areas. Zoning is also used to restrict riverine or coastal areas to particular uses, specify where the uses may be located and establish minimum elevation or flood proofing requirements for the uses.

However, many flood prone states in India have not adopted the recommendations regarding flood plain zoning and a continued persuasion for this purpose is essential.

Flood Insurance: In developed countries flood insurance scheme is found to be most effective method to regulate the land uses in the flood plains. Basically under this scheme, depending upon the nature and location of establishment in the flood plain, insurance premiums are charged. The insurance plan warrants a very high premium from the persons going for the costly establishments in the flood plain very close to the river banks. In India, at present, this scheme is not yet implemented.

Decision support system for real time flood warning and management: Decision support system for issuing the flood warning and managing the flood in real-time is an advance software which is capable of providing the information to the decision makers

for taking the necessary measures for managing the floods in real-time. Such system requires the spatial and temporal databases which include the basin characteristics, hydro- metreological variables, social and economical data etc. The databases are linked to the mathematical models developed for each component of DSS. The temporal information about the hydro-metreological variables are made available in the real time and the system provides the hydrographs of the river stages and corresponding discharges at required lead times. Such information is very much useful for the decision makers to take necessary actions for preparing the evacuation plan in real time during the flood.

For the development of such DSS in India, efforts are being made by some academic and research institutions on pilot scales. However, under the World Bank funded Hydrology Project II, which is under operation since2006, the development of DSS for real-time flood forecasting is one of the important proposed activities. The Hydrology Project II is being implemented by Ministry of Water Resources. In this project 13 States and 8 Central agencies are participating.

International cooperation: India is drained by a number of international rivers that originate beyond its borders and flow into India. India shares river systems with six neighbouring countries: namely Nepal, Bhutan, China, Myanmar, Bangladesh and Pakistan. Bilateral cooperation for various flood management measures is essential for India and the concerned country. Government of India has already taken initiatives in this regard. However, more active participation in the subject is required since river system do not understand the political boundaries and an integrated approach is the only way forward for effective management,

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Urban Flood: Case Study of Bhopal

Sanjeev Sachdeva

Urban Flood

Flooding in cities originates from high flows and may be due to sudden meteorological disturbances. Human activity influences the frequency and severity of floods, Physical damages and the consequences of pollution caused by urban flooding now days are challenges. Blocked drainage pattern and encroachments in low lying areas make urban flood more disastrous.

The destruction of the wetlands may also contribute to moderate floods. The only place where flood water can go is over its normal riverbanks and into low lying areas where it cause major damage. The purpose of planning strategies is to put forward a set of approaches for flood mitigation and management with due attention to Bhopal flood occurrence so that it would be helpful for other similar urban flood in the future.

Urban flood mitigation is a site-specific task, needs institutionalised approach through local governments under integrated concern of various concepts, measures, and techniques.

Profile Of The City

History

A cartographer's definition of Bhopal would read 23016'N and 77036'E with a maximum elevation of 550 meters above MSL spreading over seven hills. Historically, Bhopal was also the name of a Muslim princely state in central India. Bhopal, being capital of Madhya Pradesh, is the ideal base for discovering the rich historical and cultural legacy of the state. Close to the city and easily accessible by road and rail are incident sites of great dynasties, forts, monuments and cave sculptures, some of the finest examples of Indian art and architecture, chronicled in stone of the states unique heritage of fine antiques. It is the 11th century city Bhojpal, founded by Raja Bhoj, but the present city was established by an Afghan soldier, Dost Mohammed (1707-1740). His descendants build Bhopal into a

* Contributed as Bhopal city team under National Coordinated Project of NIDM (Gupta, Anil K. and P.G. Dhar Chakrabarti, *Disaster & Development*, 3 (1):1-14, 2009)

beautiful city. The 284.90 square kilometers of undulating landscape of Bhopal, well punctuated with water bodies lies sand-witched between the Malwa plateau on the north and the Vindhyas to its south. Bhopal, the City of Lakes has stuck to its name because of twin lakes, i.e. Upper and Lower lakes, which provide livelihood and add to scenic beauty. The wide stretched landscape gives this city a beautiful look, housing one of Asia's largest Mosques, Taj-ul-Masjid. The old monuments in the walled city symbolize the aristocratic part of Bhopal. The upper lake presents perfect setting for water freaks in the city.

Table 1: salient features of Bhopal at a glance

Latitude & Longitude	23°16'N and 77036'E
Planning area	601 sq.kms.
Municipal area	286 sq. km.
No. of Wards	66
Population (Census 2001)	1437354
Population density	663 persons per sq. km.
Literacy rate	79.8%
Work participation rate	10.3 %
No. of water bodies	18

Few state capitals in India have a history as eventful as Bhopal. The city of Bhopal has witnessed many changes since it was found by the Afghan soldier Dost Mohammed in the year 1708. The city has been through many phases, gentle as well as turbulent, prosperous as well as disastrous. Bhopal has been a city in which one finds traces of cultures as different as those of Buddhists, Hindus, Mughals and Afghans, all of which have been blended to perfection, providing Bhopal a distinct identity.

The genealogy of Bhopal can be tracked back a millennia, when it was Bhopal, the 11th century city of the legendary. Raja Bhoj , who has the credit for the construction of the Upper Lake. In the early eighteenth century, an Afghan soldier, Dost Mohammed Khan flees Delhi in the chaos following the death of the Mughal Emperor Aurengzeb in 1707. A beautiful Gond queen Rani Kamlabati seeks his successor after the murder of her consort. After the demise of the last Gond queen, Dost Mohammed Khan took over the reins of power and builds for himself a capital, some 11 kilometers from present day Bhopal, christening it Islamnagar, 1819 to 1926 was the era of the famed Begums. During the period of British hegemony over India, Bhopal was the second largest Muslim state. It was in this period that Bhopal witnessed the arrival of the first train and the formation of a modern municipal system. In 1949 it acceded to the Indian federation and on November 1, 1956 saw itself as the capital city of the newly carved state of Madhya Pradesh. Madhya Pradesh was originally the largest state in India until November 1, 2000 when the state of Chhattisgarh was carved out.

The city of lakes, Bhopal, is comprises of old Bhopal and new Bhopal. Both the new Bhopal and the old Bhopal have its own cultural and social importance. Being the capital

of Madhya Pradesh, it is indeed one of the important cities of the country. The origin of the city dates back to the eleventh century when Raja Bhoj founded the Bhojpal City. Bhopal has been ruled by several famous dynasties like the Mughals, Rajputs and the Afghans. The city is gifted with natural landscape and beautiful manmade structures like monuments, lakes, temples and mosques along with contemporary buildings like new Vidhan Bhavan, Judiciary complex etc . Bhopal, city combines scenic beauty, historicity and modern urban planning.

Bhopal today presents a multi-faceted profile, the old city with its marketplaces and fine old mosques and palaces still bears the aristocratic imprint of its former rulers, among them the succession of powerful Begums who ruled Bhopal from 1819 to 1926. Equally impressive is the new city with its verdant, exquisitely laid out parks and gardens, broad avenues and streamlined modern edifices. It is greener and cleaner than most cities in the country.

Topography

Bhopal has the undulating topography with hilly terrain that hops in quick drainage of surface water. In the rainy season water passes quickly through the drains and joins either in lakes or low-lying areas. The main rock types is the Deccan trap and basalt that holds soil up to few inches and allow growing vegetation. The eroded soil deposition at some of the places provides deep soil strata but below that the stony strata exist. However, maintaining of vegetal cover and holding of water in such condition is difficult as the fractured rocky strata do not hold water and thin layer of soil is not sufficient to hold the vegetal cover. The black cotton soil has less water holding capacity and upper layer of the soil quickly dried up that suppress the vegetation. In summer this problem intensified as most of the vegetation becomes dried and soil develops deep cracks due. Although surrounding area of the lake has sloppy land with ridges and furrows that drains storm water in the lake during rainy season.

Hydrology

Bhopal city is embedded with 18 water bodies of diverse sizes, located in and around the city. However, people are more familiar with only 5-6 water bodies because of their proximity to the city dwellers. Bhopal city receives water supply through lakes, especially Upper Lake and Kolar resevoir. Some irrigation reservoirs such as Hathaikhera, Kerwa and Laharpur, earlier located in the outskirts of city, have now become an integral part of the city due to expansion of city in all the directions. Following are the water bodies of Bhopal:

Table 2: Water bodies in and around Bhopal

Name of water body	Water Spread Area (in ha)	Present Use
Upper lake	3100	Water supply and recreation
Lower lake	129	Raw water supply and recreation
Shahpura Lake	96	Recreation
Motia Tank	1.89	Recreation
Siddiqui Hassan Tank	1.0	Recreation
Munshi Hussain Khan Tank	1.2	Recreation
Lendiya Pond	1.5	Recreation
Sarangpani Lake	4.2	Recreation
Kaliasote Reservoir	126	Irrigation
Laharpur Reservoir	350	Irrigation
Hataikheda Reservoir	113	Irrigation
Halali Reservoir	1625	Irrigation
Kerwa Reservoir	524	Irrigation
Kolar Reservoir	2850	Potable water supply & Irrigation
Char Imli Pond	1.2	Recreation
Ayodhya Nagar Abandon stone Quarry ponds (4 Nos.)	6.0	Recreation
Damkheda village pond	2.4	Potable water Recreation
Neelbad Abandon Stone Quarry Pond	4.5	Recreation

With rapid urbanization and consequent changes in the demographic structure especially during second half of last century all these water bodies have become subjected to various environmental problems. This resulted in deterioration of water quality through inflow of sewage, solid waste dumping, flourishing growth of invasive aquatic plants and, depletion of bio-diversity and other anthropogenic activities. The historical pond of Siddiqui Hussain has become abandoned due to siltation and excessive growth of terrestrial and aquatic plants. A part of this pond has been illegally refilled for construction of residential houses. There are four abandoned stone quarries

in the outskirts of the city near Neelbad and Ayodhya Nagar, which has been converted into small ponds. These ponds receive spring water and maintaining water level round the year. Damkheda village pond is being used by the villagers/residents for water supply, nistar and other secondary purposes besides recreational use:

Land Use

Provision of open spaces, green areas, green belts in master plans is important for city health. Landscape parks, plantation along roads, trees in public spaces maintain the micro climate within city. Native vegetation of Bhopal's uneven terrain includes trees, saplings, shrubs and also plants in wetlands help to make Bhopal green all over. Plantation helps to manage flooding and rain water retention. Vegetation of flood prone areas should be considered in flood management plans.

Distribution of land use in the Planning Area is determined by the Town and Country Planning Department, which formulates perspective development plans for the city, outlining issues, priorities and goals for managing urban growth. The first Bhopal Development Plan 1991 – BDP 1991 (addressing the period 1975 – 1991) - established broad guidelines for the city's development, which have been carried over —- with a few modifications —- into the next plan, BDP 2005. A feature of the first plan was it's attempt to integrate environmental issues in growth management. The Plan identified sensitive areas and adopted measures to ensure their protection. This approach is reflected, to a certain extent, in BDP 2005. BDP 2020 is currently under preparation.

The BDP lays down the basis / guidelines for development by making broad allocations of land for various sectors of growth —- residential, commercial, industrial etc. Based upon this, Bhopal Municipal Corporation may prepare Zonal Plans detailing provision of infrastructure, circulation …etc. The Urban Local Body, Bhopal Development Authority and the MP Housing Board are responsible for implementation of Development and Zonal Plans. In keeping with the physical characteristics outlined above, relatively low-rise development, interspersed with dense vegetation, has been promoted in the city so far. BDP 2005 anticipated the city to grow to a population of 25 lakh by the end of the perspective period. However, this projection has not been realized, and growth pressures have been less than anticipated —- due, in large part, to the bifurcation of the State, as well as the stabilization and consequent deceleration of industrial growth.

Current land use in the planning area, reflecting the city's unique locational context is presented in Map 3.4 (based on satellite imagery - May 2005 - 5.8 mts. resolution). The main features of land use in the Planning area are as under:

- Bhopal Municipal Area occupies about 286 sq. kms within the planning area extending over 601 sq. kms. The area lying outside the Municipal boundaries is largely rural, with 58 % (18,605 hac.) of the land area being agricultural and fallow land. Most of the cropped area seen is located to the north, east and south east within the planning boundary.
- Of this area, another 27% is barren and open land / quasi land. Scattered village settlements occupy barely 2.2 % of the land area.
- Only .85 % of the area (Planning Area excluding Municipal Area) lies under urban land uses —- ribbon development along the road leading to Vidisha to the North, and Kolar road to the south. The main thrust of development is along Kolar road, due to the availability of ground water in the area, as well as the proximity to Mandideep industrial area.
- Nearly 3,338 Hac. or 5.6 % of the land area falls under water bodies (rivers, lakes, ponds, reservoirs…etc) and marshy lands. (Based on pre-monsoon satellite imagery, May 2005)

Land use allocations, as per the BDP 1991, for the urbanized area of the Planning Area are given in the table below. Level of implementation, and allocations made in BDP 2005 are also given:

Table 3 : Land use Variation (1975 – 91) and Allocation – 2005

Land use	**Land allocation, BDP 1975 -1991 (Hac)**	**Habited area, 1994 (Hac)**	**% of Total Area**	**Level of Implementation (%)**	**Proposed Area, 2005 (Hac)**	**% of Total Area**
Residential	4050	3660	46.2	90.37	8190	46.48
Commercial	405	243	3	60.0	650	3.71
Industrial	1135	692	8.73	60.96	1389	7.93
Public and Semi-public	1215	912	11.5	75	1258	7.18
Public Utilities	280	200	2.5	71.42	488	2.78
Recreational	1415	1153	14.55	81.48	2925	16.71
Transportation	1620	1062	13.4	65.55	2600	14.85
Total	**10120.0**	**7922.0**			**17500**	**100.00**

Source: Bhopal Development Plan, 2005

With regards to the above land use allocation, recreational land uses account for nearly 15 % of habited area —- reflecting forest and forested slopes, water bodies…etc, which have been excluded for development, in the midst of the city. Public and semi-

public uses account for 11.5 % of habited area, indicating the administrative function of the city, as well as large cultural institutions located here.

Forest Cover of Bhopal

The planning area of Bhopal covers about 22% (601 sq.km.) of the total geographic area of the Bhopal district (2772 sq.km) and covers the entire Bhopal city and its immediate surroundings. The forest cover of Bhopal district accounts for 15.87% of total geographic area as against the forest cover of 8.2% within the planning area.

(sq.km.)

	Bhopal District Area	**Planning Area**
Total Geographic Area	2772	601
Green Cover	440	49.27
Percent	15.87	8.25

Source: Forest Survey of India

Vegetation Status (Planning Area)

Vegetation High Density	13%
Marshy Vegetation	4%
Vegetation Low Density	83%

Vegetation Type	**Area (sq.km.)**	**Percent**
Vegetation Low Density	40.78	82.76
Marshy Vegetation	6.28	12.75
Vegetation High Density	2.21	4.49

The planning area of Bhopal includes the following categories of green cover

1) Recorded Forest Area

The recorded forest area is defined as the "Geographic areas recorded as forests in Government records'. It is categorized into Reserved Forest and Protected Forests and falls under the State Forest Department.

There are four patches of Reserve Forest and Protected Forest (RF/PF) falling partially and/or wholly in the planning area and covers 0.35% (2.10 sq.km.) of the planning area. The RF/PF's are mostly located towards the fringes of planning area. The details of RF/PFs are as follows:

Forest	Area (sq.km.)
Rozibeh Protected Forest	0.08
Bhopal Reserve Forest	1.68
Raisen Reserve Forest	0.31
Bhopal Reserve Forest	0.03

2) Revenue Forest

In addition to the above, a number of revenue forests designated as Chote Bade Jhad Ka Jungle or Narangi Kshetra or simply defined as forest in the revenue records are found in the planning area. These areas are under the administrative jurisdiction of the District Collector. Since technically they cannot be used for any other purpose, they tend to be neglected, and consequently encroached. The total area of revenue forests within the municipal limits of Bhopal is about 1.95 % (11.75 sq.km.) of planning area.

3) Large scale plantation

The Capital Projects Administration through forestation and plantation activities has planted 516 identified centers with 12 lakh trees over last 20 years. The plantations are done on road sides, barren hills, identified parks etc. The plantations were also done over 986 ha of land under Bhoj wetland project. The CPA has proposals for greening more parts of the city and surrounding.

4) Recreational Parks in Bhopal

To cater to its population of more than 18 lakhs, Bhopal has a total of nearly 100 public parks varying in size, utilization, upkeep and maintaining agencies. In 1971 when the CPA became active, the Bhopal city was brought under heavy plantation through integration of several gardens into city developing plan. To name a few parks within the Bhopal city, the following gardens provide green lung to the fast growing city.

(i) Kamla,
(ii) Kilol,
(iii) Vardhman,
(iv) Firdaus,
(v) Nilam,
(vi) Mayur,
(vii) Chinar,
(viii) Ekant and
(ix) Rose Garden.

Ekant Park is spread over an area of 600 acres and is heavily planted to give it a forest impression. However, other parks still have scope of more woody plantations.

5) Protected Area-Van Vihar National Park

Van Vihar National Park is declared a national park in 1983, and covers an area of about 445 ha. It is located at the foot of Shyamla Hills, overlooking the Upper Lake. Van Vihar National Park, Bhopal is the only ex-situ conservation area that has been given provisional recognition by the Central Zoo Authority (CZA). Though, this area has been notified as a National Park in order to provide adequate legal protection, it is being managed as a modern zoological park. Here the captive wild animals have been kept in near natural habitat setup. Amongst the animals found here the tiger, white tiger, lion, bear, white bear, jackal, hyena, crocodile, alligator, turtle, peacock, drongo and python are preserved. The vegetation statistics derived from the satellite image interpretation of the planning area that about 66% area of VVNP is non vegetated and only 33% area falls under vegetal cover. This data attracts the urgent attention towards the condition of VVNP. The national park is highly degraded and needs afforestation activities to be undertaken.

The table showing green cover within planning area is given below.

Green Cover	Area (sq.km.)	Percent of Planning Area
Recorded Forest Area	2.10	0.35
Revenue Forest	11.75	1.95
Van Vihar National Park	4.45	0.74
Recreational Parks and other green areas	31.00	5.15

Forest Types of Bhopal

The forest, within and around Bhopal city is young and of southern tropical dry deciduous type. The forest found in Bhopal is mainly of three types:

- Deciduous teak forest
- Foot hill teak forest
- Mixed forest

The major species found in this region include the following

Table 4 : Major Tree Species found in the Planning Area

S.No.	Common name of tree spcies	Botanical Name
1.	Teak	Tectona grandis
2.	Salai	Boswellia serrata
3.	Jhingan	Lannea grandis
4.	Dhaman	Grewia tilliafolia
5.	Tendu	Diospyrus melanoxylon
6.	Bhirra	Chloroxylon switenia
7.	Palash	Butea monosperma
8.	Khair	Acacia catechu
9.	Reunja	Acacia leucophlea
10.	Raibans	Dandrocala musstrictus
11.	Katangibans	Bambusa arundinacia

Source – Bhopal Development Plan 2005

Forest Status & Restoration Activities in Progress

The RF/PF is located towards the periphery of planning area and comprises of low dense vegetation. These are under jurisdiction of State Forest Department and require attention towards afforestation and better management towards achieving the good density, healthy forests.

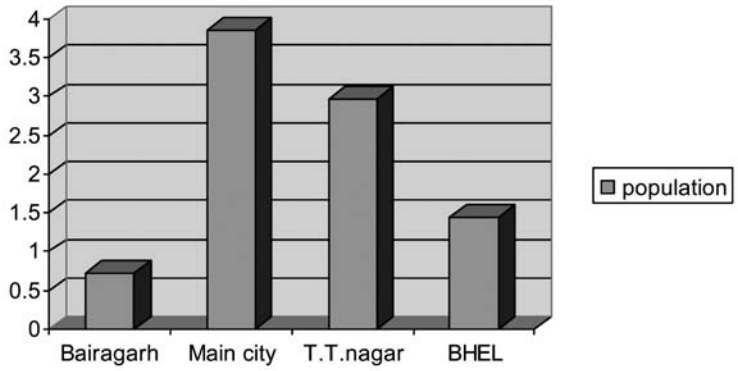
The current management practices of Van Vihar National Park are based on CZA guidelines. The area consists of degraded hillocks with intervening forest patches. The vegetation in the area is scanty with lot of denuded patches. The CPA carried out around 40 ha (8.76% area) of miscellaneous plantations. However, more afforestation needs to be done. The area is also infested with weeds such as lantana and parthenium. Weed eradication has been done only on small scale to make space for fodder growth. The fodder farm and grass plantation being done is not sufficient to meet the requirements of resident animals and needs to be scaled-up.

The existing revenue forests which are presently not under the ownership of the forest department needs protection. Such open and degraded forests, includes under stocked forests, blank and medium stocked forests which can become under stocked due to increase in biotic pressures which includes illicit felling, indiscriminate grazing etc.

Rainfall pattern

Bhopal has fewer records of flood, in the year 1973 and 2006 flood occurrences resulting in loss of life and property due to high rate of uncontrolled urbanization. The average yearly rainfall (2006) recorded in Bhopal district is 1154.2 mm. The Bhopal and its surroundings receive 900- 1200 mm average and normal precipitation. However, Bhopal has faced severe drought on account of less precipitation (Below 800mm) in the year 2000 - 01 and 02. The recharge of rain water for the Bhopal is very important because the water supply of the town depends on the rain water collected in lakes.

Demographic and settlement pattern: As per census 2001, the total population of Bhopal city is 1437354 distributed in 66 wards. As per Master plan 2005 (Census 1991), a study of existing residential built up areas has revealed that the net residential density varies between 113 persons per hect. to nearly 2286 persons per hect, The highest density would continue in central area. A gross density of nearly 305 persons per hectares has been adopted as a basis of assessment of requirement at sector level which will give approximately a net residential density of 610 persons per hect.



Areas wise Population density (as per master plan 2005, census 1991)

The city is bifurcated in two. Old Bhopal with its crowded markets, huge mosques and palaces represents the pristine glory of the bygone era. To the south beyond the lakes is New Bhopal with its broad avenues, high-rise offices and leafy residential areas presenting examples of the marvels of the modern era. The major location of work centres within the planning area included state capital complex on area hills and district administration centre and main business centres in the old city area. The BHEL, the public sector undertaking unit, trade and commerce establishments, in new market, M.P. Nagar, Old city and Bairagarh. First city survey was conducted in 1916

after the enactment of Municipal act. Upto 1956 the areas under Bhopal Municipal limit was very small, but after that few more surrounding villages were added to it. The total area under Bhopal municipal limit reached to 71.23 Sq. Kms by 1975. At present total area under Bhopal Municipal Corporation is 285 Sq. Kms. In 1983, Bhopal Municipal Council got the status of Municipal Corporation, with total 56 wards. Presently, city is demarcated into 66 municipal wards (14 zones). A total area of the present planning area as per Bhopal master plan 2005 is 601 Sq.kms. The limit of present planning area Bhopal covers, areas of Bhopal Municipal Corporation, Bairagarh, B.H.E.L, and 135 urban & rural villages .

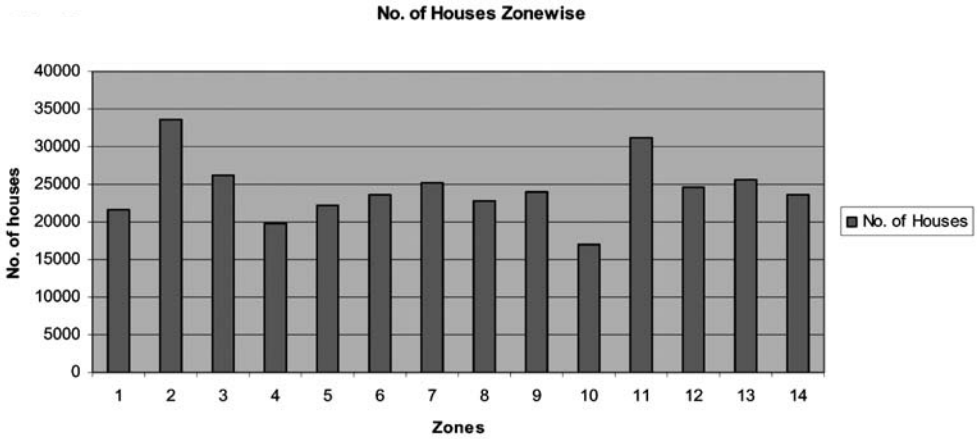


Figure 2: Zone-wise information of no. of houses

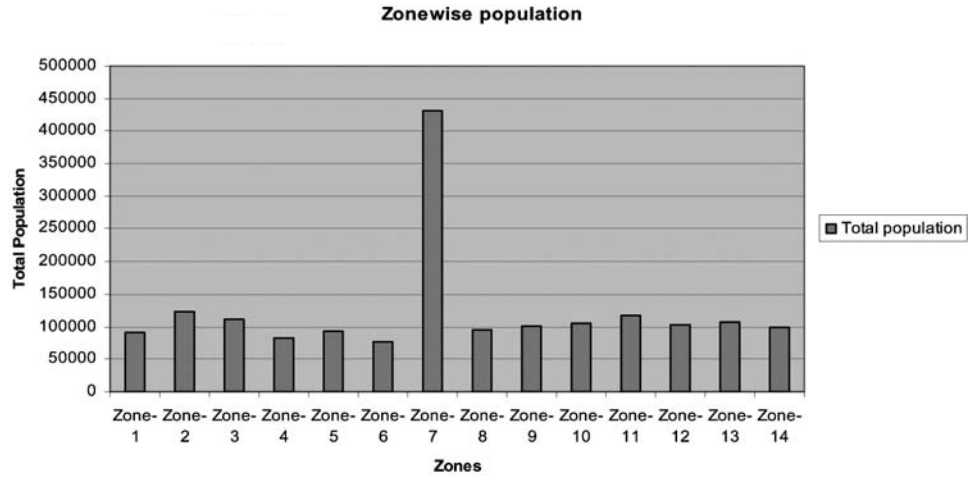


Figure 3: Population distribution among 14 zones (66 wards)

Slum Population

As per studies carried out by the Directorate of Town and Country planning nearly 1.7 lakh population is living in jhuggi-jhopdi and slum settlements, occupying strategic and precious locations and critical drainage basin. Certain areas which have become central to the city growth occupying high value land and are subjected to land use pressure due to adjacent commercial areas are proposed to be treated as regeneration areas, few areas are Juggis settlemst in BHEL and other areas, dilapidated areas within the walled city etc. Slum areas in vicinity to water bodies directly affect the water quality. Any discharge from the slum reaches into the water bodies including open defecation adopted by the slum dwellers deteriorating the water quality. Slum settlement in low lying areas choke the flow of rain water causing severe health problems and contaminates the ground water in long term. The residents of juggis are the service population for the work centres and residential areas, distributed in all use zones. Relocation of juggis in the use zones, except in catchment areas of lakes and recreational area and area of proposed roads, shall be permissible (as per Bhopal Master Plan 2005). Although the regulations are formulated but encroachments and avoidance of rules and regulations regarding city planning cause problems and lead to disputes which sometimes results in delays. Considerations to catchment areas in city planning are needed.

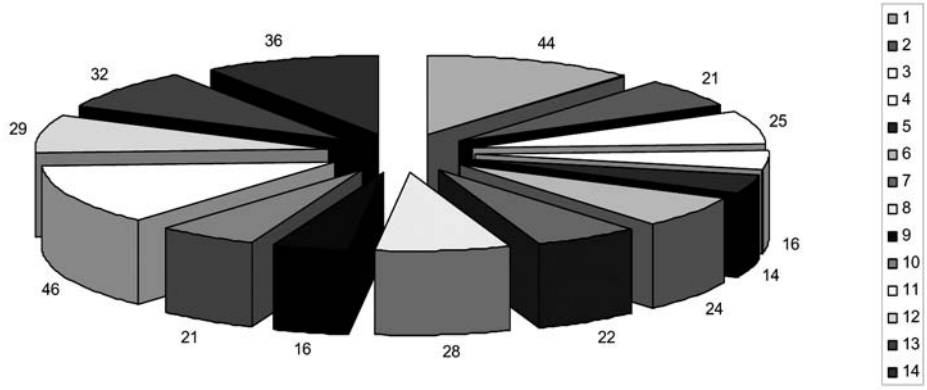


Figure 4: Distribution of Slums in 66 wards (14 zones)

Year	population	increment
1951	102333	
1961	222948	120615
1971	384859	161911
1981	671018	286159
1991	1063662	392644
2001	1437354	373692
	Total	1335021
	average	267004.2

Bhopal Development Plan was published in 1975 for the planning area of 241 sq.kms.The population of Bhopal in 1956 was 85,000 at the time of declaring it as a state capital was confined within the walled city as grown into a metropolis with around 14 lakhs inhabitant in 1993 (1991 census-10.63 lakhs). During the last four decades the urban population of Bhopal has increased at an average decade growth rate of over 70%. Thus the requirements of water, land, infrastructure, traffic and transportation etc. have to be planned for growing demand.

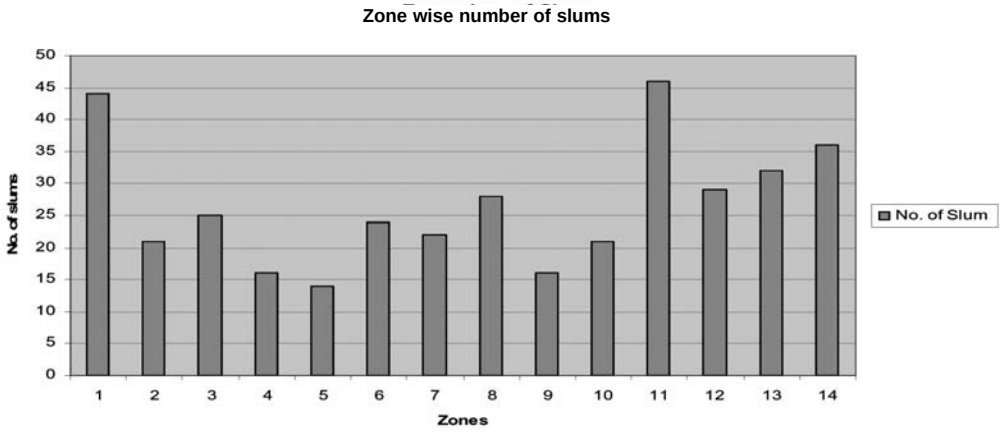


Figure 5: Zone wise number of slums

Socio-economic and cultural importance:

Occupational status, immigration, out migration, religious practices, food habits, climatic adaptation and historical background comprises of socio-economic and cultural statement of any settlement. Bhopal was once a predominantly Muslim city prior to independence, residing in the old city, is known for their sophistication. Bhopal is famous for every big festival such as Diwali, Holi, Eid etc. Bhopal has many monuments and 3 world heritage sites within and outside city limits respectively. The Taj-ul-Masajid is one of the largest mosques in Asia. Bharat Bhavan is the main cultural centre of the city and of the most important cultural centers of India. It has an art gallery, an open-air amphitheatre facing the Upper Lake, two other theatres and a tribal museum. Indira Gandhi Rashtriya Manav Sangrahalaya (National Museum of Man) showcases the various hutments that tribals of across India use for shelter. Bhopal being capital consisting of mixed culture and represent all districts of state.

In terms of economic scenario Bhopal has 10.3 % of work participation rate and the literacy rate is 79.8 %. According to 2001 Census, the city had 898 females per 1,000 males which is almost equal to the State average (Urban) of 912 females per 1,000 population, but it is lower than the other class I cities of the Region which have not been subjected to sudden migration and are socially more stabilized. Bhopal serves a large geographical area and it has extended not as a single city but as a discrete townships of the old city and its periphery, T.T Capital Township: Bairagarh (Location of army cantonment); Bharat Heavy Electrical Limited (BHEL). Township which was set up in the 1960's and was one of the largest public sector engineering companies in India, attracting additional investment and providing a large source of employment in Bhopal and other new areas. There are two industrial estates in close proximity: Mandideep with 32 large and 252 small and medium enterprises; and the newly developing Pilukhedi with 6 large and 3 small and medium sized enterprises. The service sector is becoming increasingly important provides the majority of employment in Bhopal. banks and insurance companies ,hotels and restaurants, hospitals, educational institution and shops. The sectors seems to be growing fast in Bhopal are housing, banking, insurance and education. The state economic development policy proposes Bhopal to be developed as a center for educational and institutional hub at all levels. Now a days Bhopal has become also attracting investors from all over the country.

City Infrastructure With Special References To Drainage

Roads: Bhopal is well connected with other parts of the country through roads, railways and air. Three National Highways are passing through the Bhopal and connecting to different parts of the state and country. As per Master plan 2005, the proposed roads (transportation) will facilitate the traffic in city. For proper traffic and transportation, the existing roads of city should make free from encroachments to serve the growing demand.

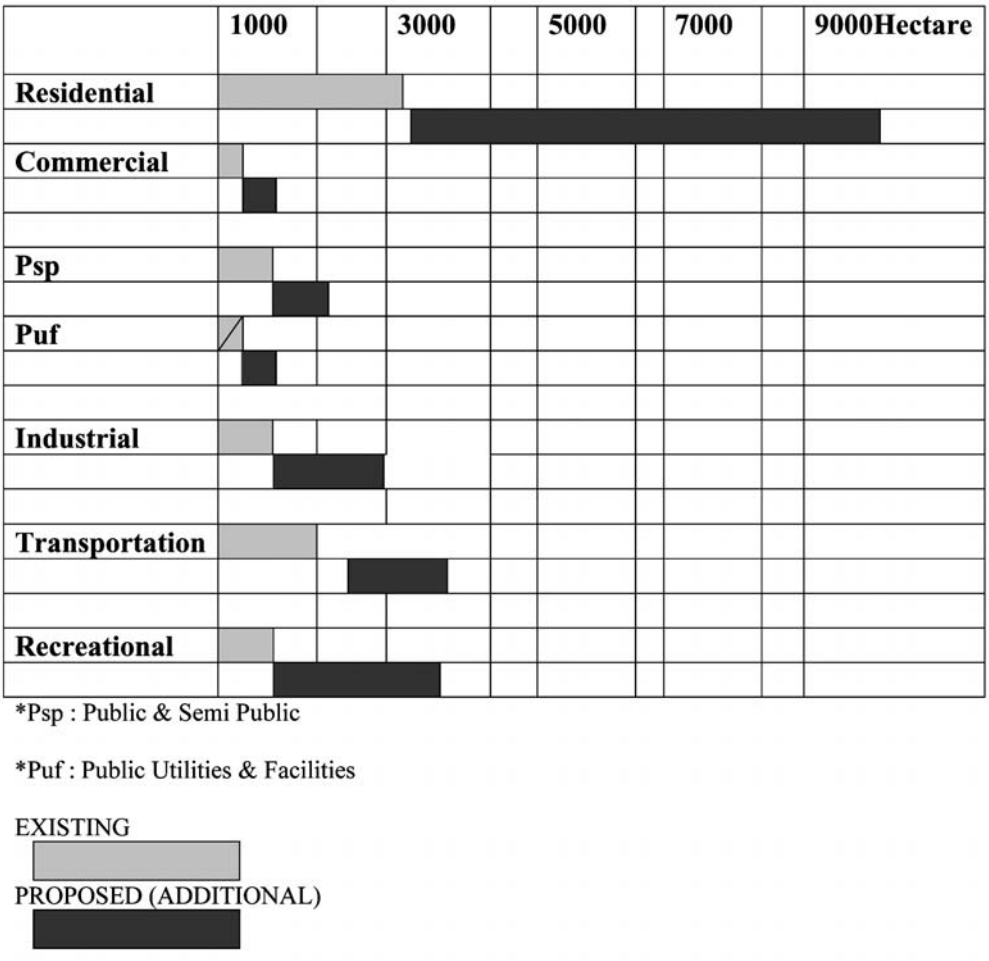


Figure 6: City Level Land use allocation (Bhopal Master Plan 2005)

Solid Waste Management

The Bhopal being an old and developing city, Bhopal Municipal Corporation (BMC) ensures regular cleanliness through collection and disposal of solid waste. Solid waste in different wards is collected using heavy vehicles with number of attendants. Presently in Bhopal open dumping at Bhanpura land fill site of is in practice. Other proposed landfills sites at Admapur Chhawni, raisen road and Fatehpur Dongra at Ratibarh are are identified per instructions of concerned agency.

Table 5: Municipal Solid waste status of Bhopal city

Quantity of waste generated within Municipal limits	500 MT/Day
Quantity of waste generated per capita	300-315 gm
Fleets of vehicles (BMC)	110 Nos.

Growing population contribute to augmentation of solid waste in city that need to manage timely with optimum use of resources under skilled manpower.

In Bhopal, BMC reports the total quantity of waste generated is about 511 MT/Day, in the municipal area of 285 Sq.km. The exact quantity and characteristic of waste produce in Bhopal is not known. Presently Bhanpur village trenching ground is used for dumping municipal waste. There are no proper arrangements for disposal so most of the refuse vehicles do not reach the disposal site. The average per capita generation of solid waste is 300-315gram.

The BMC reports that 60% of the city area is cleaned and swept daily, 30% twice per week and 10% fortnightly. The proposed site for disposal of solid waste are Aadampur chawni near Raisen road and Fatehpur dongra near Ratibad are 44 acres and 40 acres respectively.

Table-6 : Quantification of Solid Waste Generation

Table- Quantification of Solid Waste Generation from Various Sources			
Domestic	**511 MT/day**	**Vegetable & fruit market**	**25MT/day**
Commercial	38 MT/day	Construction	3 MT/day
Hotels & Restaurents	12 MT/day	Garden	0.75MT/day
Institutional	55 MT/day	Industrial Waste	105 MT/day
Bio-medical waste	3 MT/day	Slaughter	5 MT/day

Municipal Solid Wastes (Management & Handling) Rules, 2000 (MSW Rules) are applicable to every municipal authority responsible for collection, segregation, storage, transportation, processing and disposal of municipal solid.

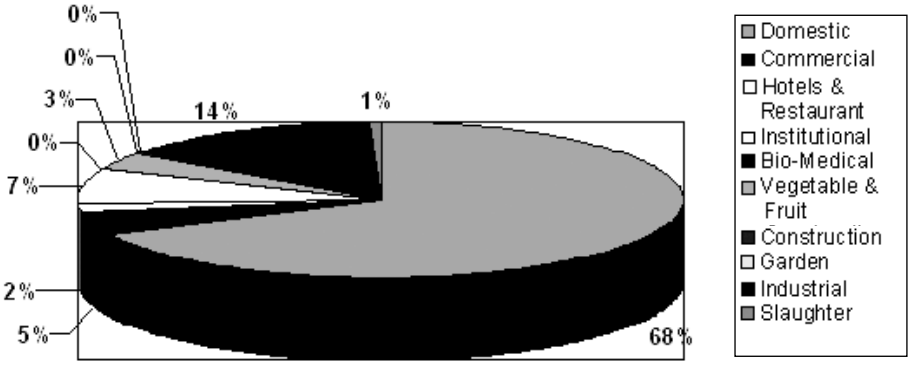


Figure 7: Quantification of solid waste generation from various sources: Bhopal city

Waste generation and Composition

Total quantity of waste generated in the country (based on weighment exercise by local bodies) is not reported. However, Ministry of Urban Development in its manual on solid waste management (year 2000) has estimated waste generation of 100,000 MT. CPCB with the assistance of NEERI has conducted survey of solid waste management in 59 cities (35 metro cities and 24 State capitals - 2004-05). The details Municipal Solid Waste in the Bhopal city are given in Annexure- 1

Table 7: Municipal Solid Waste characterization

Name of City	Compostables (%)	Recyclables (%)	C/N Ratio	HCV* (Kcal/Kg)	Moisture (%)
Bhopal	52.44	22.33	21.58	1421	43

Source: www. cpcb.nic.in

Drainage system

Bhopal is falling within the Betwa river Basin, which is a tributary of Yamuna River system..The part of Yamuna river basin is falling in the Madhya Pradesh Territory, but river Yamuna is flowing mainly in the State of Uttar Pradesh. The major tributaries of the Yamuna basin having catchment area in the Madhya Pradesh are as follows:

Fig - 8 Municipal Solid Waste Characterizations

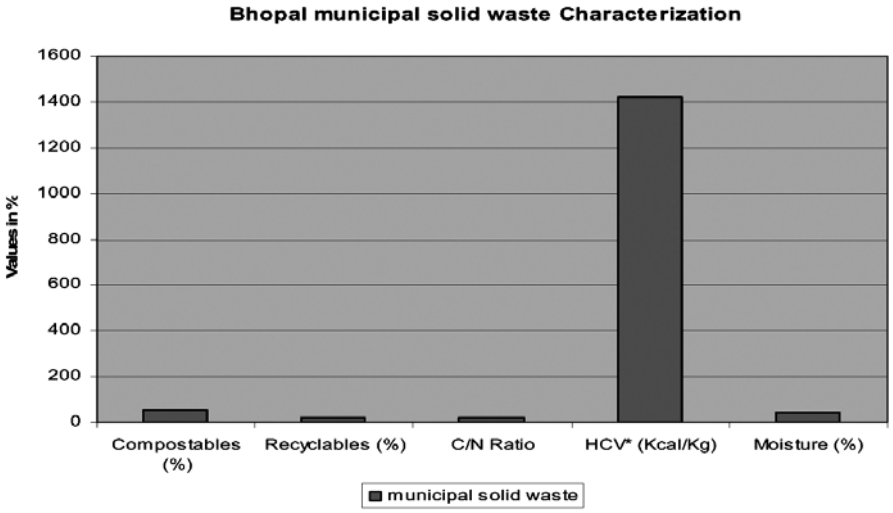


Fig-9 -Zone wise information of Waste Generation

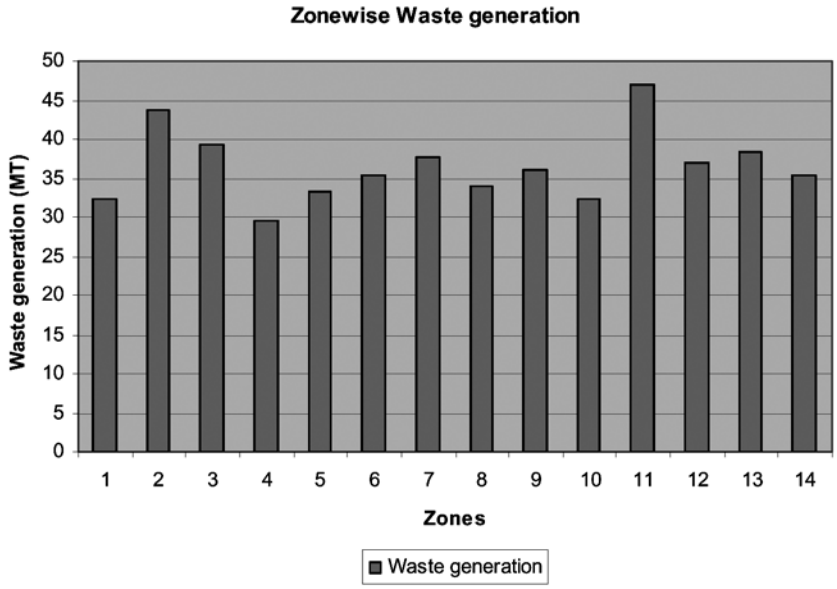


Table 8: Yamuna basin having catchment area in the Madhya Pradesh

Chambal River	Baghain River
Dhashan River	Paisuni River
Kunwari River	Sone River
Parvati River	Hasdeo River
Sevan River	Kali Sindh
Ken River	Tons River

Bhopal, the capital of Madhya Pradesh is one of the metropolitan town discharges water into the river Betwa through small tributaries.

Urban drainage systems are essential infrastructure that helps to reduce the risk of flooding and pollution of receiving water. To design such systems, understanding is required of the concepts, design inputs and processes associated with both the quantity and quality of rainfall runoff, in-sewer processes. In case of Bhopal flood conditions emerge due to the inadequate capacity of the receiving area to contain the high flow brought down from the upper catchments due to heavy rainfall. However, there is no major river flowing through the Bhopal area but there are several streams and streamlets draining the area. Out of these the Kolans River drains into the Upper Lake (Bara Talao) and Kaliasot, which is its outlet, later becomes the tributary of the river Betwa. Patra nallah constitute the outlet of the Lower Lake (Chhota Talao). In general, drainage pattern in the area is dendritic (tree like branching) in the plains and sub-parallel in the hill ranges, controlled by joints. At places, drainage is straight and is mostly controlled by joints. Trellis pattern of drainage is developed in respect of river Kolans. Close meandering pattern is seen in respect of Kaliasot, in its lower reaches due to low relief and thick alluvium. Typical dendritic type of drainage is developed in respect of river Kaliasot and Kerwa because of the homogeneity of the bedrock, which is Deccan Trap.

The detailed geomorphologic investigations of the area have revealed the presence of various landforms associated with Vindhyan Sandstone and Deccan Trap, viz;

- Structural landforms mostly comprise of cuesta, escarpments (fault scarp/fault line scarp) and hogbacks.
- Denudational landforms consisting of residual hills dissected plateaus, Mesas, buttes, pediments and pediplains.
- Depositional landforms such as in filled valleys, alluvial and colluvial fills.

Accumulation of water in low lying areas resulting from heavy rains with poor drainage because of hard surface rocks can cause flooding. Drainage pattern in urban area plays a crucial role to mitigate flood. Rain water harvesting can be adopted in Bhopal city to conserve and utilize rain water for further use.

The Upper Lake is the lifeline of Bhopal controlling risk of flood in the city and it is one of the major sources of potable water supply to the city. Bhopal City has experienced the flood situation in the year 2006 due to high intensity rainfall on 13th -14th August. On the contrary, in recent past, Bhopal city has faced the severe water crises in the year 2002 due to considerably less than average rainfall during 3 consecutive Year i.e. 2000, 2001 & 2002, when water level in Upper Lake reached to abnormally low water level even below dead storage level and water supply was affected badly in the city. After 6 years, the city again faced almost same situation in the Year 2008 due to less rainfall. The rainfall in Bhopal city was recorded 697.4 mm during June – September 2008, which is less than 456.8 mm from average rainfall of 1154.2 mm. Presently Bhopal city is facing water crises problem as water level has been drastically reduced in upper lake and reached to below dead storage level of 503.53 m. Bhopal Municipal Corporation is facing difficulty in taking desired quantity of water from upper lake for water supply to city. Presently, water supply is being provided every alternate day instead of daily supply. This situation is likely to be further degraded during coming summer season.

Existing Drainage Condition

A reconnaissance survey of major drains conducted by Tata Consultant Engineeing revealed that most of the drains have adequate capacity to carry storm water, except 3 (as mentioned below), which cause floods in some areas. However, many of the city drains, though theoretically have the capacity to carry storm water efficiently, do not do so and cause local flooding. The drains, and a description of the areas, which contribute to their flow, are given below.

Patra Nala receives flow from a number of small channels running across the city, like Gaji Khan Ka nallah, Piriya nallah, Kale Bhairon ka nallah, Maholi ka nallah, Mahamai Bagh ka nallah, Ashoka Garden nallah, Ghunsi nallah, etc. Patra nallah after collecting the Stormwater from these channels discharges to the Islamnagar River, 18 km from Bhopal, which finally flows into the Halali River. The entire network of Patra nallah is about 50 km. Patra Nala drains almost entire Old City

Saket Nagar Nala or Anna nagar nala receives flow from New market, Part of Malviya nagar, 74 banglows, Part of South T.T. Nagar, Tulsi nagar, shivaji nagar, Maharana Pratap

nagar, Rachna Nagar, Gautam Nagar, Kasturba nagar, Anna Nagar Habib Ganj Area, Saket nagar, Shakti Nagar, Narayan Nagar, Barkhera pathani, Arera colony, University, Katara hills, Vidya nagar, Baug Mungaliya etc are the major parts of the city. Saket Nagar Drain ultimately merges into Hathaikheda reservoir. The overflow of Hathaikheda reservoir outfalls into the Ajnal river, which ultimately joins Betwa River

Banganga Nala receives flow from Part of Shamla hills, part of Professor's colony and Civil Lines, Jawahar Chowk, 45 Banglows, North T.T.Nagar, and area behind Governor House. Banganga nala merges into Lower Lake (Chota Talab) over flow, of which outfalls into the Patra Nala, which ultimately joins Halali River. (Source: Report on SW Master Plan, TCE, Bhopal Office)

Water Supply Status

In Bhopal city the supply of water is through PHE department and Bhopal Municipal Corporation. There are 10 water treatment plants through which 65 MGD of treated water is supplied daily. The distribution of water from the upper lake, operation and maintenance of water treatment plant is under Bhopal municipal corporation whereas the operation and maintenance of Kolar water treatment plant is the responsibility of public health engineering dept. (PHED) of M.P. Apart from this water is also supplied to the bulk consumers from the upper lake such as B.H.E.L (Bharat Heavy Electrical Limited), M.E.S. (Military Engineering Services), Central railways etc.

Table 9: Water Source and supply

S. no.	Source of Water	Area Covered	No. of Treatment Plant	Daily Water Supply (MLD)
1.	Kolar Dam	1100 Quarters,Hoshangabad,Board Office,Maida Mills,Pulpukhta,Bharat talkies triangle,Bus stand Sindhi colony,Shanjanhabad,PGBT Tanks,Nupur KunjAnd Saket Nagar.	1	155.0
2.	Upper Lake	B.H.E.L,MilitaryEngineeringServices, Central Railway, Strawproducts, Janhagirabad,Shanjanhabad, Ibrahimpura,Baredi,Noor Mahal etc.	9	96
3.	Ground Water (Dug wells, tube wells, and hand pumps)		-	22.5

Storm Water

On an average the rainfall of Bhopal is of medium intensity. The natural drainage of storm water is comparatively good in New Bhopal one of the cause is sparsely populated settlements. In old Bhopal areas, the drainage is provided mainly by Patra nallah which receives flow from number of small channels running across the city, like Gaji Khan ka nallah, Ashoka Garden nallah, Jinsi nallah, Maholi ka nallah, Mahamai Bagh ka nallah, kale Bhairon ka nallah etc. Patra nallah after collecting the stormwater from these channels discharges it to the Islamnagar river near Bhopal, which finally flows in to the Halali river. Large portion of the city in the central region discharges storm runoff to Upper Lake and Lower lake. There are number of nallahs around the catchment area of Upper lake like Gora, Bhisan khedi, Lakhapur, Kolans inlet Iitkhedi, Bhesa khedi, Bairagarh, Khanugoan, Prempura and SAF nallah which drains strom water of city. Except rainy season these are remains dry.

Three major streams drain storm water from Bhopal. In the north-eastern side river Halali carries the drainage and on southeastern side River Kaliasote carries it, both these rivers drain to the river Betwa. In the southwestern side the drainage is carried by many small nallahs, which ultimately drain in to Kolar River. In New Bhopal area the storm water flows into Shahpura Lake.

Due to high intense rainfall in August 2006 Bhopal city got flooded in 24 hours and affect the public life and business seriously.

Water logging problems within the core urban areas and low lying area need to rectify, as the ultimate discharge of storm water and sewage of entire Bhopal is in the Betwa river either directly or indirectly.

Drains (including storm water) in the catchment area of Upper Lake and Lower Lake are as follows:

Table 10: List of Nallahs

S.no.	Name of Nalla	Peak flow lit/sec
	Upper Lake	
1.	Bairagarh bus stand nalla	15.370
2.	Lokhedi Nalla, Behind Petrol pump	23.380
3.	C.T.O nalla – Halalpur nalla	3.0
4.	Sehorenaka nalla	13.657
5.	Shiren Nalla	34.1
6.	Indra nagar nalla	6.940
7.	Sehore naka phatak road nalla,kumhar pura	13.518
8.	Khanugoan Nalla	2.314
9.	Karbala garam gaddha Nalla	9.26
10.	Kotra nalla, Behind pump house	36.00
11.	Nehru nagar nalla	3.00
12.	M.N. Borban nalla	3.00
13.	Kohefiza-housing board nalla	6.00
14.	Laukhedi Sainik colony Nalla	2.00
	Lower Lake	
15.	Badh ganga nalla	9.685
16.	Hindi Granth academy Nalla	16.133
17.	MVM Nalla	57.00
18.	Police line nalla, Near Khatlapur temple	1.426
19.	Jahangirabad Nalla, Near S.B.I Training centre	10.670
20.	Jahangirabad Nalla 1, (Near Extol)	57.00
21.	Jahangirabad Nalla 2 (Behind Vardan)	64.00
22.	Jahangirabad Nalla 3 (Near Saraswati school)	10.67
23.	Bhagwan Sahay Marg Nalla	0.37
24.	Bhagwan Sahay Marg Nalla (Near Masjid)	7.01
25.	Bhagwan pehchan Herbal	0.25
26.	Bhagwan Sahay road (Near Masjid)	10.67
27.	Bhagwan Sahay road (Near school)	8.45
28.	Nalla Batham Samaj Near Mandir	9.51
29.	Nalla near peepal wali galli	1.125
30.	Nalla Bhagwan Sahay Road Galli no 2	1.10

S.no.	Name of Nalla	Peak flow lit/sec
31.	Nalla Bhairao Mandir (Drain -1)	4.58
32.	Nalla Bhairao Mandir (Drain -2)	0.30
33.	Ginnauri Mandir Nalla	26.8
34.	Nalla near pump house,Ginnauri area	77.81
35.	Nalla near Health club, Ginnauri area	19.3
36.	Nalla near pani ki chhakki	134.63
37.	Dhobi ghat area,near sulabh complex	8.25
38.	Dhobi ghat area, Near vaishnav Bhawan	0.799
39.	Dhobi ghat area, near Neem Tree	2.70
40.	Dhobi ghat area, near House no 45	2.88
41.	Dhobi ghat area, near square appartment	0.800
42.	Dhobi ghat area, near M.L.B Hostel	3.250

Floods In The City

Cause

Bhopal experienced intense flooding during August 2006 due to heavy rainfall and poor storm water drainage system in the city. August 2006 received 775mm rainfall in Bhopal, crossing the previous record of the highest rain fall of 767mm in august 1973.

The seasonal total rainfall for Bhopal in 2006 went up to 1150.8mm as much as 408.9mm more than the normal expected till in this season. Along with heavy rainfall other factors that are responsible for the flood in the Bhopal were (a): lack of sewage network; (b): improper drainage system; (c): construction along drains and lake banks; (d): negligence in pre monsoon cleaning and maintenance of drains; (e): missing links of drainage system as per geography;(f): choking of road side and city drains; (e): dumping of solid waste into drains

The prime reason for the flooding in the city however is complete failure of storm water drainage system of the city during the rainfall. It has been observed that Nullahs in most flood affected areas were blocked by construction of houses. There are about 100 slums situated on 8 big Nullahs of the city. Due to continuous negligence over the years, several illegal structures have come up on Nullahs. The blockades in these nullahs have resulted in heavy water logging in the area.

The 286 sq. km. of undulating landscape of Bhopal, well punctuated with water bodies lies sandwiched between the Malwa Plateau on the north and the Vindhyas to its south.

Bhopal with an population of 14.37 lakhs came to a position of absolute standstill owing to the unprecedented rainfall of 225 mm during the 6 hours on 13th-14th August 2006. Although the average yearly rainfall recorded (2006) in Bhopal district is 1154.2 mm.

Among the various factors that influence the urban environment in city like Bhopal during sudden crises like flood are as follows:

- Encroachment in major portion of low lying areas and encroachment on either side of the nallas thereby reducing its cross section
- Illegal construction along main roads and extension in commercial areas.
- Densely inhabited areas without enough breathing space.
- Lack of civic sense and habits of littering cause chaos.
- Absence of buffer zone around water bodies.
- Lack of synchronization of services in old and new settlement.
- Dumping of solid waste in open grounds should be prohibited, for e.g. Govindpura Dusshera ground is adjacent to medical college, school, community centre having proper road connectivity to BHEL and new Bhopal but nearness to large patch of slums create nuisance due to unavoidable activities by them and open dumping of solid waste on ground which encourage street animals that leads to traffic disturbances. Such encroachments during rain accelerate water logging and gradually contaminate ground water that can be termed as delayed impacts of urban floods.
- Avoidance to manage demand and supply of land.
- Lack of awareness and absence of efforts to recharge rain water at household and community level.

In addition to the above mentioned, several drains in the city are constrained in the smooth evacuation of run-off waters due to the following reasons:

- Indiscriminate dumping of solid waste into the drains
- Large scale discharges of sewage, raw sewage or septic tanks overflows into the drains.
- Dumping of construction debris and waste in to the drains
- Silting of the drains
- Blocking of drains due to poles/pipes/stones/polythene being used to cross the drains.
- Lack of adequate maintenance of drains channel and associated structures (e.g. culverts etc.)

- Flat land adjacent to the nallas
- In adequate cross section resulting in lower flood carrying capacity Lower Manning's coefficient due to roughness of surface of drains which cause lower velocity and flow through drains, thus reducing carrying capacities of the drains.
- Inadequate slopes of the drains which impede velocity, thus the carrying capacities

The Bhopal city's drainage system was unable to cope on 14 August 2006 rain. The nullahs and open drains were clogged with garbage.

Constructions on the flood plains of the nullahs make worsen the problem. The high flow of rain water with garbage blocked the sewage system and all water lines were contaminated. Bhopal's Lower Lake, Shahpura Lake, and Motia Talab were all overflowing.

Bhopal face horrible due to scarcity of planned spaces and pressurised infrastructural services. High density in old Bhopal is much more vulnerable. In such areas due to lack or absence to zoning regulation, the number of causalities per disaster would be more than in less dense areas .Uneven topography with lush green areas of Bhopal is an important tool that should exploit to regulate urban development as per the extent of damage anticipated.

Table 11: Flood occurrences in Bhopal

Year of occurrence	Rainfall recorded	Affected areas
30 august 1973	284 mm in 24 hours	—
13th-14th august 2006	225 mm in 6 hours/ 321mm in 24 hours	— shown in map

Flood Affected Areas

The worst affected areas during the 2006 flood in Bhopal were the low lying ones and near the major Nullahs in the city, including Mahamai Ka Bagh; Garam Gaddha; Dwarka Nagar; Bagh Farhatafza; Kammo Ka Bagh; Shankar Nagar; Ram Nagar; Indira Nagar and Rajendra Nagar. Besides Gautam Nagar And DIG Bungalow Area Were Also In Inundated. Water Logging was also reported from Banganga; Tila Jamalpura; Atal Ayub Nagar; Chhola Kainshi Krishna Nagar; Khushipura; Chandbarh; New Kabadkhana.

Slum areas on Chhola Road, Tila Jamalpura, Banganga, Gandhi Nagar, Shahja, Ashoka Garden , Chandnbarh, Kainchy Chhola, Atal Ayub Nagar, Anna Nagar, Chhola, Dwarka Nagar, Aishbaug, Kammu Ka Baug, Bafnacolony, Kaji Camp , Tilla Jamal Pura, New Kabad Khana, Sindhi Colony, Kali Basti, Kapada Mill, Shankaracharya Nagar, Nav Bahar Colony, Nishat Pura, Noormahal, Payga, Harsh Vardhan Nagar , Rahul Nagar, Pampapur, Ambedkar Nagar Durga Nagar, Bheem Nagar and Slums of BHEL area faced flooding.. Besides, water also entered in the slums of Naya Basera, Panchsheel Nagar, Rajiv Nagar, Pumpapur, Gautam Nagar Slums, Arjun Nagar , Shanty Nagar, Bagh Mugalia and Bagh Sewania. Slum people, lower and middle income group people residing in low lying area are mostly affected due to flood in old city.

Some newly developed localities mainly those on sides of Ayodhya bypass such as Shivkalp, Abhinav Homes were inundated along with the localities of New Bhopal which included colonies at 6 no bus stop, 10 no bus stop, Manisha market, Shahpura and parts of Arera. Middle and high income group people residing in new Bhopal aera are also partially affected.

Intensity

About 60% of city areas in Bhopal were affected by the floods in between 14th till 20th August, 2006. Most of the low lying localities were inundated as water entered up to 2-3 feet in houses. Basements of various commercial building in Old Bhopal faced New Bhopal saw inundation.

The floods in 2006 have caused an estimated loss of more than Rs. 85 crores to public and private property in Bhopal district. According to reports received from government bodies including BMC and PWD the loss to public properties have been of about Rs 35 crores. Besides this, estimated loss to private properties has been of about Rs. 52 crores as reported by IL&FS Ecosmart in their report on Comprehensive Environmental Management Plan (September 2007)

Areas / Localities Prone to Flooding

As per discussions with the Municipal Engineering staff it was reported that Ambedkar nagar, part of Sudama nagar, Chawani area behind Bharat talkies, area behind Grand hotel and Capital hotel adjoining to the Patra Nallah, Gurbaksh Ki Tallaiyya, Ashoka garden, Old Subhash nagar, some parts of Chola Kainchy, Mahamai ka baug, Pushpa nagar, Nishatpura, which are areas falling along the Patra drain get flooded for about 8 to 10 days after heavy rains. The depth of the flood waters rises upto about 1 to 1.5 feet.

The areas adjoining the Upper Lake, falling in Bairagarh sub city is also remain under threat of flooding for almost the same or longer durations.

Some Emerging Issues

These can be summarized as follows:

- The indiscriminate dumping of raw\sewage and septic tank over flows into the city's natural drainage network is not only impeding their capacity to drain run-off waters efficiently, but more critically, is leading to the rapid degradation of the area's surface water bodies.
- This, in turn, is impacting the water quality in the region's rivers —- most notably the Betwa River, which receives discharges from a large part of the city
- Indiscriminate dumping of waste and construction debris in the Nallahs needs to be curtailed
- Maintenance of the drains —- including de-silting, improvement of drain geometrics (slope and cross section) needs to be improved —- is poor.

Loss of life and property

Based on survey, 26 people and 39 cattle were killed in flood affected areas of Bhopal and crop damage of 6660 hect.

Damage to about 8728 kuccha and pucca house covers 2566 juggis, 7261 kuccha house and 80 puuca houses. The total 72.52 crore rupees government's property loss and about 5502.66 lakhs rupees of private property loss was recorded in survey.

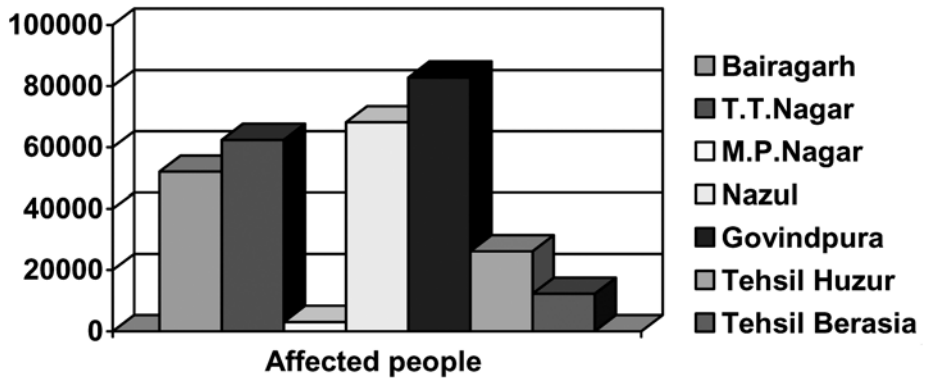


Figure 10: lood affectation

Table 12: Losses due to Flood

S.No.	affected area	affected population	loss of Human life	loss of Animals	damage to houses (Kuccha+Pucca) completely & temporally
1.	Bairagarh	52008	9	18	264
2.	T.T.nagar	62400	3	-	827
3.	M.P.nagar	3044	1	-	272
4.	Nazul	68164	5	-	440
5.	Govindpura	82772	2	2	443
6.	Tehsil Huzur	26164	5	17	4477
7.	Tehsil Bairasia	12240	1	2	2005
Total		306792	26	39+2	8728

- The above table is showing highest flood affectation to people in Govindpura which come under high risk zone (Refer map) might attribute to large encroachments in and around area.

Table-13- Flood affected area

Zone wise	No of wards	Land use in and around vicinity of wards				Flood affected wards (Low/medium/high)		
		resident-ial	commer-cial	indust-rial	slums/ encroac hments (in nos)	low zone	medium zone	high zone
1.	1, 2, 3, 4	✓	✓	—	4	1,2	4	3
2.	5, 6, 7, 8, 9, 10, 13	✓	✓	—	3	8	5	8
3.	11, 12, 14, 15, 16	✓	✓	—	4	15	11, 14	12, 16
4.	17, 18, 19, 20, 21, 22	✓	✓	—	4	—	17, 18, 19, 20, 21, 22	—
5.	23, 24, 25, 26, 27, 34	✓	✓	—	6	—	24, 25, 26	partially affected 27 and 34
6.	28, 29, 30, 31	✓	✓	—	5	—	28, 29	30, 28, 29
7.	35, 36, 37, 38, 43, 44	✓	✓	—	4	—	35, 36, 37, 38, 43	—
8.	45, 46, 47, 64	✓	✓	—	5	—	46	45, 47, 64
9.	32, 33, 48, 49, 50	✓	✓	—	10		32, 33, 48, 50	49
10.	54, 55, 56, 57, 58	✓	✓	—	4		54, 56, 57, 58	55
11.	59, 60, 61, 62, 63	✓	✓	✓	23	62, 63, 61	59, 61	60, 62, 63
12.	65, 66	✓	✓	—	8	66	65	—
13.	39, 40, 41, 42	✓	✓	—	—	39, 40	—	41, 42
14.	51, 52, 53	✓	✓	—	5		52, 53	51

Conclusion : high zone: low lying areas, surrounding area of lakes, medium zone: residential areas having Nallah/culvert in near vicinity, low zone: Agricultural land, sparsely populated settlements including remote areas of city
Source: As per assessment of Bhopal Municipal Corporation (For details refer Annexure1)

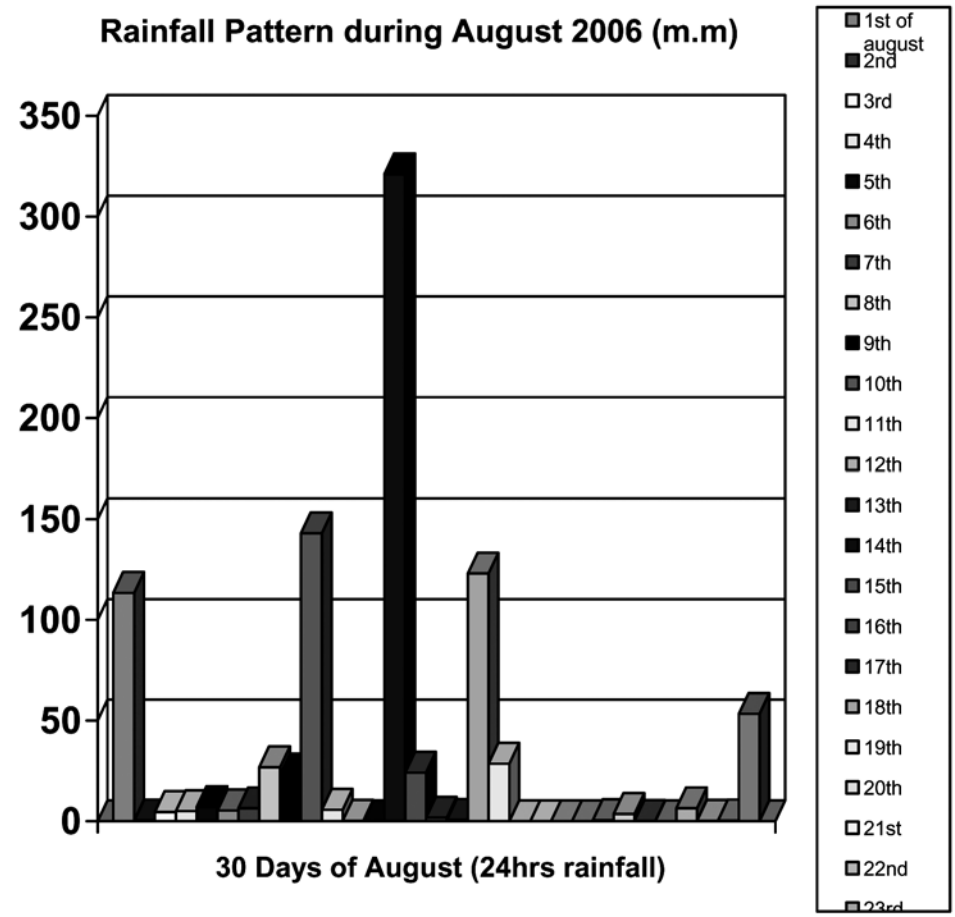


Figure 11: Bhopal city: Sudden flood due to excessive rainfall on 13th &14th of August 2006

Efforts Made To Mitigate And Manage The Floods

Master plan provisions in relation to city drainage/sewerage and carrying capacity management, extent of their implementation including regulatory or voluntary efforts.

As per Bhopal Master plan 2005, following are the specific recommendations for the protection and management of water bodies of Bhopal, which are also in support of flood mitigation.

The upper lake area is the life line of the residents of Bhopal, it needs due consideration in terms of its conservation and management. The catchment area, especially of the upper lake should be properly managed so that the pollution level is

controlled by appropriate measures such as preventive siltation dams and dense plantation along water channel and in the catchment area. The management of solid waste and its disposal should be carefully worked out so that it does not pollute the environment and the water bodies during heavy rains.

The practice of agriculture right along the fringe areas of water bodies in urban areas is proposed to be discouraged so that water is not polluted due to addition of chemical fertilizer pesticide and insecticide. In this way, we can say that such an approach can be adopted to prevent water contamination during flood in urban areas.

The old city of Bhopal is highly dense as compared to other parts of the city. Rigid nature of development plan under reduced legal control and monitoring allow people to modify the construction after permission of local authority. With high institutional changes in Bhopal, migrants and no. of trip to and from Bhopal have been increased drastically which in turn cause pressure on services designed to cater existing population. The built form has achieved higher FAR`s leads to higher occupancy in residential areas means lack of infrastructure and basic amenities.

Encroachments near to water bodies, low-lying areas, under bridges, open grounds encourage illegal activities including misuse of infrastructure and services and are prone to disasters like flood for e.g. wards no 59,60,61,62,63 are highly encroached and come under high risk zone as shown in map. slums-encroachment near to nallahs like ward no 45,47,64 also come under high risk zone and affect surrounding planned colonies like bank colony, Ankur complex etc. Low lying areas of Bhopal city should be properly planned to move people to safer side permanently to save from flash flood in next monsoon.

Various structural and non structural measures for mitigation of flood achievements and shortcomings.

Structural measures for mitigation of flood are land use regulation, building byelaws zoning regulations, widening of culverts, clearing of drains re-densification of affected areas by concerned agencies etc.

Non structural measures are flood prepared measures, local social structure strengthening, action plans for emergency response measures like communication and public information management, search and rescue co-ordination, shelter management, and distribution of food and supplies, contacting and requesting additional support, debris management, financial management, volunteers co-ordination and donations management in coordination with government, semi-government and concerned agencies with people's participation. During Bhopal 2006 flood State government started rescue and relief operation to minimize the ill effects of

urban flood as earlier as possible. Among 66 wards of Bhopal city the flood affected 60 wards consists of 207 basti, 55174 people. From the very first day (14-8-06) the rehabilitation drive started in 19 places and on 18th August, 2006 people get food packets from district administration. Nagar nigam also distribute food packets in flood affected areas. District Jail Incharge and District Home Guard also actively participated to rehabilitate and distribute food packets. Immediate surveys were conducted at household level with 194 survey teams.

Municipal Corporation provides drinking water and cleans the flooded Bhopal streets, public areas, drains etc. Restoration of all services started to normalize the life. Health department started providing services with team of 25 doctors from 15-08-06 in different affected areas of Bhopal; apart from this many private nursing homes also took part in rescue and rehabilitation drive. Badly affected areas like Pushpa Nagar, Ashbagh, Chandbad etc. got extra facilities from Narayan shri homeopathic medical college. Cross sectional area of current drains is not large enough to adequately drain rain-water runoff causing flooding conditions for homes and roads adjacent to drains/culverts. Bhopal Muncipal Corporation (BMC) had timely initiated measures of cleaning garbage and sediment deposition enters into drains. Nalla widening schemes are under implementation to cope with such flood in future. Some works of widening of the streams have already been done expeditiously after the floods, including removal of encroachments by the side of the streams and that in the channel, by the BMC. The removal of narrow necks i.e. narrow culverts in long reaches still need special attention.

What went wrong? Critical appraisal of city flood mitigation and management in terms of planning, resource, implementation, capacity, enforcement, participation.

From past 10years, rapid unplanned development and influx of population in Bhopal city results in pressure on infrastructure and services like water supply, sanitation, electricity, roads etc. Bhopal is an institutional and educational hub next to Indore in the state which compels city planners, policymakers, engineers to strengthen carrying capacity of Bhopal city in terms of infrastructure & services. Development process in Bhopal is catering existing population without much consideration to disaster mitigation planning that result in losses of recent flood.

The record breaking monsoon rains during August 2006 (the 13th /14th) in Bhopal, sparked off deadly floods in the city causing unprecedented loss of life and property & completely jeopardizing city's life and business (many markets were flooded). Following are some causes that directly or indirectly contribute to flood in Bhopal in 2006.

1. Investigations has reveal that the major cause of the flooding in the city was

"destruction of the natural drainage system of the area by human interventions for housing, business and other activities of development which imposed additional burden on part or whole of the 'natural land drainage system' and accelerated its deterioration.

2. Moreover the increasing growth of the city and its paved areas accelerated surface runoff after storms and requires channels (streams) through the city areas to be of greater discharge capacity than those hitherto served the preexisting.
3. Nallahs in city get flooded due to flash flood then immediately contaminated water spill out in houses that naturally cause damages. So encroachments near such structures should be strictly prohibited
4. Lack of consideration to natural drainage and culvert designing of areas near to lakes and water bodies.
5. Slums are located around nallah/ low lying areas/ along roads and open grounds are prone to flood like Govindpura area which has been recorded as highest number of flood affectation to human lives.
6. Extension of buildings without consideration of building byelaws directly and indirectly affects the total population of city in crises. Violation of zoning regulations in new townships and lack of synchronization with existing services.
7. Bhopal city have terrain in slopes. Rain water in such topography doesn't accumulate for recharging but directly enter in drains and nallas. Recharging of rain water can be done to mitigate the impacts of flood and can further helps to rectify water shortage problem in summer season.

These are the root causes of flooding in this city even though gifted with good natural drainage in account of hills and valleys and undulating terrain. High flows of rain water in undulating terrain carries all type of matter (plastic bags, garbage etc) and choke the nallah/culverts and gradually submerge the slums of low-lying areas due to persistent water logging. August (13-14th) 2006 has flooded Bhopal, killed human and animals destroy built up spaces, agriculture land and business. Impacts of urban floods may be attributed to lack of integrated city planning under rules and regulations. The urbanizing process usually changes the patterns of land use and aggravates urban flood problems. Bhopal city is no more exception.

Strategies for Future to Attain

1. **Assessment of the impact of flood on lives, property, agricultural land - productivity, health, social and economic life of city**

   Areas prone to frequent inundation by floods shall be identified in each ward and

clearly demarcated indicating the highest damages in last occurrence. It will help emergency response teams to identify areas to focus their operations during time of flooding.

2. **Flood Forecasting**

   For understanding of type and cause of flood, a detailed survey of the flood prone areas shall be undertaken to identify the causes of flooding, by a multi-disciplinary team, like irrigation, revenue, forest, agriculture, geological and civil engineering etc. Such site specific study can point out flood prone areas of undulating topography of Bhopal to help flood mitigation in future. Modernization of flood forecasting and warning services to the entire flood prone areas.

3. **Identification of possible preventive approach rather than curative**

   Infrastructure and services like water supply, sanitation, garbage collection and disposal, electricity, roads etc, should be managed effectively throughout the year to deal with crises like flood.

   A single unified command (Agency) with adequate powers to act without fear or favour but accountable to the public, be created for planning, implementing and maintaining the Remedial measures for defense against floods.

   City's surface drainage acts/regulations/rules may be strengthened if need be, for enabling the implementing agency to take appropriate action for the basic objective of "defense against flooding" e.g.-

- Removal of all obstructions coming in the water way (channel) of the stream e.g. long narrow culverts etc like habitation around culverts-slums.
- Deepening and or widening of the channel sections after detailed study and design w.r.t carrying capacity i.e. with proper base slopes and section.
- Creation of diversion channels /relief sewers etc. in special cases i.e. where disturbance is a real nuisance to the community.

4. **Construction of flood shelters and ensuring that public utility installations are above flood level height.**

   It may be noted that 'proper planning in detail by competent & experienced professional, of the remedial measures before implementation is of paramount importance for the success of the same. Hence the suggestions of citizens with expertise and well versed with the development of the city will be of great help. They can also be associated with monitoring of the same.

Besides the said streams the side drains of the city's streets, deserve equal attention & consideration. At present these are conspicuous by their absence or blocking of the existing ones by the inhabitants by covering with concrete. This causes storm run off

high velocity water to flow on the through the roads. This blocking of the road drainage arrangement is the root cause of destruction of most of the roads. In some small areas, citizens on their own have renovated the same and are maintaining it. Hence creation of side drains and keeping these always open, clean and operative needs to be made mandatory by act /regulation /rule.

In the new Bhopal many sewers (carrying foul domestic effluent), laid some years ago by the side of the existing streams have been completely destroyed by building activities. This creates long-lasting health hazard of Malaria, Chicken Gunia besides contamination of ground water. Hence all such destroyed and obsolete sewerage systems need immediate repair/renovation /augmentation to ensure that no sewage is allowed to flow in the streams in the interest of citizens health and sanitation of the area.

During the recent flood one of the main cause of the blockage of the drains/and even the main streams causing heading up of water and creating flood is the floating material plastic/polythene bags e.g. blocking of the main stream at the main culvert of the Hoshangabad road near the eastern end of the Mansarover Shopping Complex. The problem is known to all since long but time has come now to take it seriously and ban the use of plastic/polythene material completely.

The most important aspect is the maintenance of the streams during monsoon to keep these always clear, clean and with adequate slope to cater for minimum flows. This is indeed a difficult task .It needs constant attention, year in year out, by careful workmen specially detailed to keep them clear at all times of the day or night. Many times gratings are provided but these soon trash up or choke and overland flooding quickly results.

Hence it is suggested that a suitable division (Task Force) exclusively for this work, from the available workmen or by addition if needed, may be created for this important work.

For the finances for the above, many agencies besides the Central and State Govt. provide funds for such disaster relief projects, e.g. Central Govt's Disaster Relief Fund, ADB, Urban Renewal Project etc which can be tapped but constraint of funds should not come in the way of such relief works.

The Bhopal Master plan should elaborately take all the aspects of Municipal Solid Waste management including primary collection, storage, transfer, transport and disposal, as recommended by the concerned agency. Indicators to evaluate the improvements achieved by the civic authorities should be identified in consideration to urban flood. Public participation to strongly discourage littering and proper vigilance in all 66 wards of Bhopal city should be mandatory. It is essential that constant close watch on the programme of implementation of the remedial measures be kept, e.g. by a citizen's committee, to ensures its successful completion before the onset of the next monsoon.

Last but not the least; the key ingredient is the collaboration of state and local government with public participation to achieve common goals. Capacity building of the community, protection of the environment at city level, risk management, and implementation at grass root level should be foremost to protect the community. It may be noted that during the 1973 and 1974 flood all the intake works cum pump houses on the Upper Lake were submerged even though the intensity of rainfall was much less than that in 2006 where as the same did not happen in 2006 .This was due to widening of the narrow neck, of the spill channel of the Lake leading to the Bhadbhada spillway, by Bhoj Wet Land Project in 1998-99-a recommendation of the Naronha Committee 1975. In 1975 the Naronha Committee in its report recommended some measures for the safety of the lakes and the city from flooding. Some measures have been implemented. The remaining ones need serious thought now e.g. Spillway of the Lower Lake etc.

In order to ensure that occurrence of such floods in future are prevented, it is not only essential but an immediate vital necessity to ensure that appropriate and adequate remedial measures are planned implemented & maintained before the break of the next monsoon. The assistance of the geographical information system can be a boon in forecasting and spatial planning for preparation of flood mitigation.

The Upper Lake is the lifeline of Bhopal controlling flood in the city and it is one of the major sources of potable water supply to the city. Bhopal City has experienced the flood situation in the year 2006 due to high intensity rainfall in august. On the contrary, in recent past, Bhopal city has faced the severe water crises in the year 2002 due to considerably less than average rainfall during 3 consecutive Year i.e. 2000, 2001 & 2002, when water level in Upper Lake reached to abnormally low water level even below dead storage level and water supply was affected badly in the city. After 6 years, the city again faced almost same situation in the year 2008 due to less rainfall. The rainfall in Bhopal city was recorded 697.4 mm during June – September 2008, which is less than 402.6 mm from average rainfall of 1100 mm. Presently Bhopal city is again facing water crises problem as water level has been drastically reduced in upper lake and reached to below dead storage level of 503.53 m. Bhopal Municipal Corporation is facing difficulty in taking desired quantity of water from upper lake for water supply to city. Presently, water supply is being provided every alternate day instead of daily supply. This situation is likely to be further degraded during coming summer season.

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Annexure 1

Details of Flood Affected Municipal Wards

Zone No.	Ward No.	Rain Affected Ward during 13-14 Aug2006
1	1	Abbas Nagar(Gandhi Nagar),Gaund Basti,Peepalner vipege,Mahaveer Basti,Godarmau,Nayapura,Gandhi Nagar Nai Basti,Sector-3,Gandhi Nagar me Gaund Basti Nut Maratha and Omnagar Basti,Jain Nagar,Halalpur.
1	2	Kailash Nagar,Neelgiri Colony, B-Old &Sainik Colony,T-Ward & Area of near sant ji kutiya, Kumhar Mohalla, Bhainsakhedi, Purani Basti.
1	3	Baragarh Phatak Road Basti, Behind B-old 14 station Road,Near C.R.P.Bairak No. 35-36 Basti.
1	4	Rajendra Nagar,Sanjay Nagar,Rahul Nagar, F-ward Behind Jain MandirShops of Bus Stand ,Indira Nagar,Sehore Naka,
2	5	Koefiza, B.D.A.Housing Board Basti,Misha Apartment,Karbala Road, Khanu Gaon dairy Farm House, Shirin Basti,C-Sector B.D.A., A-12 Housing Board Colony,Kohefiza 40 Quarter ,B.D.A Colony Kohefiza, Ram Nagar Colony, Idgah Hills,fron of G.P.O. Shaheed Nagar,State Bank Chouraha. Sazia Nagar G
2	6	Sazia Nagar, Garam Gadha area,Near jhiran temple,Infront of old R.T.O, Dsjid Nagar.
2	7	Amar Basti,Chowki Emambada Road,Ward No-7.
2	8	Bagmunshi Hussain Khan to Safia College area,Sefia College Road,Bagmunshi Hussain Khan Basti,
2	9	Niyamatpura Road, Ram Nagar,Kindwai Road,Infront of Ram Nagar Colony,
2	10	Majdoor Nagar,Shahjahanabad,Sharma Colony, Majdoor Nagar Basti,
2	13	Bag Mukti Saheb, Shahjahanabad,Indira Nagar and Putli Nagar area,Indra Nagar Baltiwala area,Maszid Fakrauddin area, Bag Mukti Saheb,Old R.T.O,Kachi Maszid Kabitpura,Islami Gate,

Zone No.	Ward No.	Rain Affected Ward during 13-14 Aug2006
3	11	Ganesh Nagar,Paradise Colony,Sharda Nagar Gali No.-19,Near Kamal singh school Gali No-3,Sharda Nagar Balaji C.C. wali Gali,Harijan Basti,Nariyal Kheda, Latif Nagar ward office,Housing Board Colony Sanjay Nagar Jhiriya juggi asti,Nagar Nigam Colony Near Nallah,Sahrda Nagar Gali No-13, Sahrda Nagar Gali No-20,
3	12	Green Park Colony, Firdos nagar, Gautam Nagar,P.G.B.T college area,Rachana Colony,Shobha Ram Bawdiwala, area,Nai Basti Teelajamalpura,Fiza Colony,Krishna Colony,
3	14	Sahu Colony Near Pulia Teelajamalpura, Near Ram Mandir Rajan Bhwan ke Piche Nale ke pas,Kali Mandir area,Mandir se Rajjan Bhwan tak Maszid wali Gali, Sahu Mohalla, subedar Colony, Bholenath Colony, New Gandhi Nagar Main Road,Rajiv Nagar,Vasundhar Colony,Nai Basti,Near Babu bhaiKi Pulia,Congress Nagar and Hanuman Templ;e area,Congrss Nagar nalla area,Berasia Road area,Kali Mandir to rajann Bhwan area,Sahu Mohalla Gali wala Maszid area, Sanskrit Pathshala,Hatila Pahalwan Nalla area
3	15	Kainchi Chola main Road, First Railway Gate to Second Gate including Aadarsh Nagar and Ram Nagar Colony Kainchi Chola,Atal Ayub Nagar, New Aarif Nagar Juggi,Shakti Nagar,Union Carbide,J.P.Road,Nishatpura Juggi-Basti area,Purohit Nagar,Aadarsh Nagar New Block,
3	16	Satguru Complex area,Chinar Estate,Berasia Road, Moon complex to Firoz Gandhi Complex,J.P.Road area,Indra Sahayta Nagar,Choukse Nagri Replaced Basti and some nearest area of the Basti,Houses along with nalla in Rambha Nagar,Railway Patak to Petrol Pump,Rajgarhia juggi Basti,Lodhi Samaj,Machenic Market Rajgathia colony chhola Road Railway line ke beech,Lodhi samaj mandir area,
4	17	Ibrahimpura, New Kabad Khana,Isai Ganj, Pauliwal Hospital Gali,Ahele Adies Colony and Sai Colony Kawadkhana,Baphna Colony behind Sadbhawna trust,Bapna Colony,Sai Colony,Goyal Complex,Kaji Camp

Zone No.	Ward No.	Rain Affected Ward during 13-14 Aug2006
4	18	Chola Road Behind Mahakal Mandir,Dulichand ka Bag,Ekta Nagar,and Gali No.1,2,3,and 4,Subhash Nagar,Chhota Makbara Chhola Road,
4	19	Raja ji Kuna area and Bhopal Takies
4	20	Patel Nagar, Hamidia Road,
4	21	Kasera Gali,
4	22	Moti Maszid
5	23	-
5	24	Islampura Basti,Behind Nalla of Sheed School,
5	25	Bhairon Mandir Ke Kali Mandir,Basti Located near Lower lake,Bhagwan saheb Marg Bhoipura,Before Dange Khan Maszid,Near Mahavir Mandir,
5	26	Pratap Nagar,Hastnath Nagar,Behind Gandi Bhawan,
5	27	Banganga rotary club to Jharneswar complex Basti, Behind Barah Aftar Road No. 1 to 14 Basti situated behind it.
5	34	Roshanpura Jhuggi Basti,Shitla Nagar,
6	28	Shastri Nagar, Sarswati Nagarke E.W.S.Aawas, Dwarka Colony near P.N.T., Bheel Kheda Gaon,Gora Gaon,Bisen Khedi, Prempura Gaon,
6	29	Naya Basera,Rajeev Nagar, Ganga Nagar, Gomti Nagar, Sanjay Nagar, Near Gomti Colony,Rajeev Nagar Jhuggi Basti,
6	30	Ambedkar Nagar, Sudama Nagar, Ambedkar Nagar Janta Quarters, Lumbini parisar,Chitragupt Nagar,Aaradhan Nagar,Geetanjali Complex,Ambedkar Nagar Shades,Aradhana Nagar Jhuggi Basti, Near Hazela Hospital,
7	31	Suraj Nagar Jhuggi Basti, Pumpa Nagar Jhuggi Basti, Near Viswa Bharti School,Banjar Basti, Harshwardhan Nagar, Near Nalla, S-500 to 517 near Nehru Nagar, Near BM-56,Near Police Ground Nehru Nagar,Rahul Nagar, Bapu Nagar,
7	35	Near Pr,.School Bhim Nagar,Infront of Mazar,Bheem Nagar,
7	36	Kolipura,Lower part of Aahirpura,Vasundhara Colony,Bank Colony,New Colony near Nalla, Motia Talab, Yadav Aahir Mohalla, Motia Talab area,

Zone No.	Ward No.	Rain Affected Ward during 13-14 Aug2006
7	37	Janhagirabad Bazar(Durga Mandir to Gurudwara),Kumharpura Yadavpura,Khatlapura,Neelampark,Lilytakies Chouraha,
7	38	Yadgare Park,Kewd ka Park, Infront of Extol College,Maszid Gouhar Ali,Patra Road,Seelater House,Bharat Takies, Area of Maszid Ghughu,
7	43	Berkhedi Road,Extol College area,Rashidia School,
7	44	-
8	45	Near Nalla new Subhash nagar,Azad Nagar Jhuggi,Rajeev Nagar,Arjun Nagar,Nehru Nagar,Durga Mandir,Ravidas Colony
8	46	Arjun Nagar, Sudama Nagar, Padnabh Nagar,Moti Nagar, Ambedkar Colony Govind Garden, Acharya Narendra Deo
8	47	Ankur Complex Phase-1,2,3,4,and 5,Shanti Nagar Jhuggi,Shanker Nagar1,2 Meera Complex,Kargil Nagar,Ankir Complex,Mahila Market,
8	64	Jhuggi Nagar, Azad Nagar,Ashok Vihar,Bank Colony,Purana Ashoka Garden,Swdesh Nagar Road, B-Deshmesh Nagar,Samrat Colony,Old Ashoka Garden,Near Sonia Gandhi Nalla, Roopnagar Ghuggi Basti Govindpura near stop
9	32	Shiv Nagar,Chhki Chouraha,South T.T. Nagar, Jhuggi near Stop 1250 quarters, jhuggi behind 81 qurters,Front of Karamchari Bhawan,
9	33	Anjali Complex,Block No.01-19,Jhuggi near P.H.E Office,Jhuggi near 54 Block,Sunhari bag ki Jhuggi South T.T. Nagar,New 228 quarters,Sunhare bag 51,52,block,19,20 Block Chhaki houraha,12,14,15,16 and 17 Block Awas, Shiv Nagar, 81 and 82 Block ,Mayur Park,3 No. Stop Near Bagambri Mandir,
9	48	B.D.Colony,Shivaji Naar,Machana Colony,Sarita Complex,Jhuggi Basti near sidheswari mandir,Ashok nagar jhuggi Basti, 109 Block Shivaji Nagar, 113 Block Shivaji Nagar,
9	49	Madrasi Colony,Jai Bheem Nagar No.2,Near St. Mary School,Behind Milk Dairy area,Houses along with Harshwaqrdhan Pulia,Kumhar Mohalla and Surrounding area,1/1 to 2/1 line,Jhuggi situated Eight Shops of Indir Shoping Center,Houses and Jhuggi situated behind Budh Vihar,patrkar Colony,Area of Behind Panchmukhi Hanuman Mandir,B.D.A. Colony,Shiv Nagar,Durga Nagar,

Zone No.	Ward No.	Rain Affected Ward during 13-14 Aug2006
9	50	E-3, Arera Colony,Ward-50,E-3/1, E-3/2, E-3/3, E-3/28, E-3/122, E-3/23 A Arera Colony,Jhuggi Area Behind Bengali Colony,Kolar RoadShapura Turning infront of 56 Bhog,
10	54	Ravidas Nagar,Padamnabh Nagar,Near pulia area 4-B Saket Nagar,4-A Saket Nagar,2-A,2-B,2-C,Near Nirupama Aprtment,Near Dr, Shankerdyal Sharma playground,Madhav Bal(2-A), Infront of Alkapuri Jhuggi Basti,2-A,2-C,Saket Nagar Jhuggi,Jhuggi situated along Road connected to Shaki Nagar and Saket Nagar,Piplya Pende Khan,Bag-Mugalia16 acre,Near Umega Public High School,Area of Near Gyanouday School,Silai Center Near Bad tree,Near Vinova Bhave School,Kanjar Mohalla Berkheda Pathani,Shanti Nagar,Sabji Farm House,Atal Chouraha,Shyam Nagar Berkheda Pathani,
10	55	Vishwakarma Nagar,Gandhi Mohalla,
10	56	Gautam Nagar,Kailash Nagar,Rachana Nagar,Vikas Nagar,
10	57	Anna Nagar A-Sector behind Bus Stand,Anna Nagar Kaji Camp,Anna Nagar near Meet Market,
10	58	Jhuggi area of Govindpura,
11	59	Rajeev Nagar Jhuggi area,Pragati Nagar,
11	60	Shiv nagarJhuggi Basti,Soumya Vihar Phase-1,Radha Kunj,Vijay Lakshya Homes,Shiv Nagar Jhuggi Basti,Yathakunj Nagar Colony,Samaiya Nagar Phase-1,
11	61	100 Quarters Jhuggi BHEL area,Nehru Nagar Jhuggi Basti near Piplani Maszid,24 Quarters Jhuggi Kachhi Market,40 Quarters Jhuggi near Nalla,Jhuggi Near Nandi Foundation Road,Jhuggi near Piplani Thana,24 Quarters Jhuggi Bast Dhobi Ghat,B.H.E.L Jhuggi Basti area,Nagar Prashasan B.H.E.L Jhuggi area near Maszid,Jhuggi area near nandi Factory,
11	62	Sonagiri A-Sector Infront of ward office,Kalpana Nagar,Daulatpura,Kokta,Anand Nagar,Gupta Colony,ShivKalp Bypass,anand Nagar School Campus,Hathaikheda Dam,Daulatpura section-1Kokta,sonagiri-A,B,C,Sector,Rajat Nagar Colony,

Zone No.	Ward No.	Rain Affected Ward during 13-14 Aug2006
11	63	Aadarsh Nagarjhuggi,Nirza Nagar,D.K.Tawer,Near Mandir Indrapur A-sectorSatnami Nagar Jhuggi aea,J.K.Road,Sundar Nagar,laxmi Nagar,Rajat Nagar,Arjun Nagar,Jheel nagar,Harijan Basti Bypass Road,D.K.Tower Ground Floor J.K.Road,J.K.Egg Factory,Near Shradha Clinic Board,Aadarsh Nagar,Nirza Nagar Colony 135 Chakrawarty,Apsara Complex D.K.Tower Nalla,Indrapuri near A-116 and Mandir,Satnami Nagar Jhuggi basti,Sundar Nagar Colony s.T.D. 114 to 418,Laxmi Nagar ward 62/63,Arjun Nagar Jhuggi Basti,Seel Nagar Jhuggi Basti,Apsara Complex D.K.Tower Nalla,J.K.Road Jhuggi Basti near Mandir,Honda Factroy J.K.Road,Gautam Nagar Jhuggi Basti,Jheel Nagar Jhuggi Basti,Aydhya Bypass Road,Near Tanatan Dhaba,Ayodhya Bypass Road Indus Park Chhatrapati Nagr,Harijan Basti Narela Shankari, Near Indrapuri A/116,
12	65	Shiv Nagar Phase-1,2,3, Gupta Nagar,Sundar Nagar Kalyan Nagar,Shabri Nagar,Rasla khedi,Malikhedi,Semara,Kailash Nagar, Kolua Kala,Santosh gar,(Kolua), Damkheda, Maholi,Bhanpur East,Bhanpur Purva Gaon,Atal Nehru Nagar, Bihari Colony,Chandbadi,Preeti Nagar, Shivshakti gar,Khezra,kataria, Leeldhar,Prarthana Bhawan Road,
12	66	Krishak Nagar,Brij Colony,Rajeev Colony,Gwal Baba Jhuggi Basti Badbai,Krishna Nagar,Panchvati-1,Panchvati-2,Moti Nagar,Ekta Nagar,Palasi(Shanker Nagar) to Dhara Shiv Nagar,Kamla Nagar,Durga Nagar Jhuggi,Goya Colony,Shanti Prakash Nagar,Panna Nagar,Edevkati Nagar,Navibag, Panchvati Phase-3,Geeta Nagar,Nabab Colony,Annu Nagar Jhuggi,Jiya Colony,Vilal Colony,Sundar Nagar near Jhuggi,Prem Nagar, Shriram nagar,Nav-Jeevan Colony(near Chhaki,) Jhuggi behind Nav Jeevan Colony,Chhola mandir Jhuggi(near railway line),Gareeb Nagar Jhuggi, Gareeb Nagar (timber maket)Shanker Nagar Jhuggi Basti(Behind F.I.C.), Udiya Basti,Chandwadi,
13	39	Kapada Mill Ki Chal,Garam Gadha,Nav Vihar Colony and Shankaracharya Nagar,Sourabh Colony,Nehru Colony
13	40	Dwarka nagar,Krishna Nagar, Vijay Nagar Khushipura,Karariya, Hinotia Laxmipuri

Zone No.	Ward No.	Rain Affected Ward during 13-14 Aug2006
13	41	Mahamai Ka Bag, Kampu Ka Bag, Pushpa Nagar,Bag Umrao Dulha,Chankyapuri,Bismillah Colony
13	42	Antyodya Nagar,Bag Dilkusha,Ahmad Ali Ka Janta Quts,House Board, Sonia Gandhi Afkar Colony, Vikas Colony,Ashbag Janta Colony, Jagnath Colony, Sikandarpuri,Bag Farahafja,Gurunanakpura
14	51	Nupurkunj,E-7 near hanuman Mandir,E/7 near Vivek Apartment,Gautam Nagar,P.C. Nagar,E-6 behind Shrivastava Tent House,Near Durga Ji Chabutra, E-7 AjantaAlora,Abhimanyu Apartment
14	52	Shapur B-Sector,Near B-59, Near B-94,Infront of Ayushman Hospital, baba Nagar Panhuch Marg,Jhuggi Basti near Manish Market,
14	53	Ganesh Nagar,Near Durga Nagar Nalla,Near Bawadiyakala railway line,Near Bawadiyakala Nalla,Amrai Housing ward Jhuggi area,aadarsh Nagar,Ahmadpur,Nai Basti Jatkhedi,Misrod

Annexure 2

Table: Zone wise ward name, population, and main area under wards

Zone No.	Zone Name	Ward Name	Ward No	Population	Main Area under ward
1.	Sant Hirdaram nagar	Mahatma Gandhi	1	32459	Gonder mahu,baragarh kala,Khedi singar choli
		C.T.O	2	17691	Pipalner,M.E.S quater , bhasaddedi, vehata , gurunanak road , tagore road , Berik B-54 , North part Bada talab ka
		Hemu Colony	3	16519	Railway line,Jairam das Marg, Vivakanand Marg,Hospital Road
		Sadhu Vaswani	4	24085	B-52 , Berek,North Part of Vivaknand Marg,Bhasakhedi Gram ka East Sima,Riyan Manzil,Akhada Bag
2.				**90754**	
	Shahajanbad	Koh-E-Fiza	5	17127	Lalghati choraha,Sultania Road, J.A.D chouraha,Karbala & Rizwan Bag Road
		Nor-Mahal	6	16125	Pari Bazar Road,Ali Manzil, Pamisghat Fathgarh Road Modal School
		Malipura	7	13554	Noormahal Road, Bhagipura, Choki Emamwada gate, Pirgate, Moti Masque & Soltania road, Sadar Manzil
		Bag Munshi Hasan	8	16747	Vinava Bhave Road, Shahajanbad Bazar, Islami Gate, Barasia Road,Safia College Road, Bhopal Tikiz,Ali Manzil Road

Zone No.	Zone Name	Ward Name	Ward No	Population	Main Area under ward
		Idhal Hills	9	23326	T.B Hospital, Kumharpura, G.A.D Choraha, Paribazar Road, Barah Mahal, Sharma Colony, Infentry Gate, Gufa Mandir
		Babu Jagjivanram	10	15478	Regiment Gate, Mufti Bag, Model Ground, Kachi Mosque, Northan & Jamalpura, Golghar
		Shahajanbad	13	20741	Putlighar, V.T.O, Kaachi Mosque tak Mufti Bag Road
				123098	
3.	Bersiya Road	Gufa Mandir	11	36466	Naveri Gram, Barasia Road Crossing, T.B Hospital ,Slum's of Regiment Road
		Gitanjali	12	20721	Nariyal Kheda, P.G.B.T College Gotam Nagar
		Congress Nagar	14	18928	Barasia Road, B.T.O Road from Nala,Sindhi Colony ka Sangam
		Motilal Nehru	15	20979	Barasia Road Railway Crossing, Chola Road, Union Carbide Road
		J.PNagar	16	13695	Vapana Colony, J.P. Nagar, Barasia Road, Union Carbide Sangam
				110789	
4.	Mangalwara	Ibahimpura	17	22980	Ibahimganj, Hamidia Road, Classified Market
		Ram mandir	18	12326	Mangalwara Cent, Over Bridge, Malgogown Road , Railway Barier line, Mandir kamali, Sabzi Mandi
		Mangalwara	19	12116 12915	Gurubaksh Talaya Road, Jummerati Post Office , Chawani Road, Over Bridge Road, Agrawal Puri Bhander ki Oor

Zone No.	Zone Name	Ward Name	Ward No	Population	Main Area under ward
		LalBahadur Shastri	20	--	Mandir Kamali Road, Mangalwara, Moulana Azad Road, Itwara Bazar, Over Bridge, Sultania Road
		Mahavir Ward	21	12603	Ghoda Nakkas Road, Budwara, Charbatti, Fish Market, Jhumarati, Door to Loha Bazar, Ibrahimpura Chouraha tak
		Jain Mandir	22	10270	Near to Moti Mosque from Ibrahimpura chouraha, From Pir Bazar Chouraha to Dist Huzur Road, Moti Mosque Tak
				83210	
5.	Aachaya Nrendra Dev	Moti Mosque	23	17976	From Moti Mosque chouraha to Budwara char Batti Tak Purana Kila, Ginnori School, Diwan, Doulat Rai Road,Mata Mandir Se Retghat Gali No 2, Gulam Mehmud Road Hathikhana
		Islampura	24	12129	Moulana Azad Road, Sultania Hospital ke Chouraha, Tak, Moulana Azad Library, Fish Market Tak
		Bhaipura	25	16572	Budhara char Batti Chouraha ginnoriSchool, M.L.B college From Chotha Talab ka Kinara to Sultania Hospital Chouraha
		Vivakanand	27	20065	Old ShimalaRoad,Bhadbhada Road, Jahawar Chok P & T Shed, M.P.S.R.T.C Road

Zone No.	Zone Name	Ward Name	Ward No	Population	Main Area under ward
		Jawahar Nehru	34	12352	Banganga Road se tagore Bhawan 1250 Road, Malviya Nagar Road, Rajbhawan Ke Piche se Tagore Bhawan
				93527	
6.	Mata Mandir	Ambedkar	28	23395	Gram Bamhori, Gram Vilkheda, Vishan khedi, Gora gaon, Prempura, Bhadbhada Road, Kotra Sultanabad, Near of Lake Gram Kheda
		Tulsi Bai	-	25260	From Kotra Sultanabad main road to Panchsheel Nagar, MACT road, Main road no 3 to main road no 2
		Panchsheel Nagar	30	15264	Gram Amkheda, Bhadbhada main road no 3 to Kotra Sultanabad, Panchsheel road, Barkhedi Kala, Gram Barkhedi khurd, KhudaGanj,Chandanpura, from Singhpur to Chuna Bhatti
		Maulana Azad	31	35577	-
				76101	
7.	**Barkhedi**	Madan Mohan Malviya	35	25519	Lal Ghati Chouraha, Sultaniya road ,G.A.D. Chouraha, Karbala road and Rizvan bagh road.
		Ravindra Tegore	36	189696	Church road, Jinsi Cha. Vaitnary h. Nala. Su. road, South Area.
		JhangiraBad	37	171195	Bhrat Takies Chouraha, Filay Plaint, Jhangirabad, Malviya Nagar, MLA Rest House road gaun Park, Gali Bans Behda

Zone No.	Zone Name	Ward Name	Ward No	Population	Main Area under ward
		Barkhedi	38	16670	Pul Boghda Railway Crosing to Sultania road Chouraha, Barkhedi Chouki to Pulboghda, Coute Talab Kinare to Bharat Takies Choraha.
		Maharani Laxmi Bai	43	14471 13601	Pul Boghda Mata Mandir, PevdiPura Road Street, Chikload road, Barkhedi Chouraha to Aishbagh Railway Crosing.
		Jinsi	44	-	Church Road, Jinsi Chouraha, Bahoda Gali
				431152	
8.	**Pul Boghda**	Maidamill	45	17996	Jail Road, Jhada, Harjumal Jail Road to Maidamill road press Complex Railway Line, Subhash Nagar Colony to Raisen road , Momin Pura,, Poltriform road
		Netaji Subhash Chandra Bose	46	24810	Behind Maidamill, RailwayLine, Sufiya Road, Sufiya Market to BHEL, Subhash Nagar Railway Line to Raisen road
		Maharana Pratap	47	15365	Maidamill Road, Press Complex road to Railway Line, Habibganj road, MP Nagar, Zone-I & Zone II, Board Office Chouraha, Ankur Complex, Government Colony, Mahadev Apartment, MPSRTC to 7 No. stop
		Gurunank	64	37621	Ashoka Garden to Semrakala Bhargava Industries, Koluakala Gram, Khanti Road, Piliya Nala Road.
				95792	

Zone No.	Zone Name	Ward Name	Ward No	Population	Main Area under ward
9.	**Shivaji Nagar**	Shivaji	-	17507	Main road No.1, 1250 to 1464 road, Main road No.2 to 1464.
		T.T. Nagar	33	11220	Bhdbhada road, Main road 1 to 1250 road main road 2 to 1250 main road No. 2
		Ravi Shankar	48	19859	Subhash Nagar road, Main road 1 to 1464 main road, Arera Colony road, Char Imli, 5 No. stop, Government Colony.
		Dr. Rajendra Prasad	-	28692	Panchsheel Nagar, Kolar road, Chuna Bhatti, Janki Inclave, Shalimar Chinar street, Chppan Bhog.
		Indira Gandhi	-	24036	Arera Colony, E-1 to E-5 Subhash School, Bithan Market, Habibganj Thana, 10 No. Market, BJP Office
				101314	
10.	**BHEL**	Barkheda Pathani	54	32608	Saket Nagar Road, Barkheda, Sector-A, Bagh Mugalya, Jatkhedi, Laharpur, Amravad Khurd, Barkhedi Pathani, Pipalya Pende Khan
		Saket Shakti	55	14341	BHEL Hospital road, Dashara Ground road, Govindpura, berkheda A Sector road
		Kasturba	56	18751	Old Subhash Nagar Colony Road, to BHEL Hospital Govindpura, C-Sector road , Habibganj railway line and from Hospital road to Press Complex Road, Railway
		Anna Nagar	57	11821	I.T.I. shed, GovindPura, C-sector Road, Habibganj Sector, B-Road

Zone No.	Zone Name	Ward Name	Ward No	Population	Main Area under ward
		Barkheda, BHEL	58	13133	Audhyagik Khetra Road, Raisen Road, Barkheda Road, Factory Road, Piplani, A-Sector Road, Sufia Market Road, Raisen Road Sangam
		Govindpura	59	13935	Barkheda Pathani Road, Barkheda C-Sector Road, Saket Nagar Road, Barkheda C-Sector Road
				104589	
11.	Sonagiri	Piplani	60	23424	Htaikheda road, Khajuri Khurd Gram, Khajuri kala, Gram Raisen Road
		Goutam budha	61	12424	Piplani a Sector Road, Khajuri kala gram Raisen road, factory Road
		Sonagiri	62	**36779**	Narela Sankari Road, Hatai kheda, Kokta Gram, Sonagiri Road
		IndrapuriPathani	63	45235	Narela Sankari Road, from sangam to ITI road, Raisen road, audyogik road
				117862	
12.	**Bhanpur**	Rajiv	65	35922	Malikhedi, Chola road, khejra baramad gram chola, bhanpura sema, railwayline, and hinotea kachi semra kala, raslakhedi baipas road
		Navibag	66	67866	Badwae gram gondrimao, palasi malikhedi, chola road, second railway crossing to baipas road, chola road , from gram kaveri to railway
				103788	

Zone No.	Zone Name	Ward Name	Ward No	Population	Main Area under ward
13.	**Chand Bad**	Chand Bad	39	17916	Patranala, garamgadda road, kishor takiz, sikandari saray, from bharat takiz to patra railway godam road, Sikandari saray
		Kapda mill	40	25481	Kararea sagida gram seema power house road, textile mill, semrakala nale tak chola road and from kararea to power house railway line
		Bag umrao dulha	41	29302	Ashoka garden, nala purani khanti road, navbahar colony, patra nadi ki kalwart railway crossing tak pilia nala and khanti road sangam
		Eshbag	42	35091	Housing board ke sangam se pilia nale tak, barkhedi railway crossing se raisen road tak, eshbag road ka sangam
				107790	
10.	**12 No. Stop**	Shahpura	51	23621	E-7, Arera colony, 1100 Quaters, Prashasan Academy, E-6 K LIG, MIG, LIG, 11 no. stop, shalimar inclave
		Asha Niketan	52	42035	Shahpura A,B,C Sector, Ayushman, Siddi bhawan, Baba Nagar, Trilanga, Gulmohar, G-1, G-2, G-3, Danapani, Sabjifarm, Bharat nagar, Ishwar nagar, Saibaba nagar, Shahpura gram, Starling Inclave
		Barkatullah	53	33737	Shakti nagar, BHEL road, Saket nagar, Jatkhedi, Nisrod road, babdiya kala, vidhya nagar indus garden, RRL, Habibganj railway crossing se shakti nagar road.
				99393	

Source: http://www.bhopalmunicipal.com

The above table reveals that zone 1, 11, 14 are having highest number of slums which cover Ward no.60, 61,62, 51, 52, 53.
Among 14 zones, zone 7 (Barkhedi) is having maximum population. Ward no. 35, 36, 37, 38, 43, 44 Madan Mohan Malviya ,Ravindra Tegore, JhangiraBad , Barkhedi , Maharani Laxmi Bai , Jinsi covered under zone 7.

Annexure 3

Municipal solid waste: Ward wise information of waste generation

Zone No.	Ward No.	Name of the ward	No. of Household	Waste generation MT
1	1	Mahatma Gandhi	7701	11.55
	2	CTO	4197	6.29
	3	Hemu Kalani	3919	5.87
	4	Sadhu Waswani	5714	8.57
		Total	21531	32.28
2	5	Koh-e-Fiza	4063	6.09
	6	Noor Mahal	8226	5.73
	7	Malipura	3216	4.82
	8	Bagh Munis Husain	3973	5.95
	9	Idgah Hills	5534	8.30
	10	Babu Jagjiwan	3672	5.50
	13	Shajanabad	4921	7.38
		Total	33605	43.77
3	11	Gufa Mandir	8651	12.97
	12	Geetanjali	4916	7.37
	14	Congress Nagar	4491	6.73
	15	Motilal Nehru	4977	7.46
	16	J P Nagar	3249	4.87
		Total	26284	39.4
4	17	Ibrahim Ganj	5452	8.17
	18	Ram Mandir	2924	4.38
	19	Mangalwara	2874	4.31
	20	Lal Bahadur Shastri	3064	4.59
	21	Mahaveer	2990	4.48
	22	Jain Mandir	2436	3.65
		Total	19740	29.58
5	23	Moti Masjid	4265	6.39
	24	Islampura	2878	4.31
	25	Bhoipura	3932	5.89
	26	Rani Kamlawati	3424	5.13
	27	Vivekanand	4760	7.14
	34	Jawaharlal Nehru	2930	4.36

		Total	22189	33.22	
6	28	Ambedkar	5550	8.32	
	29	Tulsi	5993	8.98	
	30	Panchsheel	3621	5.43	
	31	Maulana Azad	8440	12.66	
		Total	23604	35.39	
7	35	Pandit madan Mohan Malviya		6054	9.08
	36	Ravindranath Tagore		4388	6.58
	37	Jahangirabad	4079	6.11	
	38	Barkhedi	3955	5.93	
	43	Maharani Laxmi Bai		3433	5.14
	44	Jinsi	3227	4.84	
		Total	25136	37.68	
8	45	Maida Mill	4269	6.40	
	46	NetajiSubhashChandra		5886	8.82
	47	Maharana Pratap	3645	5.46	
	64	Gurunanak	8975	13.38	
		Total	22775	34.06	
9	32	Shivaji Nagar	4153	6.23	
	33	T T Nagar	2662	3.99	
	48	Ravi Shankar	4711	7.06	
	49	Dr. Rajendra Prasad	6807	10.21	
	50	Indira Gandhi	5702	8.55	
		Total	24035	36.04	
10	54	Barkhera Pathani	-	11.60	
	55	Saket Nagar	7736	5.10	
	56	Kasturba	3402	6.67	
	57	Anna Nagar	2804	4.20	
	58	Barkhera BHEL	3116	4.67	
		Total	17058	32.24	
11	59	Govindpura	3306	4.95	
	60	Piplani	5557	8.33	
	61	Gautam Nagar	2947	4.42	
	62	Sonagiri	8726	13.08	
	63	Indrapuri	10732	16.09	
		Total	31268	46.87	

12	65	Rajeev	8522	12.78
	66	Nabi bagh	16101	24.15
		Total	24623	36.93
13	39	Chand barh	4250	6.37
	40	Kapra Mill	6045	9.06
	41	Bagh Umrao Dulah	6952	10.42
	42	Aishbagh	8325	12.48
		Total	25572	38.33
14	51	Shahpura	5604	8.40
	52	Asha Niketan	9972	14.95
	53	Barkatulah	8004	12.00
		Total	23580	35.35
		Total	341000	511.17

BMC has 110 fleets of vehicles for collecting and transporting waste from collection points to the disposal site. Each of the vehicles is allotted specific area for collection and transportation to Bhanpur site. There are about 1327 nos. of intermediate collection points in the city and 366 nos. of wheel barrow are provided by BMC.

Urban Floods: Case Study of Chennai

T. Sundarmoorthy, Lalitha Ramadurai and N.G. Anuthaman

Profile of the City

Tamil Nadu constitutes the south-eastern extremity of the Indian peninsula. Chennai is the capital city of the State, besides being an important district. The district city is one of the metropolitan cities of India, which serves as the gateway of the culture of South India. It has emerged as a cosmopolitan city playing an important role in the historical, cultural and intellectual development of India, representing the distinct components of the Dravidian civilisation.

History

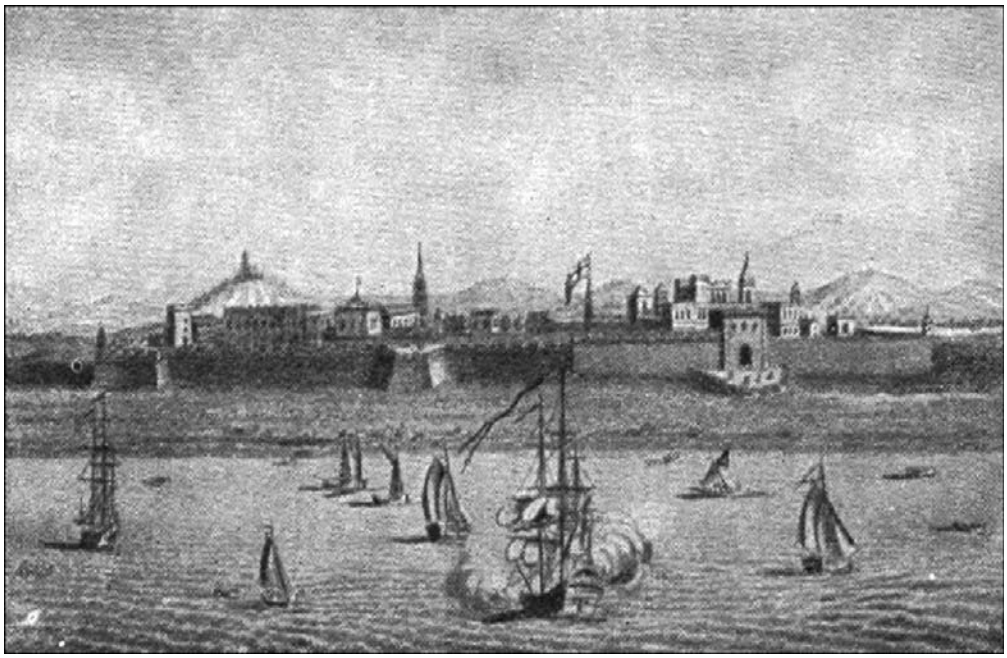
The city of Chennai came into being due to a strategic necessity and historical accident. It symbolises the rise of British power in South India by setting up and consolidation of the East India Company in the 17th century with its headquarters at Fort

St.George in Chennai as a trading centre. Within 350 years, a few scattered villages (important ones being Mylapore, Triplicane and Chennai Patnam) have developed into a modern metropolitan city without shedding its traditional customs, religious outlook and other traditions.

Chennai, originally known as Madras Patnam, was a cluster of villages, perched amidst paddy fields, bordered by palm trees. The Pallavas, the Cholas, the Pandyas and the Vijaynagar Empire - all the popular dynasties of South India - have had an influence over the city.

The origin of the metropolitan city started in 1639, when Francis Day and Andrew Cogan, two merchants of the East India Company, started a factory-cum-trading post here. A settlement was built to serve as the control centre and it was completed on 23rd April 1640 and was named as St. George's fort. The native town, officially called George Town, was established outside the ramparts of the fort. In the later part of the 17th century, Chennai steadily progressed under many Governors during the regime of Governor Elihi Yale (1687-92); the most important event was the formation of the

* Contributed as Chennai city team under National Coordinated Project of NIDM (Gupta, Anil K. and P.G. Dhar Chakrabarti, *Disaster & Development*, 3 (1):1-14, 2009)



Fort St.George

institution of a mayor and Corporation for the city of Chennai.

In 1746, Chennai, along with Fort St George, came under the sway of the French, who ransacked the town and the nearby villages. The British again got command over Chennai in 1749, attributable to the Treaty of *Aix-la-Chappell*. Under the British rule, Chennai went under drastic changes, to become a prominent city with strong naval base.

With the introduction of railways in the late 19th century, Chennai got linked with other important cities like Mumbai and Kolkata. Facilities of trade and communication in the city boosted, connecting it with the hinterland too. Chennai was the only city of India that was attacked during the World War.

When India became independent in 1947, Chennai city was declared as the capital of Madras State, which was later renamed as the state of Tamilnadu in 1968. In 1997, the Government of Tamil Nadu officially changed the name of Madras to Chennai.

Central Railway Station - 1925

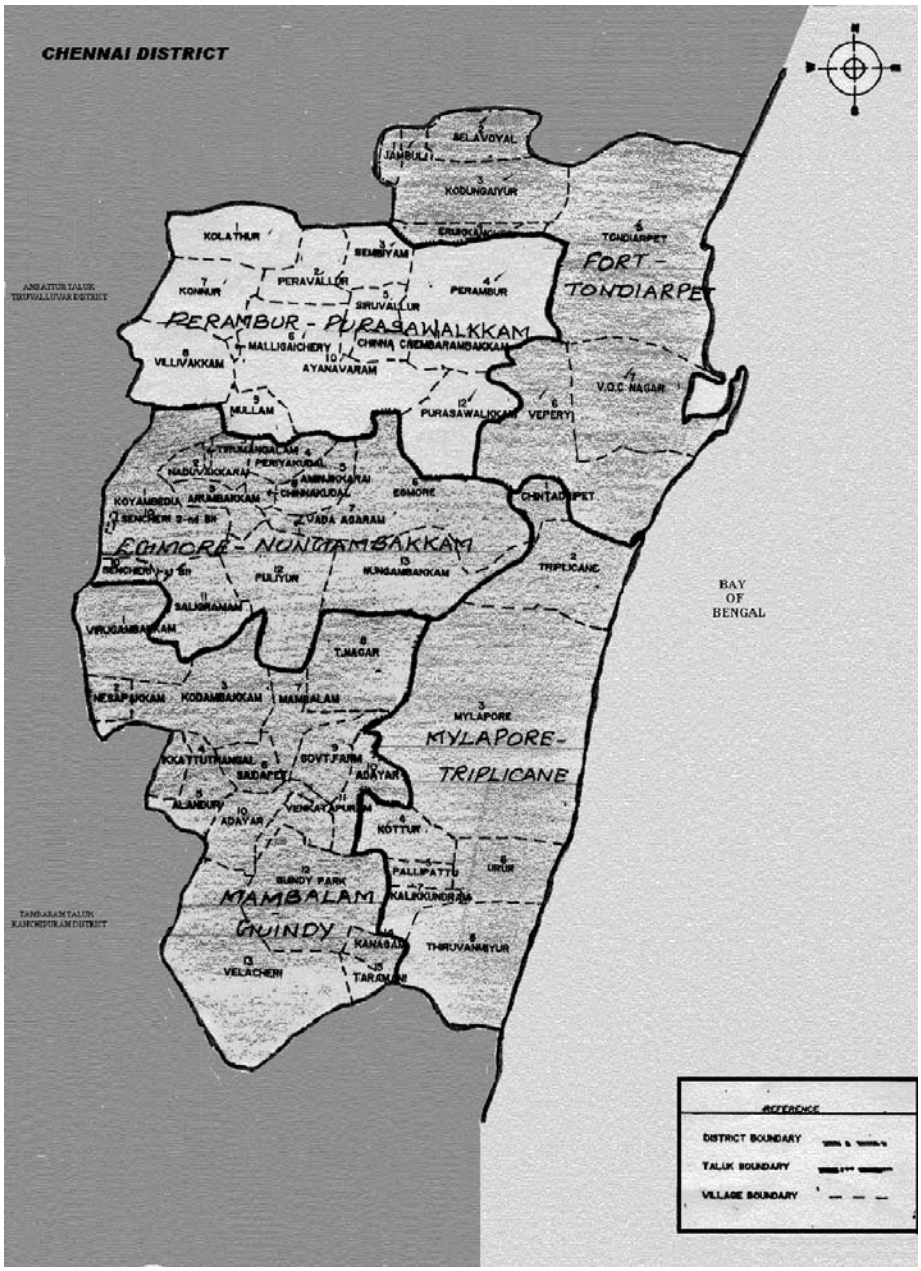
Topography

Chennai is situated on the north-east end of Tamil Nadu on the coast of Bay of Bengal. It lies between 12o50'49" and 13o17'24" of the northern latitude and 79o59'53" and 80o20'12" of the southern longitude.

The topography of Chennai city is extremely flat, with very few isolated hillocks in the south-west near St.Thomas Mount, Pallavaram and Tambaram. The average elevation of about 6.7 meters (20 feet). The land stretches nearly 25.60 kms along the Bay coast from Tiruvanmiyur in the south to Thiruvottiyur in the north and runs inland in a rugged semi-circular fashion. The city is bounded on the east by the Bay of Bengal and on the remaining three sides by Kanchipuram and Thiruvallur districts.

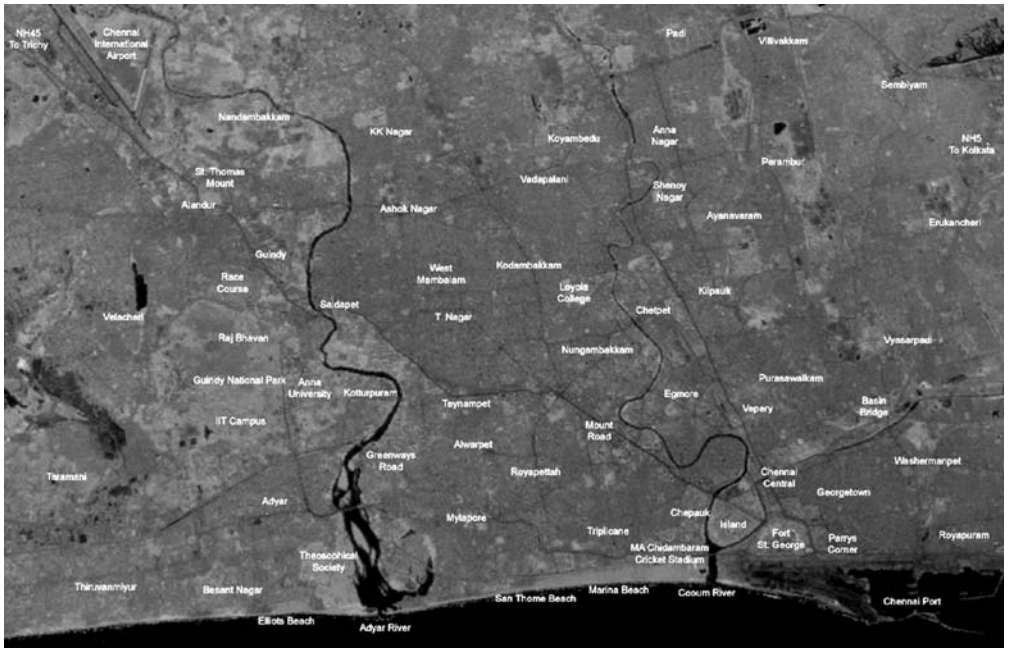
Vegetation

Some centuries back the only vegetation in Chennai was *Albizia amara* and *Acacia* species. But due to the introduction of innumerable foreign species, today we have varied vegetation and thick forests abound in places like Guindy, Tambaram, Vandalur, etc.



Chennai District Map

(Source: http://www.chennai.tn.nic.in/chnmap.htm)



Satellite image of Chennai

Some common trees of Chennai are - *Albizia lebbeck*, *Lannea coromandelica*, *Syzygium cumini* and ornamental / avenue trees like *Bauhinia purpurea*, *Cassia fistula, Delonix regia* and *Peltophorum pterocarpum*. The estuary of the Adyar river, parts of the Buckingham canal and the back waters of Ennore have a small portion of tidal mangrove vegetation where *Avicennia officinalis* is the only mangrove tree species growing. Most of the trees found in Madras (Chennai) today are alien species introduced by the British.

Climate

Climate lies on the thermal equator and is also coastal, which prevents extreme variation in seasonal temperature. For most of the year, the weather is hot and humid. The hottest part of the year is late May and early June, known locally as *Kathiri Veyyil*, with maximum temperatures around 38 - 42 °C (100 - 107 °F). The coolest part of the year is January- February, with minimum temperatures around 19 - 20 °C (66 - 68 °F). The most prevailing winds in Chennai are the south-westerly between May and September and the North-easterly during the rest of the year.

Monthly Averages - Temperature of Chennai

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
Average High (°C)	28	31	33	36	38	37	35	34	34	32	29	28	32.9
Average Low (°C)	20	21	23	26	27	27	26	26	25	24	22	21	24

(*Source: Weather.com - The Weather Channel Interactive*)

Rainfall

The city gets most of its seasonal rainfall from the north-east monsoon winds, from mid-September to mid-December.The average annual rainfall is about 1,300 mm (51 inches). The mean rainy days are about 52 days.

Monthly Average Rainfall (in mm) at Redhills, Cholavaram & Poondi (Average)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
2003	0	0	5	5	6	26	141	139	103	231	98	56	**810**
2004	30	0	0	7	229	50	51	37	191	275	297	5	**1171**
2005	0	0	9	101	32	52	84	119	207	590	514	501	**2208**
2006	0	0	28	31	22	139	55	113	172	420	224	36	**1240**
2007	0	6	0	12	19	68	245	271	175	265	118	270	**1449**
2008	85	6	189	0	28	128	89	2	-	-	-	-	**527**

(Source: http://www.chennaimetrowater.tn.nic.in/AVGRAIN.HTM)

24 Hours Maximum Rainfall Recorded in Chennai

The table below gives the extreme case of daily maximum rainfall recorded in Chennai basin. This shows the monsoon in some years where one day's rainfall is equal to one season's rainfall.

Date	Rainfall (mm)
21-10-1846	520
24-10-1857	460
26-05-1952	450
25-11-1976	452
13-11-1985	347
14-06-1996	348
27-10-2005	400
02-12-2005	320

Demography & Settlement Patterns

Over the last 350 years, Chennai has evolved from a group of fishing hamlets and villages into the administrative and commercial centre of the Madras Presidency during the colonial period, and the capital of the State of Tamil Nadu after independence.

Chennai is today the fourth largest metropolis in India, with a geographical spread of 170.98 sq. km. or 17,098 hectares. The Chennai Metropolitan Area (CMA) comprising of the city of Chennai and contiguous areas around was notified in 1974. It extends over 1189 sq.km. and includes Chennai City Corporation area (Chennai District), 16 Municipalities, 20 Town Panchayats and 214 villages forming part of 10 Panchayat Unions (in Thiruvallur and Kancheepuram districts).

The growth of the city is well reflected in the growth of the urban population as well.The population of Madras in 1871 was 3,67,552; in 1881 - 4,05,848; 1891 - 4,52, 518 and in 1901 - 5, 09,346. The table below gives the growth of city's population since 1901.

Growth of Population in Chennai City (1901-2001)

	1901	**1911**	**1921**	**1931**	**1941**	**1951**	**1961**	**1971**	**1981**	**1991**	2001
Population (Lakhs)	5.41	5.56	5.78	7.13	8.65	14.27	17.49	24.69	32.85	38.43	43.44
Area (sq.km.)	68.17	68.17	68.17	68.17	77.21	128.83	128.83	176	176	176	
Rate of growth of population* (in percent)	--	0.27	0.39	2.12	0.69	0.11	2.06	3.51	0.27	1.58	1.23
Population density per hectare	80	82	85	105	112	111	136	192	187	218	247

*Note: Arrived for a unit area for the purpose of comparison since the city extent varied over time. (The figures given area for the decade ended with that year.

(*Source: Census of India*)

Growth of Population in CMA (1971 -2001)

	Population (in lakhs)				Annual Rate of Growth (%)			Area (sq. km.)	Density per Hectare in 2001
	1971	**1981**	**1991**	**2001**	**71-81**	**81-91**	**91-01**		
Chennai City	26.42	32.85	38.43	43.44	2.20	1.58	1.23	176	247
Municipalities	4.84	8.14	11.84	15.81	5.24	3.80	2.91	240	66
Town Panc hayats	1.11	1.64	2.71	3.86	4.43	4.94	3.62	156	25
Panchayat Unions	2.67	3.38	5.20	7.31	2.40	4.38	3.58	617	12
CMA Total	35.04	46.01	58.18	70.41	2.76	2.37	1.93	1189	59

(*Source: Census of India*)

The population of Chennai, which had stabilized at around half a million at the turn of the century recorded maximum growth rates of more than 2% during the decades 1951-61 and 1961-71. The reasons for this rapid growth rate can be attributed to industrial developments and increase in economic activities and employment opportunities in the city and its suburbs attracting large migrant population.

The negative growth during 1971-81 is normally attributed to the annexation of lesser dense (then) Panchayat areas in 1978 viz. Velacheri, Taramani, Kanagam, Thiruvanmiyur, Kodambakkam, Saligramam, Koyambedu, Senjery, Thirumangalam, Virugambakkam, Nesapakkam, Kolathur, Villivakkam, Konnur, Erukkanchery, Jambuli, Kodungaiyur, Selaivoyal, comprising about 47 sq. km.

The city corporation area consists of 155 divisions with within 10 zones (Zone No. I to X) presently. The number of these divisions and its extent varied over time. Hence, for the purpose of comparison, the demographic details have been arrived for the years 1971, 1981 and 1991 keeping the 155 Corporation division boundaries in 2001 as the basis.

Chennai City - Population Growth in Corporation Zones, 1971 - 2001

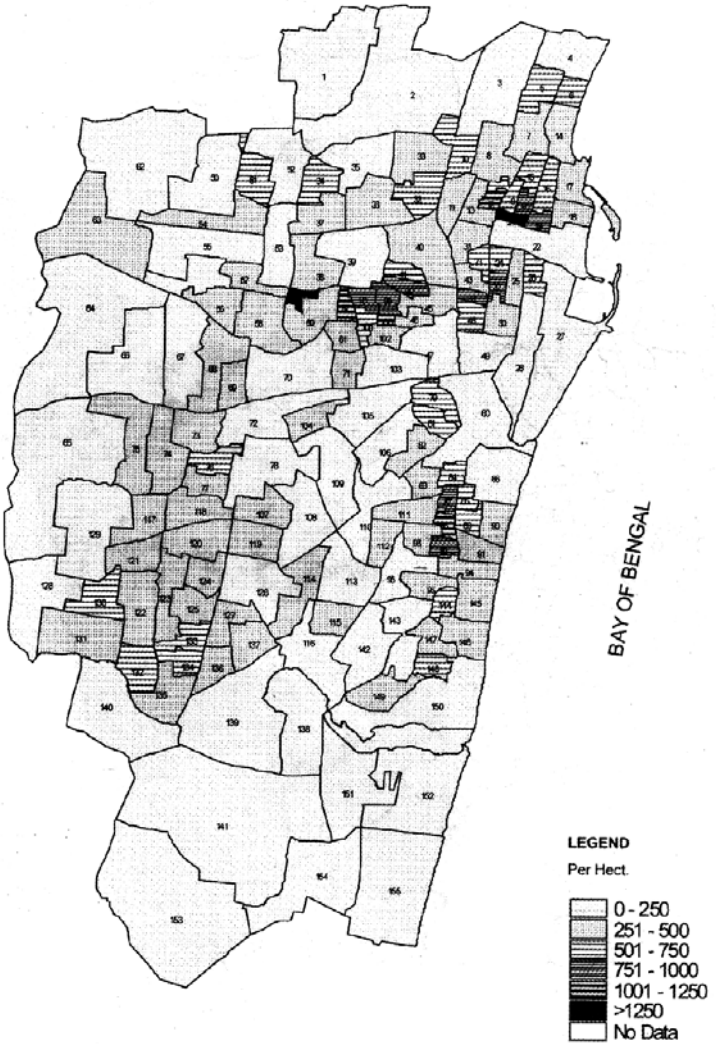
Zone Nos.	Corporation Zone	Area (sq. km.)	Population (in Lakhs)				Annual Rate of Growth (%)		Density per Hectare in 2001	
			1971	1981	1991	2001	71-81	81-91	91-01	
I	Tondiarpet	17.30	2.01	2.69	3.72	4.10	2.95	3.28	1.00	243
II	Basin Bridge	11.52	3.59	3.52	3.27	3.76	-0.21	-0.74	1.40	335
III	Pulianthope	13.51	3.34	4.13	4.31	4.60	2.13	0.44	0.64	349
IV	Ayanavaram	19.76	2.22	3.58	4.12	4.97	4.89	1.42	1.89	258
V	Kilpauk	26.38	2.18	3.45	4.94	5.42	4.68	3.66	0.93	211
VI	Ice-House	10.15	3.27	3.49	3.20	3.42	0.63	-0.84	0.65	346
VII	Nungambakkam	12.90	2.91	3.09	3.20	3.48	0.61	0.35	0.83	277
VIII	Kodambakkam	13.00	2.48	3.33	4.39	4.66	2.96	2.81	0.61	368
IX	Saidapaet	23.56	1.89	2.61	3.33	4.15	3.25	2.48	2.23	180
X	Mylapore	27.92	2.50	2.97	3.95	4.88	1.70	2.89	2.13	180
	City Total	176.00	26.42	32.85	38.43	43.44	2.20	1.58	1.23	247

(*Source: Census of India*)

Population growth in different zones within city Corporation area is found to be not uniform and its rate varied from 0.61% to 2.23%. The locus of new residential development is the south and the west, in an ever-growing semi-circle with the centre gradually moving southward. Saidapet and Mylapore zones have recorded growth rate exceeding 2% during 1991 - 2001.

Chennai's population today has grown to more than four millions, the most rapid growth having taken place in the peripheral zones of the city and in the suburbs. The draft second Master Plan of the Chennai Metropolitan Development Authority (CMDA) estimates that the city's population will increase to about 6 million by 2011. *(Source: http://www.hindu.com/2007/04/12/stories/2007041213350400.htm).*

The city is one of the high density cities in India. Its density varies from 180 persons per hectare in Saidapet and Mylapore Corporation Zones and 368 persons per hectare in Kodmbakkam zones within the Corporation limits. The gross density for Chennai city is 247 persons per hectare.



Chennai City - Gross Density of Population 2001

(***Source : CMDA***)

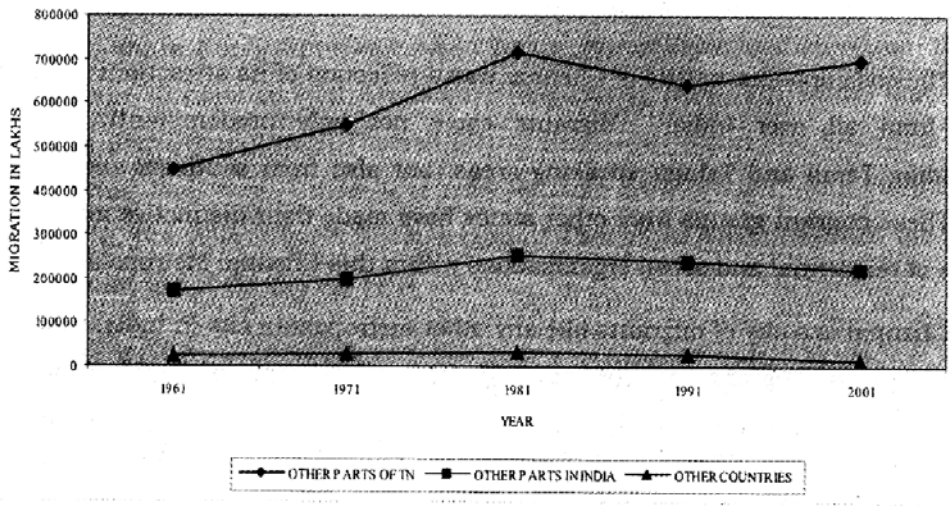
The majority of the population in Chennai are Tamilians and Tamil is the primary language. The average literacy rate is 80.14%, much higher than the national average of 64.5%.The sex ratio is 951 females for every 1,000 males, again better than the national average.

Chennai also has a large migrant population, who come from other parts of Tamil Nadu and the rest of the country. As of 2001, out of the 937,000 migrants (21.57% of its population) in the city, 74.5% were from other parts of the state, 23.8% were from rest of India and 1.7% were from outside the country.

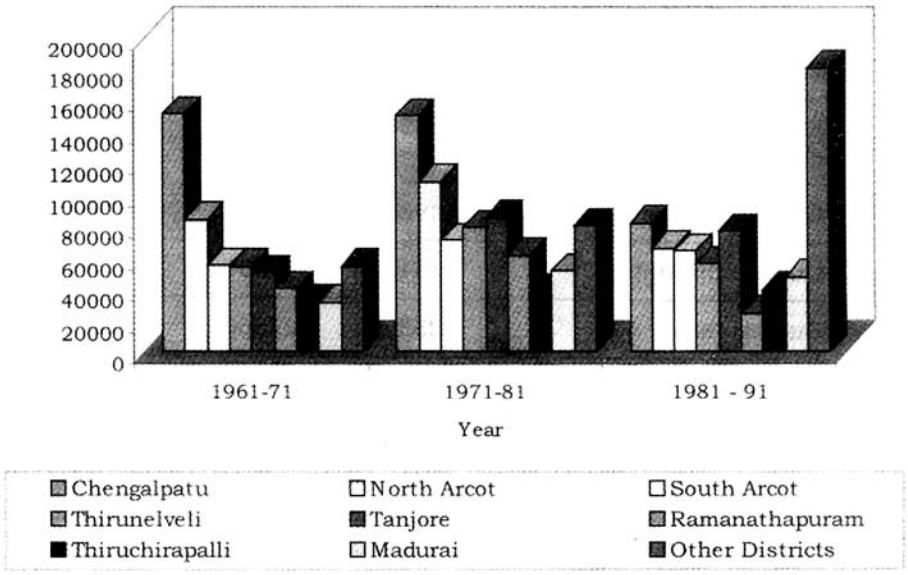
Migration to Chennai City

Year	Total Population	Total Migrants to the city from								% of Total Migrants to the Total Population
		Other parts of T.N.		Other parts of India		Other Countries		Un-classifiable	Total Migrants	
		No.	%	No.	%	No.	%			
1961	17.29	4.47	69.45	1.71	26.60	0.25	3.90	-	6.44	37.24
1971	24.69	5.51	70.61	2.00	25.63	0.29	3.76	-	7.80	31.59
1981	32.84	7.19	71.28	2.55	25.31	0.34	3.41	-	10.08	30.70
1991	38.43	6.44	70.51	2.42	26.47	0.28	3.01	0.04	9.18	23.90
2001	43.44	6.98	74.49	2.23	23.81	0.16	1.71	-	9.37	21.57

(*Source: Census of India, 1961, 1971, 1981, 1991 Social & Cultural Tabl*e)



Migration to Chennai City 1961- 2001



Number of Migrants to Chennai

Slums in Chennai

The vast majority of people who migrated to Chennai were attracted to the city due to oppurtunities available as well as the comforts offered by modernisation. Most belonged to working class and found it difficult to secure accomodation with their meagre means. So, they squatted on every open space available. Chennai city has the fourth largest population of slum dwellers among the cities of India, with about 8,20,000 people (18.6 % of its population) living in slum conditions.

Slum Areas on River Margins

There are three major watercourses in the Chennai city and the banks of all the three are encroached. The slum families are living there without any basic amenities and are subjected to annual flooding. They often pollute the water courses.

Slums along Feeder Canals

Feeder Canals like Mambalam - Nandanam Canal, Otteri Nullah and Captain Cotton Canal, etc. are encroached on either sides preventing the free flow of water and causes stagnation of water during the rainy season in nearby residential areas. It has been identified that 5,288 families are living on the margins of these channels.

Slums on the banks of the Cooum River

Table: Slum Famlies along rivers

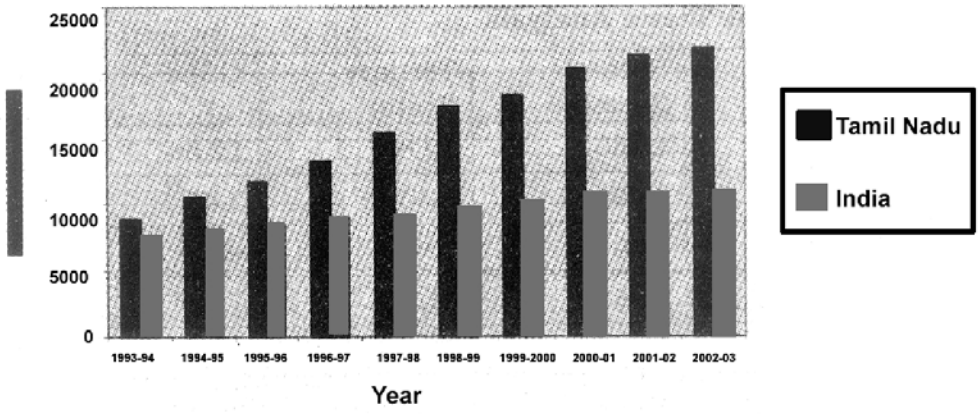
No.	River	No. of Slum Families
1.	Cooum	8432
2.	Buckingham Canal	15,733
3.	Adyar	6757
	Total	**30,922**

Socio-economic Profile

The economic base of the Chennai City had shifted from trade and commerce to administration and services by the early part of the 20th Century. In the post independence period, manufacturing became an important sector and Chennai Metropolitan Area (CMA) continues to be the most important industrial center in the State.

Today, Chennai has a diversified economic base anchored by the automobile, hardware manufacturing, healthcare and financial services industries. Recent trend shows that the economic structure of the city is tertiarised with growing contribution by Information Technology / Information Technology Enabling Service / Business Process Outsourcing (BPO) Industries. Chennai is perhaps the only city in India to have all the top 10 IT Indian Multi National Companies and the 3 IT majors viz. Infosys, Tata Consultancy Services Ltd. and Wipro which have acquired lands in and around Chennai to meet their expansion plans.

The city alone accounts for 10.94 percent of the State Income. Estimating the income in the areas of Kancheepuram and Thiruvallur District, which fall within CMA, based on proportion of population, roughly, it works out to 2.8 percent and 2.5 percent respectively. These show that CMA accounts for 16.21 percent of the state income from all sectors.



Percaptia Income of Tamil Nadu and India at current prices

Income Estimates - NDDP (Net District Domestic Product) at current price

S. No.	District	At current prices 1999-2000 (Rs. in Lakhs)
1	Chennai	12,48,833
2	Kancheepuram	8,24,702
3	Thiruvallur	4,96,671
4	Tamil Nadu State	1,14,30,943

(*Source: CMDA*)

As of 2001, the total workforce in Chennai was about 1.5 million, which was 31.79% of its population.

Chennai's culture reflects its diverse population. Though smaller in comparison to other metropolitan cities of India, has had a cultural identity of its own that is unique, yet obvious. The city is best known for its Carnatic music and classical dance called Bharathanatyam.The city is also famous for its ancient Hindu temples including the famous Kapaleeshwarar temple at Mylapore. With buildings and churches built during the British period, Chennai has also imbibed the European culture like no other city in India.

Occupational Structure CMA - 1991 and 2001

1991			2001		
	Chennai City	CMA		Chennai City	CMA
Total Workers	1173062	1675512	**Total Workers**	1488364	2519278
Main Workers	1171739	1669213	**Main Workers**	1380757	2284457
Main Cultivators	883	19778	**Main Cultivators**	15149	33170
Main Agriculture Labourers	199	70085	**Main Agriculture**	5849	33390
Fishing and Forest	9982	15422	**Main Household**	25836	43394
Mining	1245	3484	**Main others**	1333923	2174503
Manufacturing Household	7683	20271	**Marginal Workers**	107607	234821
Manufacturing and others	275916	423253	**Marginal Cultivators**	2026	5728
Main Construction	74856	104913	**Marginal Agricultural**	1233	22681
Main Trade	300928	372672	**Marginal Household**	5156	10511
Main Transport	125853	166648	**Marginal others**	99192	195901
Main others	374194	472687	**Non-Workers**	2855281	4859201
Marginal Workers	1323	6299			
Non-Workers	2668334	3753958			

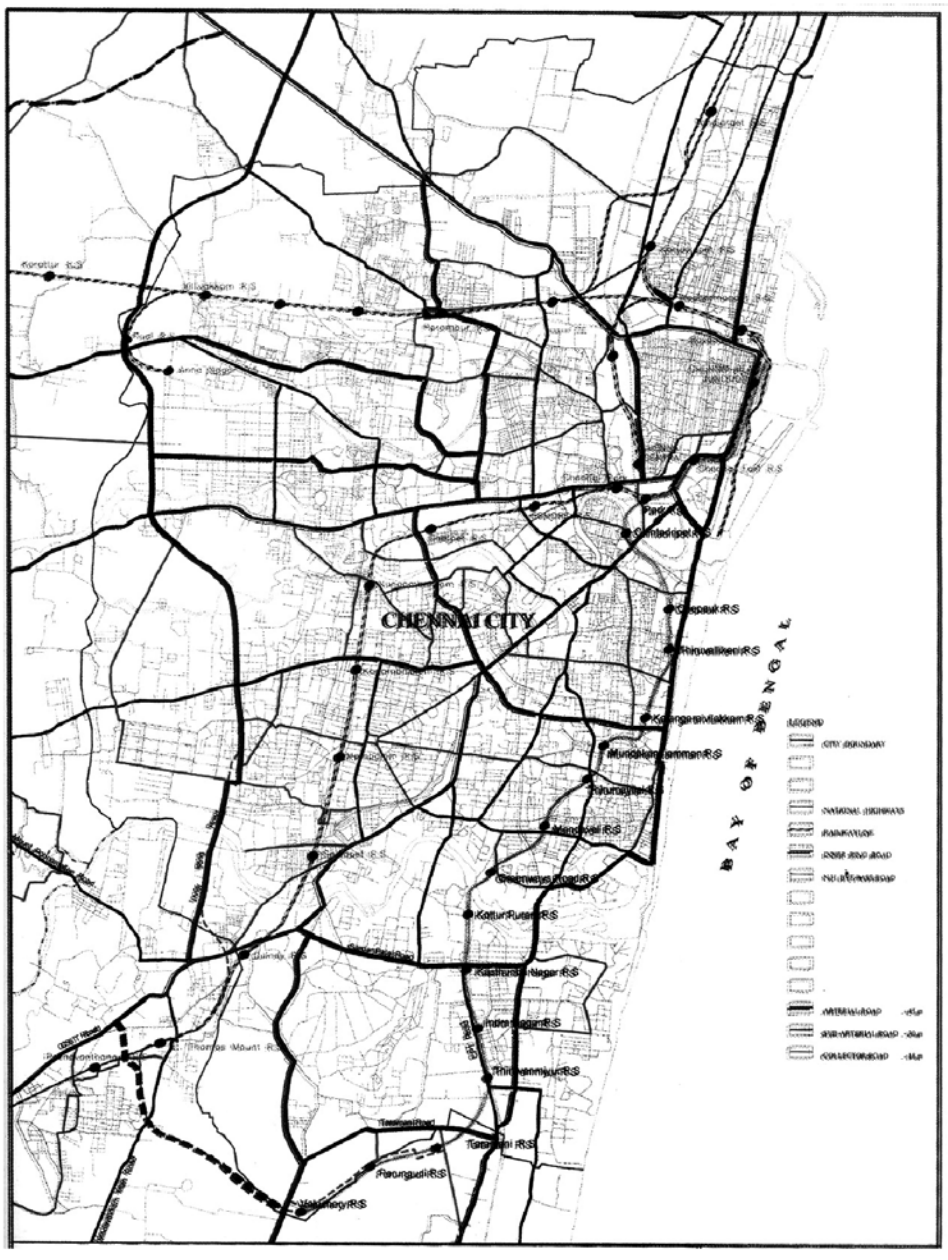
(*Source : Census of India*)

City Infrastructure

Every city is highly reliant on infrastructure. In recent years, the city of Chennai has experienced a complete turnover in its all round infrastructure. But at present we will confine only to those infrastructure facilities connected to flooding and water logging.

Roads

The road network of Chennai is dominated by a radial pattern converging at George Town, which is the main Central Business District (CBD) of the CMA. The road network



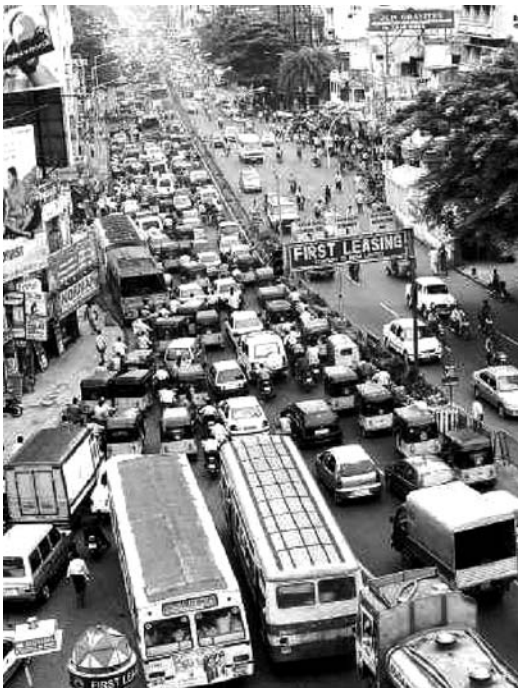
Chennai City Road Network

(Source: http://www.chennaicorporation.gov.in/departments/roads/abstract.htm)

is primarily based on the four National Highways, leading to Calcutta (NH5), Bangalore (NH4), Thiruvallur (NH 205) and Trichy (NH 45). In addition to these, Arcot Road, Kamarajar Salai, Thiruvottiyur High Road, Old Mahabalipuram Road and East Coast Road are the other important radial roads in CMA. The total length of roads in Chennai city is 2,847 km.

The rapid growth of population and increasing number of motorised and non-motorised vehicles put the city's road network into a complex problem. On an average, about 425 new vehicles are put on roads every day without corresponding increase in motorable road space. The increase in road space accounts for only 3 to 4% of the total area, the value of very low order when compared with 11% in Bangkok and 20-25% in developed cities such as London, Paris or New York.

Arterial roads leading to CBD carrying heavy traffic due to concentration of commercial, industrial and other employment-related activities in the CBD are highly congested. Other major roads are also congested. Capacity of almost all roads in the present system is reduced due to poor quality of riding surface, inadequate pedestrian pavement, poor lighting conditions and lack of properly designed intersections.



Traffic jam on Mount Road

Sewage

In early 1890, surface drains in the city were connected to pumping stations and the wastewater conveyed for disposal away from inhabitation. The proposal for comprehensive drainage scheme to cater to the needs of a topographically flat, fast growing city was formulated in 1907 and works were initiated in 1910 and completed during 1914 in stages.

The systems were designed for the population of 6.5 lakhs expected in 1961 at 114 lit. per capita per day of water supply. The system originally consisted of a network of force mains and brick gravity sewers served by 3 Pumping Stations at Royapuram, Purasaiwalkam and Napier Park and ultimately discharging wastewater into the sea at Kasimedu on the Northeastern boundary of the City.

A fundamental change to this system was made in 1956 by laying a force main to divert part of the sewage discharged from the Purasaiwalkam pumping station to Kodungaiyur where the sewage farm was started. Thereafter a comprehensive wastewater management scheme was formulated. The implementation of these schemes commenced in 1961 and had undergone modifications periodically commensurate with the system requirements of an expanding city and the growing population. The wastewater system for the city has been divided into five drainage zones. These zones of macro systems covering the entire city had independent zonal collections, conveyance, treatment and disposal facilities.

Zone-I of sewerage system forms the oldest part of the city and is in the north eastern portion of the city bounded by Bay of Bengal to the East, the city limits to the North, the Buckingham Canal to the West and Pycrofts Road to the South. It covers the areas of Tondaiarpet, Washermenpet, Royapuram, George Town, Chindadripet etc. The sewage collected from this Zone-I is drained to the treatment plant located at Kodungaiyur (Zone-I Plant) which was commissioned in 1991 for the capacity of 80 MLD.

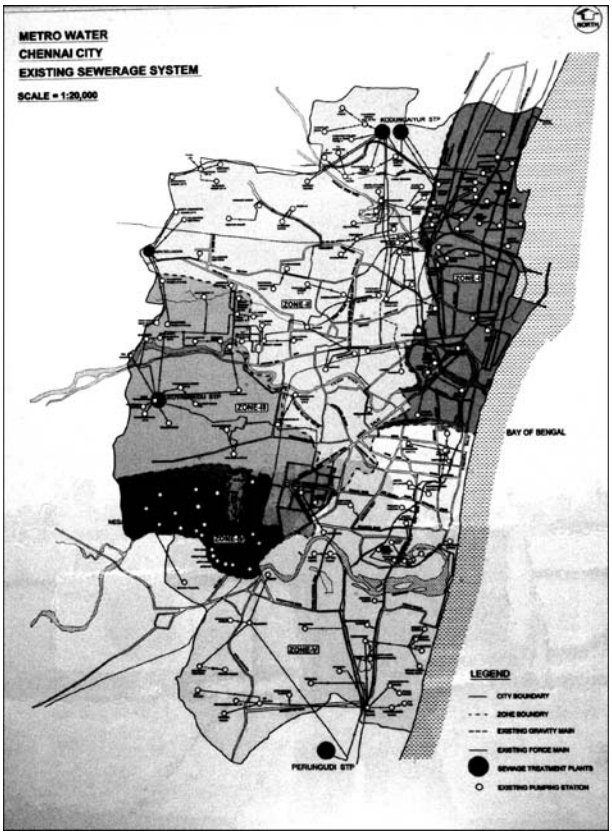
Zone-II is the largest of the five macro systems and serves the central and northern portions of the city. It is bounded by the Buckingham Canal in the East and the corporation limits in the North. The area served are Nungambakkam, Chetpet, Kilpauk, Egmore, Purasaiwalkam, Ayanavaram, Perambur, Vyasarpadi, Sembium, Kolathur, Periyar Nagar, Jawahar Nagar and Kodungaiyur etc. The wastewater generated in these zones is drained into the treatment plant at Kodungaiyur (Zone-II Plant) which was commissioned in the year 1989 for the capacity of 80 MLD.

Zone-III lies between Zone-II and Zone-IV to the west. It comprises Thyagaraya Nagar, Kodambakkam, Arumbakkam, Anna Nagar and Koyambedu. The wastewater generated in this zone is conveyed to the treatment plant at Koyambedu (Zone-III Plant),

which was commissioned in the year 1978 for the capacity of 34 MLD.

Zone-IV is the smallest of the macro systems lying to the southwest of the city. The areas covered are Ashok Nagar, Saidapet, Jafferkhanpet, K.K. Nagar and Nesapakkam. The wastewater generated in this zone is conveyed to the treatment plant at Nesapakkam (Zone-IV Plant) which was commissioned in the year 1974 for the capacity of 23 MLD.

Zone-V is the second largest of the five macro systems and is to the south of the city, which is bifurcated by the Adyar River. Areas covered are Ice House, Mylapore, Adyar, Guindy, Velacherry, Gandhi Nagar, Indra Nagar, etc. The wastewater collected in this zone is conveyed to the treatment plant at Perungudi (Zone-V Plant) which was commissioned for primary treatment only in the year 1980 for the capacity of 45 MLD.



Metro Water Chennai City Existing Sewerage System

(Source: http://www.chennaimetrowater.tn.nic.in)

The Master Plan for Wastewater Management (Sewerage) was formulated in 1978 to serve the population expected in 2008. Extension of sewer systems to the newly developed Areas and improvements to the existing system were carried out based on this Master Plan. During 1989-1991 proposals were formulated for short term and long term improvements to the sewerage interceptor system, sewage pumping stations, pumping mains and sewage treatment plants. The works were carried out in stages for improvement to the collection system, pumping stations and sewage treatment plants. At Villivakkam, a small treatment plant of 5 MLD capacity developed by the Housing Board for SIDCO Nagar of Villivakkam was taken over by C.M.W.S.S. Board during 1984 and is being maintained.

The Master Plan was updated in 1991 to cater to the needs of population expected in 2021 and the proposal envisages improvement to (a) sewage collection and conveyance system in the City which includes strengthening of the existing collection system for all zones, strengthening the existing conveyance system including force main, improvement to critical sewage pumping stations, provision of collection and conveyance system for un-sewered areas, (b) the sewage treatment and disposal facilities. The works were executed in stages according to the priority by mobilizing funds in-house by Metrowater.

The detailed design and engineering for sewage collection & conveyance and for the sewage treatment & disposal were finalized through independent consultants during 1995-1998 for expanding the capacity of sewage collection, conveyance system and treatment & disposal arrangements to meet the requirement for the population expected in 2021 and due to increase in the availability of water under Krishna Water Supply Scheme.The total estimated cost of the proposal was about Rs.1,300.00 crore.

Based on this detailed design and engineering, project proposals were formulated for implementation under Chennai City River Conservation Project in the year 2000 at the estimated cost of Rs.720.00 crore as first phase for 2011 sewage flow. The proposal consists of laying of interceptors 59.2 km. improvements to 28 nos. of pumping stations, construction of 3 nos. of new pumping stations and laying of sewage pumping mains 28.85 km. gravity conveying main 17.3 km. and expansion of sewage treatment capacity for 264 MLD. These works were commenced in January 2001 and completed in August 2006.

The improvement works to the old treatment plants were carried out during the year 2001 to maintain the treatment capacity as follows:

S.No.	Treatment Plant	Treatment Capacity in MLD
1	Kodungaiyur Zone - I	80
2	Kodungaiyur - Zone II	80
3	Koyambedu Zone - III	34
4	Nesapakkam Zone - IV	23
5	Villivakkam Zone - V	54
	Total	222

Newly constructed Sewage Treatment Plants:

S.No.	Treatment Plant	Treatment Capacity in MLD
1	Kodungaiyur Zone - I & II	110
2	Koyambedu Zone - III	60
3	Nesapakkam Zone - IV	40
4	Perungudi - Zone V	54
	Total	264

(*Source: http://www.chennaimetrowater.tn.nic.in*)

The present capacity of the treatment plant is 486 MLD.

Sewage Treatment Plant at Kodungaiyur

(Source: http://www.hinduonnet.com)

Due to the enhancement of capacity of the 28 sewage pumping stations and construction of 3 new pumping stations, the pumping capacity has been increased from 440 MLD to 575 MLD. The capacity of the sewerage treatment plants has been increased from 222 MLD to 486 MLD and the sewage overflow and untreated sewage entering the waterways have been reduced.

In the sewage treatment process, bio-gas is produced and is being used to produce power to run the plants. This incidentally reduces the discharge of Green House Gas into the atmosphere and provides for Carbon Trading. CMWSS Board has adopted Clean Development Mechanism (CDM) which is likely to generate revenue in the range of Rs.3.50 to Rs.4.00 crore per annum.

The growth in the sewerage services compared to 1978 when the C.M.W.S.S. Board is given below:

Details	1978	March 2007
Area Covered	74%	99%
No. of dwellings with sewer Connections	1,14,000	5,15,560
Length of sewer mains	1,223 km.	2,663 km.
No. of pumping stations	58	180
Treatment Plants	3 Nos.	5 Nos.
Treatment Capacity	57 mld	486mld

(*Source: http://www.chennaimetrowater.tn.nic.in/operationmain_main.htm)*)

As the capacity of sewers was limited, during rainy days they became surcharged due to ingress of storm water. Any surplus of sewage in excess of pumping stations capacity was drained into the nearby natural water courses of the city viz. Cooum river, Adyar river, Buckingham canal and Otteri Nalla.

Drainage

Waterways in Chennai

Rivers

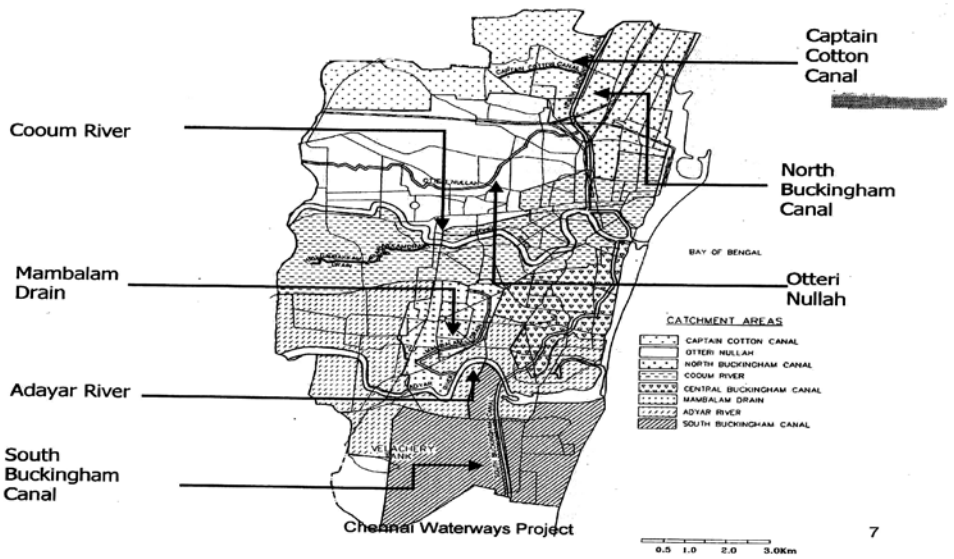
The city is traversed by languid streams namely the Cooum and Adyar. Cooum runs through the heart of the city and enters the sea in-between the University of Madras buildings and the Fort. St. George underneath the Napier Bridge, while the latter wends its way through the southern part of the city and enters the sea near Adyar.

Chennai District - Drainage Map

These two rivers are almost stagnant and do not carry enough water except during rainy seasons. During the rest of the year, they act as a carrier of wastewater from sewage treatment plants and others. The TNPCB periodically monitors the water quality of the rivers. According to the findings, the waterbodies are polluted and not suitable for any designated use.

Waterways in Chennai (maintained by the Public Works Department of Tamilnadu)		
Waterway	**Length in City**	**Length in CMA**
Cooum River	18.26	40.0
Adyar River	14.60	24.0
North Buckingham Canal	7.1	17.1
Central Buckingham Canal	7.2	7.2
South Buckingham Canal	4.2	16.1
Otteri Nullah	8.7	8.7
Virugambakkam-Arumbakkam Drain	6.36	6.36

(*Source: CMDA & http://www.chennaicorporation.gov.in/departments/storm-water-drain/introduction.htm#intro*)



Chennai Waterways

Waterways Basin-wise Sewage generation (Year 2000)			
S.No.	**Waterway**	**Drainage Area (Sq.km.)**	**Sewerage Generation (MLD)**
1.	Adyar River	12	87
2.	Cooum River	20	92
3.	Buckingham Canal		
	North	10	83
	Central	5	46
	South	2	29
4.	Captain Cotton Canal	10	47
5.	Otteri Nullah	24	129
6.	Mambalam Drain	6	19
	Total	**89**	**532**

(*Source: TNPCB*)

The Cooum and Adyar rivers play a major role during floods. River Cooum collects surplus from about 75 tanks in its catchment within CMA and Adyar river collects surplus from about 450 tanks in its catchment, apart from overflows from the Chembarambakkam tank.

Lakes

Chennai and its suburbs also once boasted of over 150 small and big waterbodies. Today the numbers of waterbodies in Chennai have been reduced to a mere 46, thanks to all the onslaught of development. The lakes, which were earlier used as water source for irrigation and now, serve as flood accommodators. Apart from these lakes there are a large number of ponds in CMA.

List of Lakes in Chennai

S.No	Name of the Lake	Location	Area (in hectares)
1.	Adambakkam Lake	Adambakkam	100.82
2.	Ambattur Lake	Ambattur	-
3.	Annanur Lake	Annanur	-
4.	Avadi Lake	Avadi	11.15
5.	Ayanambakkam Lake	Ayanambakkam	-
6.	Chetpet Lake		-

S.No	Name of the Lake	Location	Area (in hectares)
7.	Chitlapakkam Lake	Chitlapakkam	18.0
8.	Chittheri Lake	Thiruneermalai	21.66
9.	Gowrivakkam Lake		-
10.	Hasthinapuram Lake	Hasthinapuram	-
11.	Irumbuliyur Lake		-
12.	Katcherimalai Quarry	Old Pallavaram	1.2
13.	Kilkattalai Lake	Kilkattalai	-
14.	Korattur Lake	Korattur	816.32
15.	Kovilambakkam Lake	Kovilambakkam	4.00
16.	Madhavaram - Manali Lake	Madhavaram	28.0
17.	Madipakkam Lake	Madipakkam	-
18.	Maduravoyal Lake	Maduravoyal	-
19.	Maduvankarai Lake	Velachery	0.468
20.	Moovarasanpattu Lake	Moovarasanpettai	14.88
21.	Mugappair Lake	Muggapair	-
22.	Naina Lake	Thiruneermalai	-
23.	Narayanapuram Lake	Narayanapuram	-
24.	Nimilichery Lake	Chrompet	-
25.	Paleripattu Lake	Paleripattu	-
26.	Palkudam Lake	Old Pallavaram	-
27.	Pallikaranai Lake	Pallikaranai	400
28.	Parithipattu Lake	Avadi	83.67
29.	Peerkankaranai Lake	Peerkankaranai	-
30.	Periya Lake	Chrompet	-
31.	Periya Lake	Tambaram west	18.78
32.	Periya Lake	Thiruneermalai	76.61
33.	Perungudi Lake	Perungudi	-
34.	Puzhal Lake	Red Hills	-
35.	Puzhudhivakkam Lake	Puzhudhivakkam	-
36.	Ramapuram Lake	Ramapuram	-
37.	Rettai Lake	Madhavaram / Kolathur	-
38.	Rettai Lake	Porur	-
39.	Sekadu Lake	Sekadu	120.0
40.	Selaiyur Lake	Selaiyur	-
41.	Sunnambu Kolathur Lake	Pallikaranai	-
42.	Thirusulam Lake	Thirusulam	-
43.	Vannan Eri	Tambaram	
44.	Velachery Lake	Velachery	147.06
45.	Vilingiyambakkam Lake	Vilinjiyambakkam	40.0

Madhuravayal Lake

Chetpet Lake

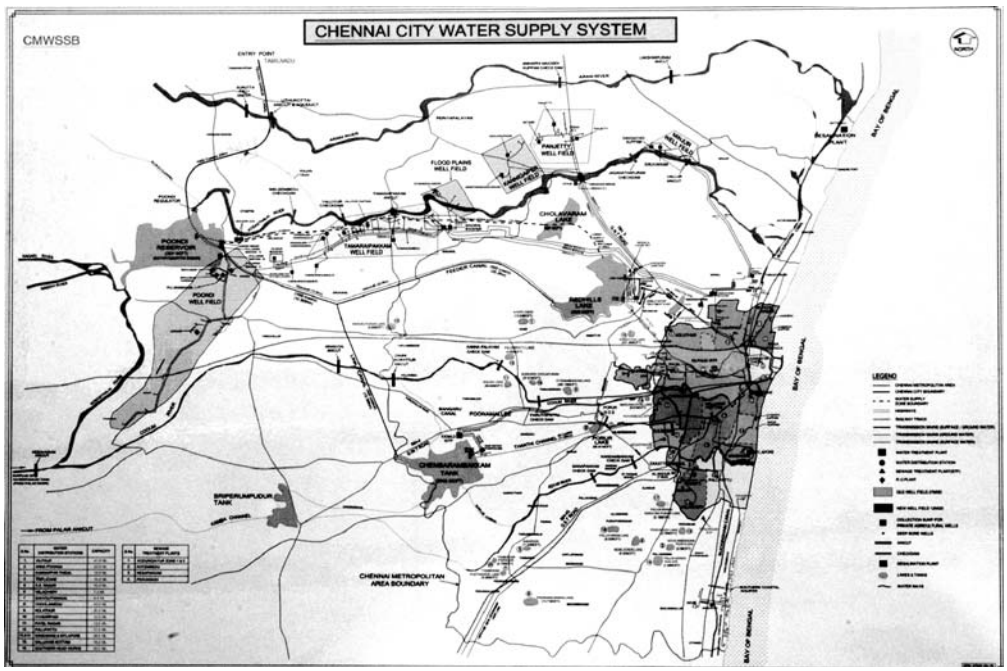
Perungudi Lake

Moovarasampet Lake

Tanks

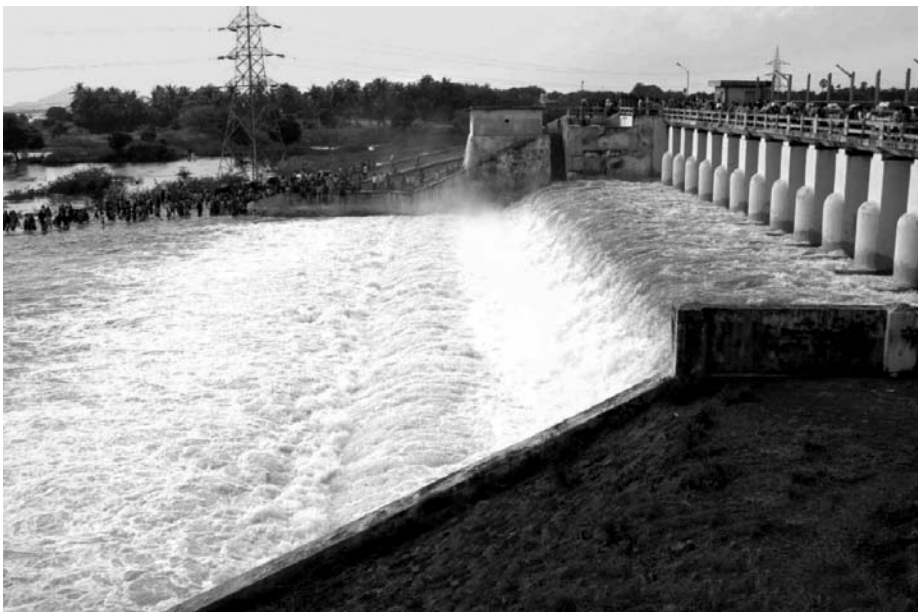
Tanks were an integral part of India's famous and highly evolved traditional water mnagement systems. In areas (particularly the Deccan peninsula) where the rivers are not snow-fed, the different kinds of tanks - percolation ponds, natural lakes, artificial reservoirs and temple tanks - proved to be of great use.

The Sholavaram tank, Red Hills tank and Chembarambakkam tank are the major tanks in the CMA. Red Hills tank is the main source of water supply to the Chennai city and during storm events water is released to Red Hills surplus channel, which enters the Kosasthalaiyar river and discharges into the sea. Its maximum storage capacity is 3,285 Mft3 (93 Mm3). Sholavaram Tank is the secondary storage tank receiving water from the Poondi Reservoir via Poondi Feeder Canal to supply Red Hills Tank. Chembarambakkam Tank has recently been developed as one of the sources for water supply to Chennai City and has maximum storage capacity of 103Mft^3.



Chennai Water Supply Map

Red Hill Reservoir



Chembarambakkam Reservoir

Poondi Reservoir

(Pictures Courtesy: http://www.chennaimetrowater.tn.nic.in)

Temple Tanks

While the tanks and artificial reservoirs were used for activities like irrigation, washing, etc, the temple tanks were sanctified and the waters were drawn only in times of drought.

These tanks were revered no less than the temple itself. Their waters (*tirtham*) are believed to cleanse all sins. In fact, devotees are required to wash their hands and feet in the temple tank before entering the temple. The waters are also used to perform the daily ritual bath (*abishekam*) of the temple deity. Annual float festivals (t*eppotsavam* in Tamil) are conducted in the tanks, wherein the idol of the deity is floated around the tank on a decorated raft. (called 't*eppam*' in Tamil).

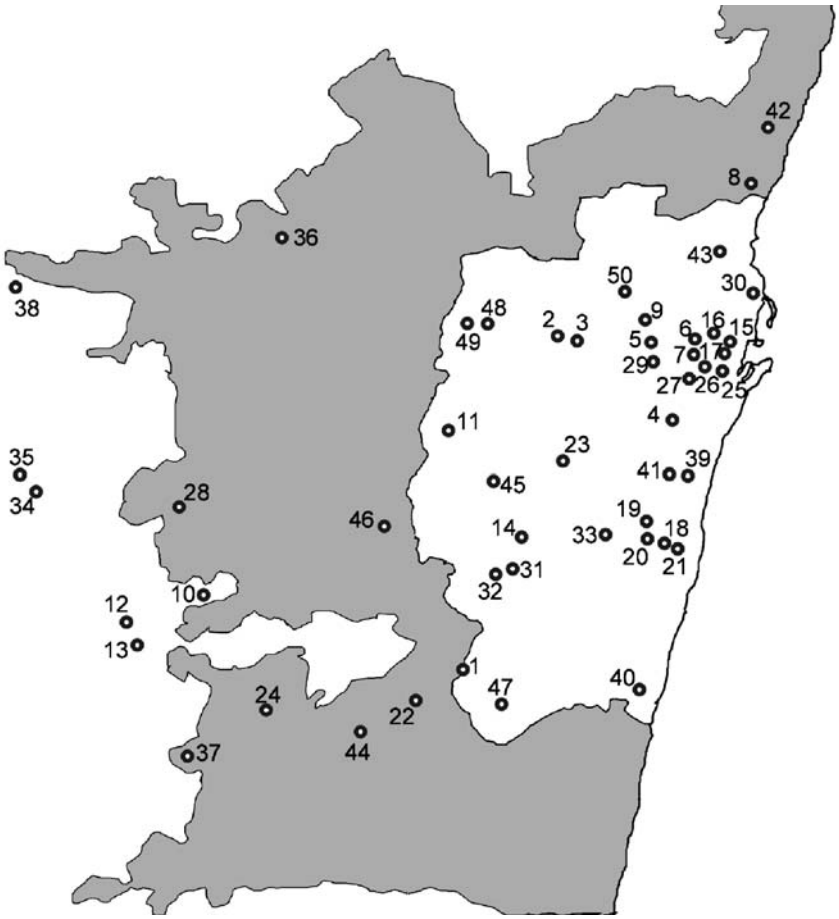
Since the water from the temple tanks was not extracted for everyday chores, they served the vital purpose of recharging the underground aquifers. They reduce the runoff and enhance the water stagnation time, which ensures sufficient water in the domestic wells during the summer months.

***Teppotsavam at* Sri Kapalishwara temple tank, Chennai**

C.P.R. Environmental Education Centre took up a survey of 50 temple tanks in Chennai during 2004. The visual survey and recording of information was accompanied, in several places, by water analysis for both physical and chemical.

	Location of Temple Tanks in Chennai (Survey by CPREEC)	
S.No.	**Location**	**Name of Temple**
1.	Adambakkam	Nandheeswarar Temple
2.	Ayanavaram	Parashuramalingeshwarar Temple
3.	Ayanavaram	Kashi Vishwanathar Temple
4.	Chintadripet	Adhipureeswarar Temple
5.	Choolai	Angala Parameshwari Amman Temple
6.	George Town	Kashi Vishwanathar Temple
7.	George Town	Kachchaleeshwarar Temple
8.	Kaaladipet	Kalyana Varadharaja Perumal Temple
9.	Kosapet	Kandaswamy Temple
10.	Kovur	Sundareshwarar Temple
11.	Koyambedu	KurungalishwararTemple
12.	Kundrathur	Murugan Temple

13.	Kundrathur	Vada Nageshwarar Temple
14.	Mambalam	Kothandaramar Temple
15.	Mannady	Krishnan Temple
16.	Mannady	Chengazhunir Pillaiyar Temple
17.	Muthialpet	Mallikeshwarar Temple
18.	Mylapore	Kapalishwarar Temple
19.	Mylapore	Virupakshishwarar Temple
20.	Mylapore	Madhava Perumal Temple
21.	Mylapore	Adi Kesava Perumal Temple
22.	Nanganallur	ArdhanarishwararTemple
23.	Nungambakkam	Agastishwarar Prasanna Venkatesha Perumal Temple
24.	Pammal	Arkishwarar Temple
25.	Park Town	Ekambareshwarar Temple
26.	Park Town	Kandaswamy Temple
27.	Parry's Corner	Chenna Kesava Perumal Temple
28.	Poonamallee	Sri Varadaraja Perumal Temple
29.	Purasawalkam	Gangadishwarar Temple
30.	Royapuram	Angala Parameshwari Temple
31.	Saidapet	Karanishwarar Temple
32.	Saidapet	Prasanna Venkata Narasimha Perumal Temple
33.	Teynampet	Balasubramania Swami Temple
34.	Thirumazhisai	jagannathaPerumalTemple
35.	Thirumazhisai	Othandishwarar Temple
36.	Thirumullaivoyal	Masilamanishwarar Temple
37.	Thiruneermalai	Ranganatha Perumal Temple
38.	Thiruvatteeswaranpetai	Bhaktavatsala Perumal Temple
39.	Thiruvallikeni	Parthasarathi Temple
40.	Thiruvanmiyur	Marundishwarar Temple
41.	Thiruvatteeswaranpettai	Thiruvatteeswarar Temple
42.	Thiruvotriyur	Tyagarajaswami Temple
43.	Thondaiyarpet	Arunachaleswarar Temple
44.	Thrisoolam	Thrisoolanather Temple
45.	Vadapalani	Palani Andavar Temple
46.	Valasaravakkam	Agastishwarar Temple
47.	Velachery	Dandishwarar Temple
48.	Villivakkam	Sowmiya Damodara Perumal Temple
49.	Villivakkam	AgastishwararTemple
50.	Vyasarpadi	RavishwararTemple



Location of Temple Tanks in Chennai

Presently, most of the temple tanks in Chennai have fallen into a state of repair and disuse due to one of the following reasons:

- ✦ Unchecked extraction and blocking of inlet ducts (either by unplanned construction or litter) has led to the drying up of some of the temple tanks.
- ✦ Pressures on the land have lead to the encroachment of these dried out tanks. For example, in Chennai, the famous Dandishwarar temple tank has been drained and is used as a dumping yard for waste and defecation.
- ✦ Also, the tanks have become sinks for sewage and garbage of the neighbourhood.
- ✦ Those tanks that still have water have been invaded by various kinds of weeds, rendering them unfit for use.

Angala Parameshwari Temple Tank, Royapuram

Thrisoolanather Temple Tank, Thrisoolam

Dandishwar Temple Tank, Velachery

Canals & Other Channels

Like any region in South India with agricultural lands, CMA also has a network of canals and channels within its boundary. The Buckingham - the most important one - was constructed during the year 1806. It enters CMA at Athipattu village, passes through the Chennai City and leaves CMA at Semmencheri village. It finally connects to Ongur River at Yedayanthittu Kaliveli near Cheyyar. Its total length is 418 kms and in CMA its runs through 40Kms. It runs in the North South direction and connects all the major three rivers in CMA.

The canal was originally formed as a navigation channel and even served as an inland waterway till 1954. But within CMA for various reasons it now only serves as a draining channel for water from the Araniar, the Kosasthaliyar, the Cooum and the Adyar rivers before draining into the sea. It also collects storm flood from various storm water drain systems in west Chennai, including Kodungaiyur drain, Otteri Nallah, Captain Cotton canal.

The Otteri Nullah is a channel to accommodate flood, which originates from a place called Otteri near Padi, flows through the city at Anna Nagar, Kilpauk, Purasawalkam, and Perambur and joins Buckingham Canal near Basin Bridge.

Virugambakkam-Arumbakkam Drain originates near Oragadam passes through Virugambakkam-Arumbakkam area of the city and joins into Cooum River.

The Corporation maintains 16 canals of 27.92 km., criss-crossing the city. Rainwater runoff gets drained through storm water drain network & canals and reaches the see via four waterways - Otteri Nullah, Buckingham Canal, Adyar River and Cooum River - running across the city.

List of Canals maintained by the Corporation of Chennai

S.No.	Name of the Canal	Starting Point	Ending at	Length (kms.)
1.	Kodungaiyur Canal	Moolakadai	Buckingham Canal	5.235
2.	Link Canal	Captain Cotton Canal	Kodungaiyur Canal	0.485
3.	Captain Cotton Canal	GNT Road at Sharma Nagar	Buckingham Canal	3.000
4.	Vyasarpadi Canal	Dr. Ambedkar College Road	Captain Cotton Canal	1.265
5.	Egankipuram Canal	Perambur Railway Station	Otteri Nullah	1.272
6.	Jawahar Canal	Madavaram High Road	Captain Cotton Canal	1.272
7.	T.V.S.Canal	SIDCO Industrial Estate	Otteri Nullah	1.753
8.	Trustpuram Canal	Arcot Road	Cooum River	1.486
9.	Nungambakkam Canal	Nungambakkam High Road	Cooum River	1.410
10.	Mambalam Canal	Valluvar Kottam	Adyar River	5.890
11.	Nandanam Canal	Mambalam Canal	Adyar River	1.020
12.	Reddikuppam Canal	Aranganathan Subway	Mambalam Canal	0.471
13.	Jafferkhanpet Canal	Jafferkhanpet Main Road	Adyar River	0.612
14.	M.G.R. Nagar Canal	Dr. Ramasamy Salai	Adyar River	1.749
15.	Chellammal College Canal	Anna Salai	Adyar River	0.365
16.	Raj Bhavan Canal **Total**	Raj Bhavan	Velachery Lake	1.138 **27. 921**

(*Source: www.chennaicorporation.gov.in*)

Storm Water Drains

Geographically Chennai is a plain terrain and lacks natural gradient for free run off. This necessitates an effective storm water drainage system. The Corporation of Chennai has developed and maintains a storm water drain network of 855 km in the city. The storm water drainage system can be largely divided into:

Micro Drainage System

The collector and feeder drains laid along the roads mainly to collect and convey storm water are called Micro system. These drains discharge directly into the macro systems. The micro drainage systems are constructed and maintained by the local bodies - Chennai Corporation in Chennai city, Municipalities, Town Panchayats and Panchayat Unions (in Chennai Metropolitan Area)

Macro Drainage System and Carrier System

The storm water, treated / untreated effluents from industries and commercial establishments are collected by the macro drainage system, which in turn is connected with major water ways referred to as carrier systems. Some of the macro drains and carrier system are under the control of the Public Works Department (PWD).

Composition & Characteristics of Solid Wastes	
Physical	
Paper	8.38 %
Rags	3.11 %
Organic Matter	51.34 %
Plastics	7.48 %
Metals	0.19 %
Rubber & Leather	0.19 %
Inert	26.01 %
Glass	0.29 %
Coconut	2.48 %
Timber / Wood	0.50 %
Bones	0.01 %
Chemical	
Moisture Content	47.00 %
pH Value	6.20 - 8.10 %
Volatile Matter at 550 %	42.62 %
Carbon	24.72 %
Nitrogen Content	0.88 %
Phosphorous P2O3	0.44 %
Potassium K2O	0.89 %
C / N Ratio	29.25
Calorofic Value in Kj/kg	

Waste Generati	
Residential	68 %
Commercial	16 %
Halls, Schools, Institutions	14 %
Industrial	2 %
Hospitals & Clinics	Separately disposed by Hospitals.

(*Source: CMDA & http://www.chennaicorporation.gov.in/departments/solid-waste-management/index.htm*)

2.4 Solid Waste Management

The Corporation of Chennai is the agency responsible for solid waste management in the city corporation area. Chennai Corporation area is divided in to 10 zones and each zone is further sub divided in to about 15 Divisions totaling to 155 Divisions.

According to Census 2001, the average per capita solid waste generated with in the city is estimated to be about 585 grams. It has been estimated that 3200 tonnes of solid waste is generated in these 10 zones in the city area daily and in addition Chennai Corporation also handles about 500 tonnes of building debris.

As seen from the above table, the Municipal Solid Waste of Chennai contains higher moisture content, small percentage of recyclable materials and more of compostable (organic matter) and inert materials. These characteristics show the low potential for applying refuse derived fuel and waste to energy (i.e. incineration) processing option due to the low combustibles, high moisture and high inert contents of the wastes. However, they indicate high potential for composting of solid wastes.

Present System of Waste Handling in Chennai

Headed by the Superintendent Engineer of the Department of Solid Waste Management, Corporation of Chennai looks after removal of solid wastes in the city. Door to door collection of garbage is practiced in most parts of the city except certain zones. NGOs, neighbourhood associations and other bodies assist communities to collect a solid waste that is deposited in dustbins, which are cleared by the Chennai Corporation.

Solid wastes from the Chennai Corporation area is taken to the Transfer Stations and from there it is finally disposed off at two designated disposal sites viz. Kodungaiyur located in the northern part of the city and Perungudi in the south. Both the sites are located in low lying areas and are adjacent to the Metro water sewage treatment works. About 45% of the total solid waste generated is disposed at Kodungaiiyur and the remaining at the Perungudi sites.

Garbage being burnt at the Perungudi landfill site
(Source : http://www.hindu.com)

Land Use Change

Urban Land use through the ages

Madras in 1600

Madras in 1600 was formed of scattered settlements separated by long distances. Each settlement grew around a nucleus of a temple and has its own history. The most important area at that time was Mylapore. There were small settlements in Purasawalkam, Thiruvatteeswaranpetta, Egmore, Nungambakkam, and Saidapet. Among the suburbs, Tiruvottiyur, Velachery, Tiruneermalai, Mangadu, Padi, Poonamallee, Kunnathur, Ayanavarum, Vyasarpadi, Villivakkam, Ambattur, Koyambedu etc. already existed. Each of these villages was self-contained and had its own agricultural production and household industries.

Madras being on the coast, had many sand ridges, but during the 16th century the level of the sea rose and inundated lands within the settlements. When the sea withdrew, lagoons and ridges were left behind. The lagoons took some time to become filled in and the sandy ridges were places of safety where new temples and settlements were established.

Madras in 1700

The Cooum River and the Elambore River or North River which flows into the Cooum at its mouth were running very close to each other (near the Central Jail area) and during floods they inundated the whole area. The two rivers were linked by a cut, at this point, to equalise the floods in the rivers. A bridge was constructed in 1710 across the cut between the two rivers. The Principal road to Egmore from that time up to 1931 had been the road in front of the present Central Jail. In this era there was a lot of building activity (a redoubt at Egmore, a bridge and churches at the Fort and many private buildings in and around the Fort).

Due to congestion inside the Fort, the British constructed some garden houses in what is known as Peddanaickenpet. In 1733 there was a lot of congestion in George Town and the weaving Community started settling in Chintadripet area and Collepetta near Tiruvottiyur since abundant open space was available for weaving. The washer men who were in the Mint area then moved towards the west. The Potters from this area moved outside the Fort on the north side and formed a new colony (Kosapet).

Because the British started living along Cooum River, roads were laid to give access to them and thus Marshalls Road, Halls Road, Montieth Road and Casa Major Road all became thoroughfares even in 1798. Mowbrays Road and Royapettah High Road were formed to give access to these people.

During this time, the British found that Triplicane was a good area for settlement and a large number of people moved there. The presence of the Nawab of Arcot increased the economic prosperity of the area and more and more Muslims settled in Triplicane

Madras in 1800

After the founding of the Corporation, conservancy and improvement of the City were begun. The City was divided into 8 Divisions. The broad-gauge line from Royapuram to Arcot was laid in 1864. Central station was formed in 1872 and linked to the main line. By 1861 the British authorities realised the necessity of a harbour. A pier was constructed in 1862 and further development took place from 1868 onwards.

The formation of Royapuram station in 1862 induced people to move northwards and settle in Royapuram. The railway line passed through the present Perambur area, which had so far been lying as swampy waste because of its low level. The introduction of the railway line gave development potential to the hitherto uninhabited place. From 1850 onwards, the necessity of providing recreational facilities was perceived. Many parks such as the Peoples Park, Napier Park and Richardson Park were created in this period. A Museum and a Zoo were also established.

Before 1800, the roads were in a radial pattern, but after 1810 ring roads were developed inside the City. Mount Road was important and access to it was given from Triplicane High Road, Chamiers Road, Edwards Elliot's Road and Royapettah High Road. To the North of Mount Road, Pantheon Road, Halls Road, Marshalls Road, Spur II-5 Tank Road and Nungambakkam High Road were formed to serve the new residential areas. Later Brick kiln Road and Perambur Barracks Road connected Poonamallee High Road with Konnur Road, which was extended towards the Railway.

To facilitate trade the harbour was completed in 1896 just to the east of George Town. The building of the harbour was responsible for sand accretion to the south of it and the sea which was washing the ramparts of the Fort at one time was then 2.5 km. away with a wide beach between the land and the sea. A number of public buildings were constructed fronting this beach early in the 19th century, which still add dignity to the city.

Madras in 1900

The important developments during the period 1901 and 1941 were the commissioning of the electrified suburban metre-gauge railway between Beach and Tambaram in 1931 which gave a fillip for the development of the outlying suburban areas as far as Tambaram, and the development of the area occupied by the long tank at Nungambakkam as a planned residential neighbourhood by the Corporation. By 1941 Madras had developed into a provincial metropolis enjoying the best of both worlds - urban amenity and rural atmosphere. It was still primarily an administrative and commercial centre.

The thirty years between 1941 and 1971 saw tremendous growth in population and economic activity in and around the City. The setting up of the Tamil Nadu State Housing Board however, helped in the creation of large residential areas like Anna Nagar on the west and Sastri Nagar on the south. The city's boundary no longer remained well defined. The developments extended into the adjoining areas, particularly, on the north up to Ennore, west up to Avadi and south up to Vandalur. This growth did not take place in a regulated manner nor did it correspond to the available infrastructure facilities. This fact coupled with the rapid growth of population on the one hand and the increase in number of motor vehicles on the other has given rise to the many problems faced by the Metropolis today.

In the last three decades, the agricultural activity within Chennai has become abysmally minimal for various reasons including non-availability of water for irrigation purposes, labour cost, and cost of agricultural inputs. In the northern wedge between

GNT Road and T.P.P. Road, because ayacut rights of Puzhal and Redhills lakes had been cancelled and local water sources are not adequate, the agricultural activity in these areas is very minimal.

Similar is the position in the northwestern wedge between CTH Road and GNT Road, which lie in the catchment area of these lakes, which are the main sources of water supply to the city. The Chembarambakkam lake, another large lake in CMA, is being converted as another source for city water supply and very minimal agriculture activity is being carried out in its ayacut area which lie in the south-western wedge. In the southern wedge between Old Mamallapuram Road and GST Road only in few pockets to a limited extent the agriculture activity in the south of Tambaram - Madipakkam Road continue.

Land Use under the First Master Plan

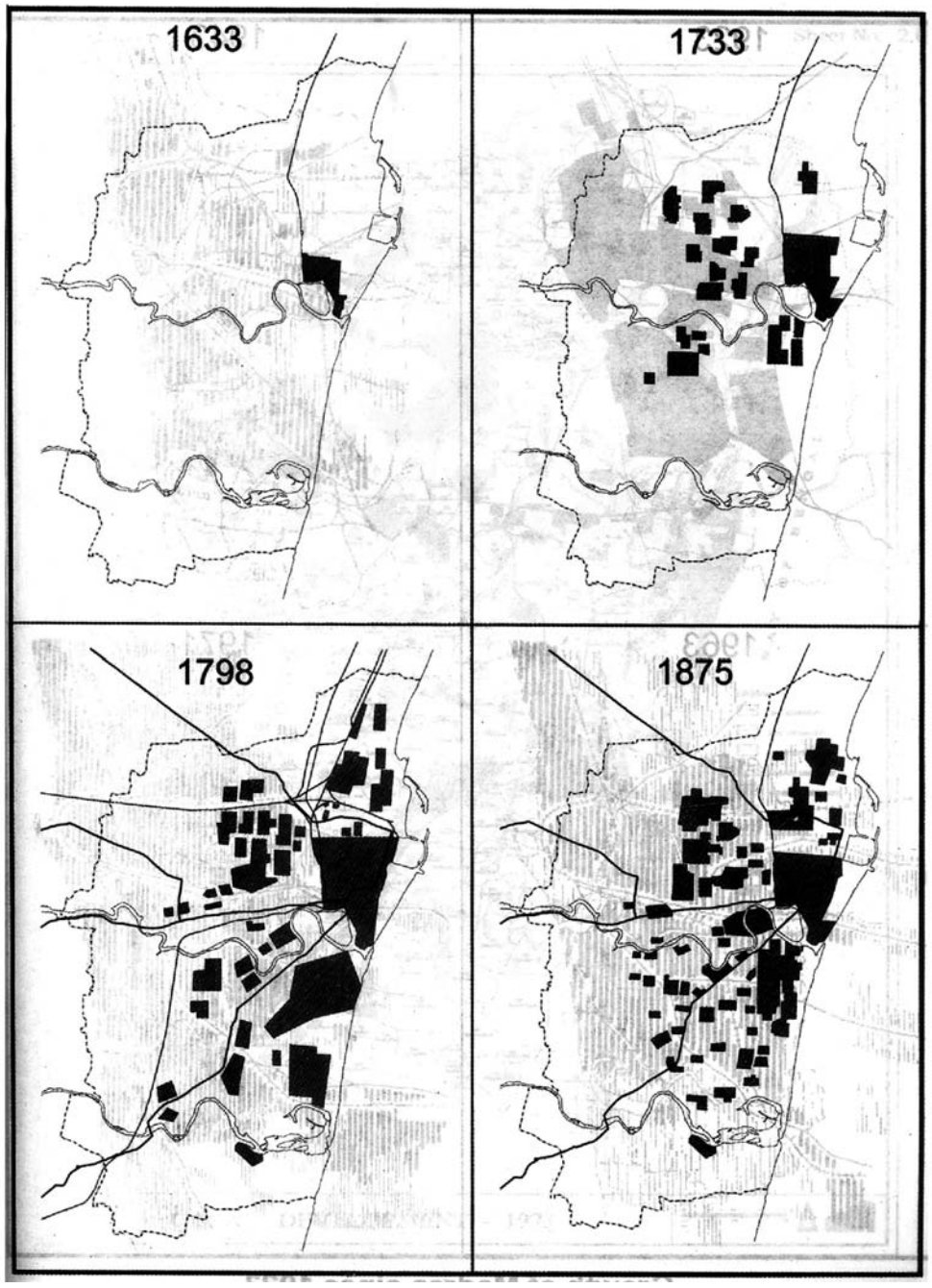
The First Master Plan for the Chennai Metropolitan Area (CMA) was prepared during 1973-75 and approved in 1976. It was then estimated that, by 2001, the CMA will have a total population of 7.1 million, including four million in Chennai city. The Master Plan laid down policies and programmes for the over all development of the CMA. It was the basic document for the infrastructure agencies like Metrowater, highways Department inplanning and provision of infrastructure by them within the CMA.

The plan recommended that development projects would need to be oriented towards raising the levels of income both at the State level and metropolitan level. To achieve this, the Master Plan also suggested large-scale industrialisation, strengthening of service and light type industries with medium range employment and increasing tertiary sector employment.

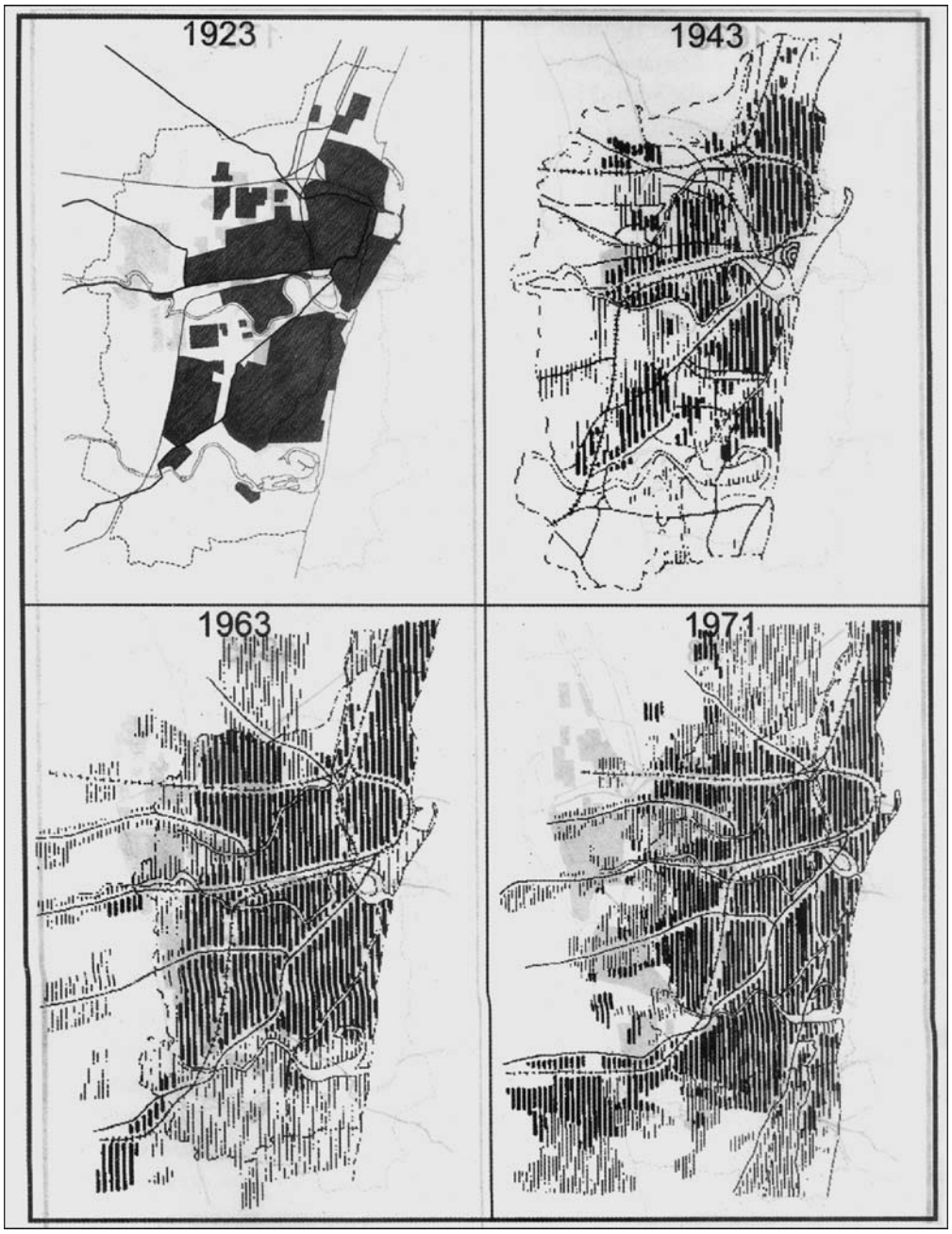
Location of large-scale industries in the hinterland of CMA to satisfy the employment needs of the resident population was recommended. The only way to regulate economic activity, it reasoned, was to optimise the use of the existing infrastructure facilities and plan their expansion to meet future needs by regulating land use and building activities. It favoured decentralizing economic and industrial activities into proposed nodes and satellite towns.

The important projects identified in the FMP were: Mass Rapid Transit System (from Manali to Tiruvanmiyur), electrified suburban system between Chennai and Tiruvallur and Chennai and Minjur, construction of circular railway, construction of combined railway terminals and widening of major arterial roads within the city.

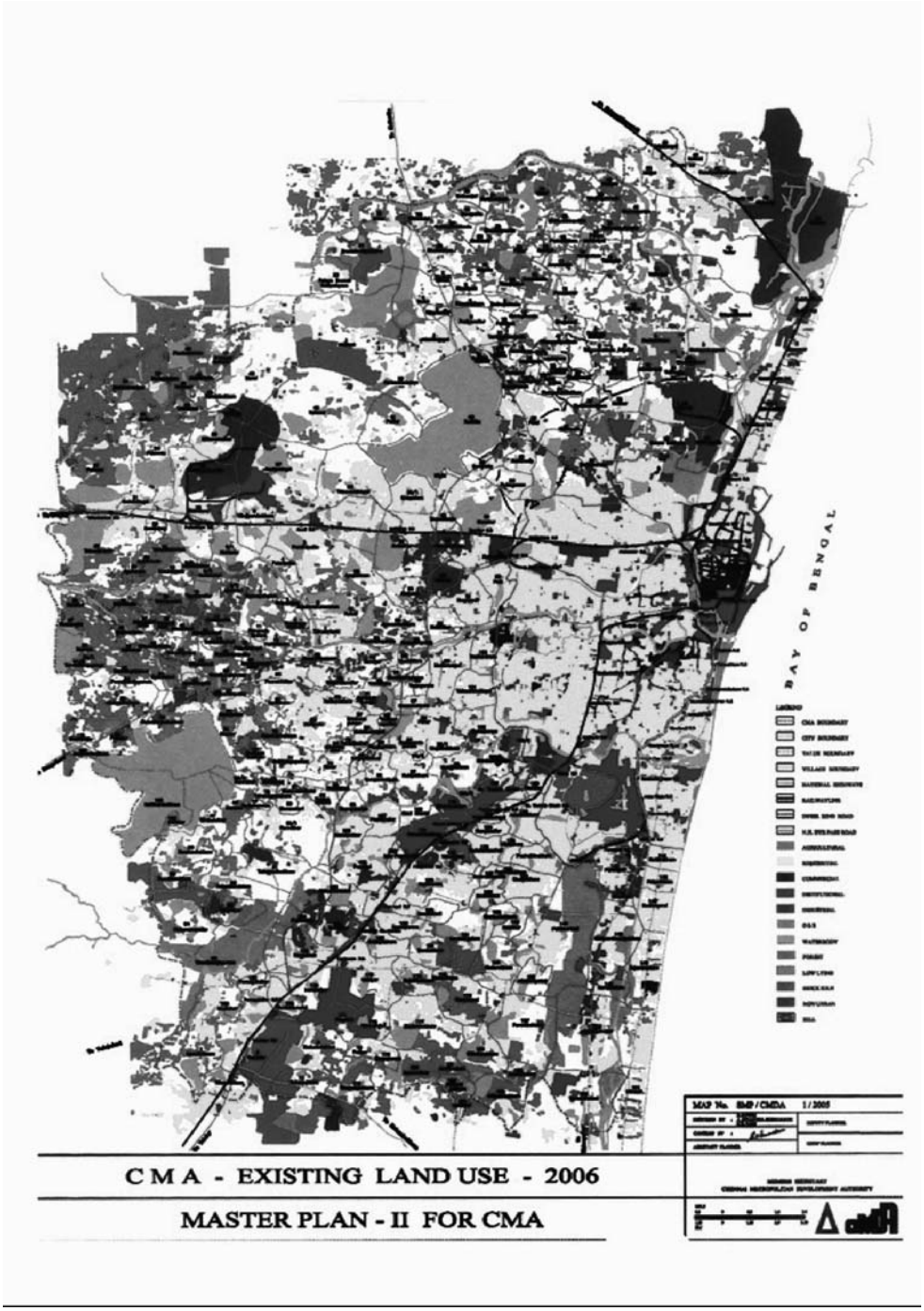
Replacement of level crossings, construction of an Inner Ring Road, Intermediate Ring Road and Outer Ring Road and construction of three bus and truck terminals on the radial corridors at the junctions of Outer Ring Road were the other projects

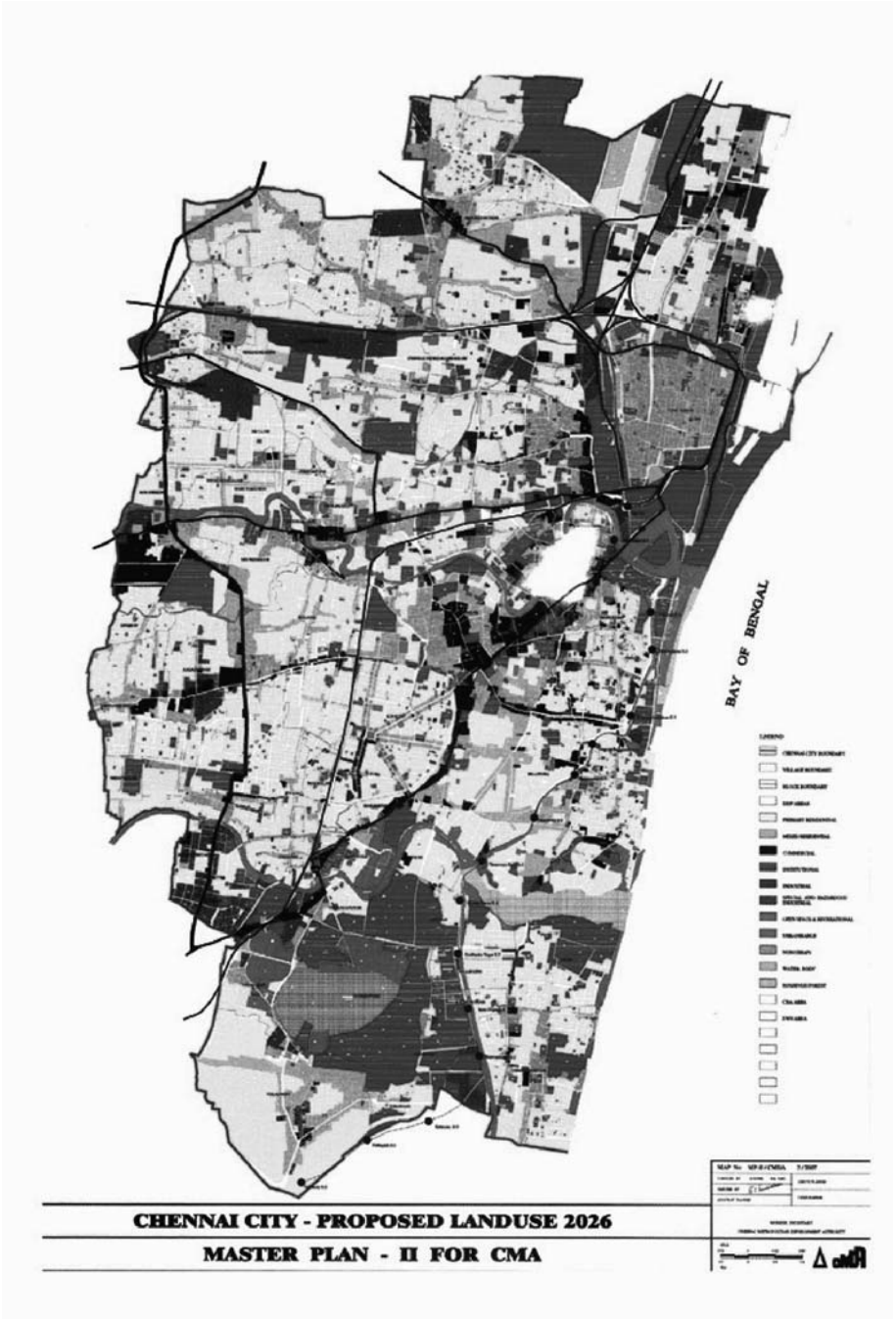


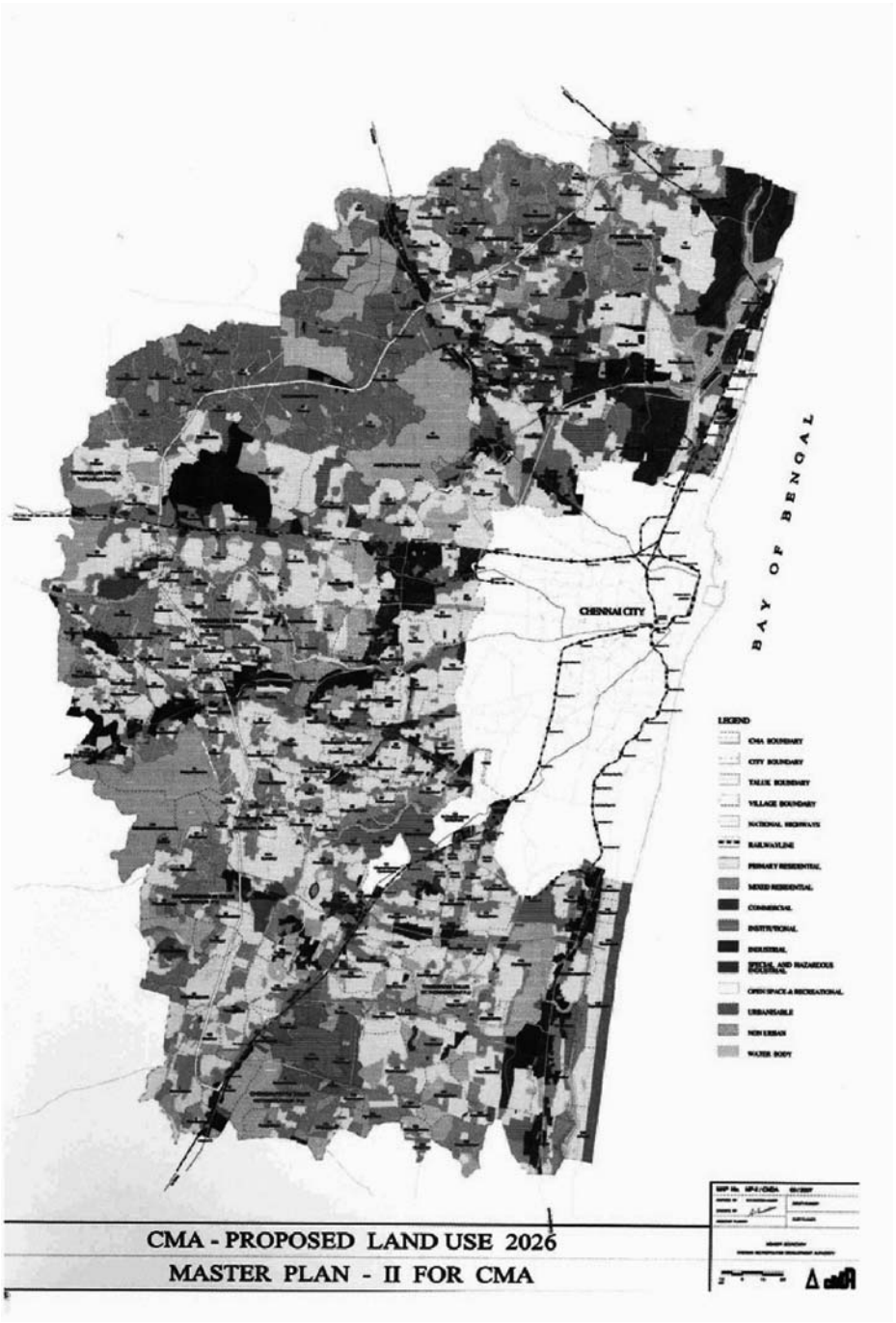
Growth of Madras since 1633



Growth of Madras since 1923


BAY OF BENGAL
CMA - EXISTING LAND USE - 2006
MASTER PLAN - II FOR CMA


BAY OF BENGAL
CHENNAI CITY - PROPOSED LANDUSE 2026
MASTER PLAN - II FOR CMA


BAY OF BENGAL
CHENNAI CITY
LEGEND
CMA - PROPOSED LAND USE 2026
MASTER PLAN - II FOR CMA

Land Use Details - I Master Plan (1975) and Existing Land Use

S.No.	Land Use	Proposed in I Master Plan				In 2001			
		Chennai City		Rest of CMA		Chennai City		Rest of CMA	
		Extent in Hectares	%	Extent in Hectares	%	Extent in Hectares	%	Extent in Hectares	%
1.	Residential	8082	48.57	32256	30.48	9293	52.94	20833	19.92
2.	Commercial	973	5.85	895	0.86	1238	7.05	378	0.36
3.	Industrial	1107	6.66	6362	6.11	890	5.07	6419	6.14
4.	Institutional	2746	16.51	4935	4.74	3180	18.11	2876	2.75
5.	Open Space and Recreational	3254	14.55	7767	7.46	364	2.07	200	0.19
6.	Agriculture	-	-	50924	48.91	94	0.53	12257	11.72
7.	Non-urban	476	2.86	979	0.44	82	0.47	1689	1.61
8.	Others	-	-	-	-	2413	13.75 1	59953	57.31

Land Use - 2006

	Extent in Hec.	%	Extent in Hec.	%
Residential	9523.18	54.25	22876.51	21.87
Commercial	1244.81	7.09	390.04	0.37
Industrial	908.42	5.17	6563.40	6.28
Institutional	3243.39	18.48	3144.35	3.01
Open Space and Recreational	366.43	2.09	200.26	0.19
Agriculture	99.29	0.57	12469.65	11.92
Non-urban	82.46	0.47	2433.30	2.33
Others (Vacant, Forest, Hills, Low-lying, Waterbodies, etc.)	2086.93	11.89	56506.60	54.03

suggested. Assuming the water demand at 227 lpcd and, recognising the severe limitations that prevailed then, the FMP suggested that detailed studies be taken up and programmes for meeting the future demand worked out on that basis.

Noting the severe housing requirements then, the FMP recommended taking up a

massive housing programme by acquiring about 12,000 hect. (120 sq.km.) at urban nodes and satellite towns; most of the new housing by public agencies to be provided in the urban nodes.

The land use plan was enforced through a set of regulations under Development Control Rules, which formed part of the First Master Plan. Any person intending to make any development is required to apply under Section 49 of the Tamil Nadu Town and Country Planning Act, 1971, and obtain Planning Permission. The structure proposed was of radial pattern with city as hub. The main elements of the strategy were:

(a) Restriction of density and population growth in the city;
(b) Restriction of industrial and commercial developments within CMA.
(c) Encouragement of growth along the major transport corridors and development of urban nodes at Manali, Minjur, Ambattur, Avadi, Alandur and Tambaram.
(d) Dispersal of certain activities from CBD.
(e) Development of satellite towns, beyond CMA at Maraimalai Nagar, Gumidipoondi and Thiruvallur.

The land use zoning classifications as per the Master Plan - I are (i) Primary Residential Use zone, (ii) Mixed Residential Use zone, (iii) Commercial Use Zone, (iv) Light Industrial use zone, (v) General Industrial use zone, (vi) Special and Hazardous Industrial use zone, (vii) Institutional use zone, (viii) Open Space and Recreational Use zone, (ix) Agriculture use zone and (x) Non-urban use zone. Further considering the character of (then) existed developments, the CMA was divided into three areas viz. (i) George Town and Continuous Building Area, (ii) Chennai City, Municipal and Township areas (excluding the areas mentioned in (i)), and (iii) rest of Metropolitan area.

The CMDA has been periodically reviewing the land use zoning part of the plan. When a large number of requests are received in a particular area, comprehensive reclassifications have been made not only for residential activities, but also for industrial activities, such as zoning of about 300 m on either side of Poonamallee By-pass Road, OMR, etc.

In 1980, the Development Control Rules provisions were comprehensively reviewed and amendments made whenever necessary particularly in respect of plot extent for residential and commercial developments.

Floods in the City

Historical Floods

Past Records have shown that there were several catastrophic flooding in Chennai in 1943, 1976 and 1985 caused by heavy rain associated with cyclonic activity. These events

of catastrophic flooding were found to be attributable to failure of the major rivers and other drainage systems.

1943

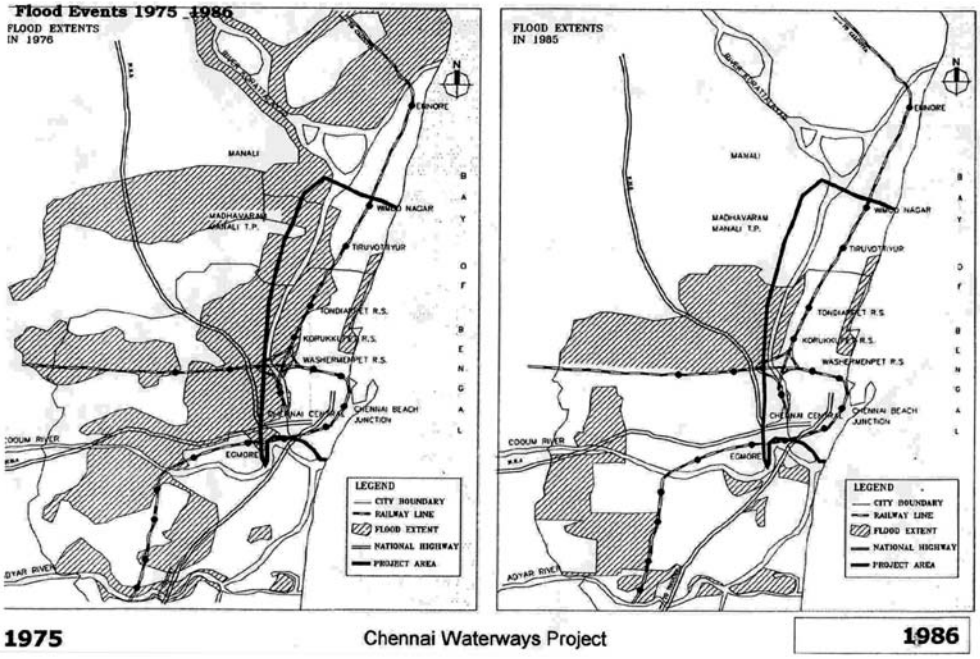
The floods of 1943 damaged the Cooum river badly. Based on the Er.A.R.Venkatachary's report the Govt. had improved the Cooum river and provided a sand pump at the river mouth for removal of sand bar.

1976

In 1976, Adyar, Kosathalayar and Cooum caused heavy flooding of several low-lying areas, and breaches in the bank resulted in heavy damages to the Housing Board Colony. Er.P. Sivalingam Committee had given it's recommendations for prevention of further damages from floods and recommended schemes worth about Rs.12 Crores to be implemented then under priority and schemes worth Rs.10 Crores in the long run (at the 1970's rates).

1985

In November 1985, a rainfall of 727 mm in a span of three days leading to flooding and water logging in many parts of the city.



Recent Floods in Chennai – Detailed Account

2002

October -November

Heavy rains lashed several coastal districts of Tamilnadu including Chennai between October 30 & November 2, 2002. On October 31, Meenambakkam, a southern suburb, received 12.7 cm in just three hours in the evening, while Nungambakkam recorded 7.4 cm. On November 2, 2002, Nungambakkam recorded 16 cm and Meenambakkamrecorded the highest rainfall of 20 cm. The heavy rainfall was attributed to a trough of low pressure, which extended from the Gulf of Mannar to the southwest bay off the Tamil Nadir coast.

Flooding at Madipakkam in 2002

Immediate Impacts

- Many residential areas became `islands' and contact with the outside world was virtually cut off.
- The rains paralysed many parts of the city, leaving thousands of commuters stranded on major roads, scores of vehicles stalled and train and bus services suspended for hours.
- Several parts of North Chennai were heavily inundated with water.
- Water logging also in New Ambattur Industrial Estate Road and at Tirumangalam Police Station, Red hills and Kolathur.

- Anna Salai, Kamarajar Salai, Poonamalee High Road, the three major arteries in the city, and the Inner Ring Road were all choked by flooding of stretches.
- Perambur and Vyasarpadi subways totally submereged - cutting off arterial traffic. In these places, two-wheelers were transported on fish-carts. Doraisamy and Madley road subways were also under couple of feet of water.
- The water-logging on the railway track near Guindy resulted in local train services getting affected. While the EMU services from the Beach station were turned back at Saidapet, those from Tambaram were turned back at St.Thomas Mount. Even some long distance trains were delayed.
- The entire area around the Egmore Railway Station was flooded.
- Water entered several households of Vijaya Nagar and Ram Nagar in Velachery.
- The Keelkattalai bus terminus was covered with sheet of water.
- Severe inundation was also witnessed on Sullivan Garden Road in Mylapore.
- A woman died when she stepped on a live wire on the flooded Sait Colony II Cross Street, Egmore

2004

November

Chennai experienced heavy showers on November 5, 2004. The city about 6 cm rainfall within a period of 24 hours.

On Novermber 12, 2004 due to a trough of low pressure formed over the southwest Bay of Bengal. While Nungambakkam recorded a rainfall of 8 cm and Meenambakkam 5 cm between 8.30 a.m. and 5.30 p.m.

Velacherry

Tiruvottiyur High Road

Immediate Impacts

- Traffic in many parts of the city was affected due to water logging. Motorists had to negotiate knee-deep water on General Patters Road, Royapettah, and many vehicles were trapped in low-lying areas such as Zam Bazaar in Triplicane.
- Stretches of the Poonamallee High Road and Pantheon Road in Egmore were under sheets of water.
- Parts of Velachery and the road from the bus terminus leading to Pallikaranai were badly affected after two days of heavy rain. The road near the bus terminus was flooded and traffic was severely crippled. At Velachery, flooding in several areas forced some schools to declare a holiday.
- In Perungudi and Taramani areas, the road surface has been eroded badly in front of American International School, causing major traffic problems.
- In north Chennai, the Tiruvottiyur bus terminus was flooded and Tiruvottiyur high road suffered severe damage.
- Many slum areas in Tondiarpet were completely inundated.

2005

October

During the north-east monsoon of 2005, a deep depression over Bay of Bengal brought torrential rains in Chennai. The city received 42 cm of rainfall between 8.30 a.m. on 26th Oct 2005 and midnight on 27th October 2005. An additional 18.70 cms was received on October 28, 2005.

Immediate Impacts

- Several low-lying areas, especially in northern Chennai were completely inundated. The worst was Kargil Nagar locality.
- At least 50,000 people in Chennai were shifted to relief centres.
- Schools and colleges remained closed and government offices and private establishments reported thin attendance.
- Buses operated with a skeleton staff.
- Train services were crippled following flooding of the tracks. All trains leaving Chennai were cancelled and those coming into the city stopped at suburban stations, inconveniencing thousands of passengers.
- Flight schedules were disrupted early in the morning.
- The Tamil Nadu Electricity Board, as a precautionary step to avoid electrocution, disconnected power supply in heavily-flooded areas.

- ❖ Water logging and uprooted trees created traffic jams in the morning.
- ❖ Telecommunication came under strain as the mobile networks were fully jammed and landlines failed in some exchanges.
- ❖ Two persons electrocuted in Chennai.
- ❖ On November 6, 2005 , six women died and several others injured in a stampede at Dr.Ambedkar Arts College at Vyasarpadi in North CHennai when flood-affected residents made a dash to a relief distribution centre.

November

Around the 20th of November, a depression was formed over southwest Bay of Bengal and generated heavy spells of rain over the coastal parts of Tamilnadu including Chennai over a period of 4-5 days. Between November 21-22, Tambaram recorded 8 cm, Meenambakkam registered 7 cm while Nungambakkam received about 4 cm.

On November 26, Nungambakkam recorded 5.3 mm of rainfall and Meenambakkam received 0.5 mm of rainfall between 8.30 a.m. and 5.30 p.m. The incessant rains lead to flooding in many parts of the city.

Immediate Impacts

- ❖ Many areas in the city including Mogappair, Kilpauk and Perambur were flooded with rainwater.
- ❖ There was water-logging in parts of western Tambaram. The vast area between Mudichur Road and Tambaram-Somangalam Road was completely inundated.
- ❖ The Selaiyur Lake overflowed and flooded areas around Velachery-Tambaram Main Road, throwing traffic out of gear for a couple of hours. The floodwater entered several houses in Selaiyur and Adhi Nagar. Selaiyur police station was also inundated. Water let out from the lake inundated several areas such as Thiruvalluvar Nagar and Ramakrishnapuram in nearby Chitlapakkam.
- ❖ Most roads in West Velachery were lying under a sheet of water with the flooding entering into a number of homes at Andal Nagar, AGS Colony, MGR Nagar, Ram Nagar North Extension, Padmavathi Nagar and Muruga Nagar.
- ❖ Houses in Mahakavi Bharathi Nagar, Perungalathur are surrounded by waist high water for days now.

December

A cyclonic storm developed in the Bay of Bengal at about 350-400 km east southeast of Chennai. Though the cyclonic system weakened into a well-marked low-pressure area, Chennai and its neighbouring areas experienced heavy rainfall. Numgambakkam in

recorded 23.4 cm rainfall and Meenambakkam 28.2. Tiruvallur district north of CHennai recived 23 cm and CHengalpattu in Kanchipuram to the south reported 15 cm in 24 hours.(between 8:30 am on Decmber 02, 2005 - 8:30 a.m. December 03, 2005). Tambaram, the southern suburb received the maximum rainfall in the state - 31.4 over 24 hours. With the reservoirs already full from the rains during October, heavy flooding gripped the entire city.

Immediate Impacts

- The city's two rivers Cooum and Adyar were in spate forcing thousands of people living along their course to flee their homes. Atleast 75,000 persons were moved to 140 relief camps.
- Houses in Kotturpuram, Ramavaram, Manapakkam were submerged in about 6-7 feet of water. In some parts, residents commuted by boat to buy essentials.
- Stretches of interior roads in Virugambakkam, Arumbakkam, Madipakkam-Taramani and Koyambedu areas were water-logged.
- In Ambattur industrial estate, work was badly affected in 500 of the 2000 units.
- Arterial roads such as the Poonamalle High road, Kodambakkam High road, Arcot Road, Santhome HIgh road were flooded, resulting in heavy trafiic jams.
- Traffic pile-up due to flooding also acute in T.Nagar - vehicle users were stranded in knee-deep water for nearly an hour.
- Purasawalkam High Road and Millers Road were in knee-deep water, while most of Gandhi Irwin Road in Egmore was submerged. Arunachala Naicken Street in Chintadripet was also under water.
- A portion of Inner Ring Road near Tirumangalam junction and the Annanagar West terminus was under water. The Central and East Avenues of Korattur on the city's outskirts and the adjoining streets were in knee-deep water.
- The national highway near Sriperumbudur was water logged, buses from Chennai to Bangalore were diverted via Chengalpattu.
- In the southern suburbs, houses were damaged near lakes such as 'Pazhaya Eri' Moovarasampet, Keelkattalai, Zamin Raayapettai `periya eri', Hasthinapuram and Nemilichery and Selaiyur lakes.
- Water entered the Chennai airport, flooding the departure and arrival halls and the conveyor belt area. Inside Anna International Terminal, water logging was noticed up to the baggage scanning x-ray machines, resulting in the late departure of over 12 international flights, with delays ranging from one to three hours. In the domestic airport, the delay in the departures and arrivals of flights ranged from one to two hours.

- Four dead - Two persons were electrocuted and another two including a child were drowned.
- On December 18, 2005, atleast 42 people were killed and 37 seriously injured in a stampede at a flood relief centre (Arignar Anna School in MGR Nagar) in South Chennai when a crowd of 4000 gathered to collect food coupons.

Kotturpuram

Seetharam Nagar Velachery

Stranded passengers at Central Station

Adyar Bridge

2006

October

On October 27-29, 2006, torrential rains hit several parts of Tamilnadu due to a low pressure that developed in the Bay of Bengal. Some areas that received high amounts of rainfall were in and around Chennai.

On the 27th alone, Tamaraipakkam - one of the catchments for the city reservoirs, recorded 15 cm while Meenambakkam and Red Hills received 14 cm each. Sriperumpudur, Tambaram, Ponneri and Tiruvallur recorded 11 cm each, whereas

Sirkazhi, Parangipettai and Ramanthapuram received 10 cm. The entire city was thrown out of gear with roads getting flooded and public transport being disrupted.

Immediate Impacts

- Water entered homes Ambattur, Vepery, Kolathur, Valasaravakkam and T.Nagar
- The southern suburbs especially Madipakkam, Ullagaram and Perungudi were badly hit. Clogged drains in these areas resulted in water stagnation up to three feet on the streets. The day's worst affected areas were Kubera Nagar and Kubera Nagar Extension, Madipakkam, which resembled an island.
- Residential areas in western Velachery including Saraswathi Nagar, AG's Colony, Netaji Colony, Lakshmi Nagar and Ram Nagar Second Street, V.G.P. Selva Nagar, Annai Indira Nagar and Anna Nagar Extension were flooded with rainwater.
- Several areas falling under Ambattur municipality such as Ram Nagar, Vijayalakshmipuram, Padi Kuppam Road, Ambattur Industrial Estate and Korattur were also flooded.
- Kargil Nagar in north Chennai was covered with two feet of water.
- The stretch from Retteri to Padi junction on Inner Ring Road, Second Avenue at Anna Nagar, Poonamallee High Road, Taylors Road and Dr. Radhakrishnan Salai were flooded with rainwater.
- In Old Washermenpet, two persons were injured when they fell off their bike on Pensioners' Street, 4th Lane, which was under knee-deep water.
- One person drowned in Adyar near Ekkaduthangal off Guindy.
- Several roads in Valasaravakkam lay under water a foot deep, and residential areas such as Sree Lakshmi Nagar, AKR Nagar and Radha Nagar were completely inundated.
- Perambur and Kellys in central Chennai were inundated.
- Ganesapuram subway, which was thoroughly waterlogged, was closed for vehicle traffic and police were regulating the chaotic traffic coming from Vyasarpadi through Stephenson Road and other streets.
- Five of the Metropolitan Transport Corporation's (MTC) - Ambattur, Ennore, Iyappanthangal, Tambaram and Tiruvottiyur - depots reeled under heavy flooding, leading to depleted bus services on Friday. Lakhs of commuters who depend on the MTC's 2,100 plus buses in the metropolis were left to suffer, sometimes for hours, waiting for a bus. — were flooded. The worst affected was the Ambattur depot, which lay under nearly three feet of water.
- All mainline trains to Chennai Egmore from southern districts arrived at least an

hour late due to signal failures between Tiruchi and Egmore. Similarly trains that left Chennai Egmore on Thursday reached their destinations behind schedule.

- Due to water logging on the track between Basin Bridge and Chennai Central, long-distance trains had to be detained at Basin Bridge. They were brought to Chennai Central after the rainwater drained. Suburban services were also hit because of the continuous rain.

Poonamalle High Road

Porur

Kargil Nagar

6th Avenue, Anna Nagar

Govt. declared holiday for all schools on October 27th 2006

Villivakkam Bus Terminus

Perungudi

Fort Station Road

Poonamalle High Road

2007

January

On January 29, 2007, few residential areas of Chennai including Bhanu Nagar, Saraswathy Nagar, Venkateswara Nagar extension and Ayyappa Nagar in Ambattur located on the periphery of the Red Hills lake on Saturday. The lake has been receiving inflow from Poondi reservoir to increase its storage for a few months now. As the inflow into the lake increased, the water spread also increased.

October

On October 28, heavy rains lashed the city of Chennai. Between 8.30 a.m. and 8.30 p.m. on October 28, the Meteorological Observatory in Nungambakkam recorded 11.8 cm rainfall, while the observatory at Meenambakkam recorded 11.7 cm.

- The heavy rains left several roads under water and led to fallen trees. Traffic on P. T. Rajan Salai and Ramasamy Salai in K. K. Nagar, R. K. Mutt Road in Mylapore and at Tirumurthi Nagar near Nungambakkam High Road came to a standstill for a while after trees fell.
- Arterial roads, including Dr. Ambedkar Road in Vyasarpadi, were flooded. The Vyasarpadi Jeeva Railway Station subway was under 2-3 foot deep water.

- Several parts of Perambur were covered with more than knee-deep water.
- Power cuts lasting for few hours were reported from many parts of the city.
- Arterial roads in Velachery and nearby localities were left battered and bruised. Rainwater stagnated on large swathes of Velachery Main Road between the Vijayanagar Bus Terminus and the Gurunanak College.
- The Taramani Link Road and Medavakkam Main Road was also inundated.
- A tree fell across the railway tracks near Perungalathur delaying several trains.
- October 29 was declared a holiday for all schools in the city.

Radhakrishnan Salai, Mylapore

Vyasarpadi

Slums inundate at Saidapet

Vyasarpadi Subway

Kargil Nagar

Taramani

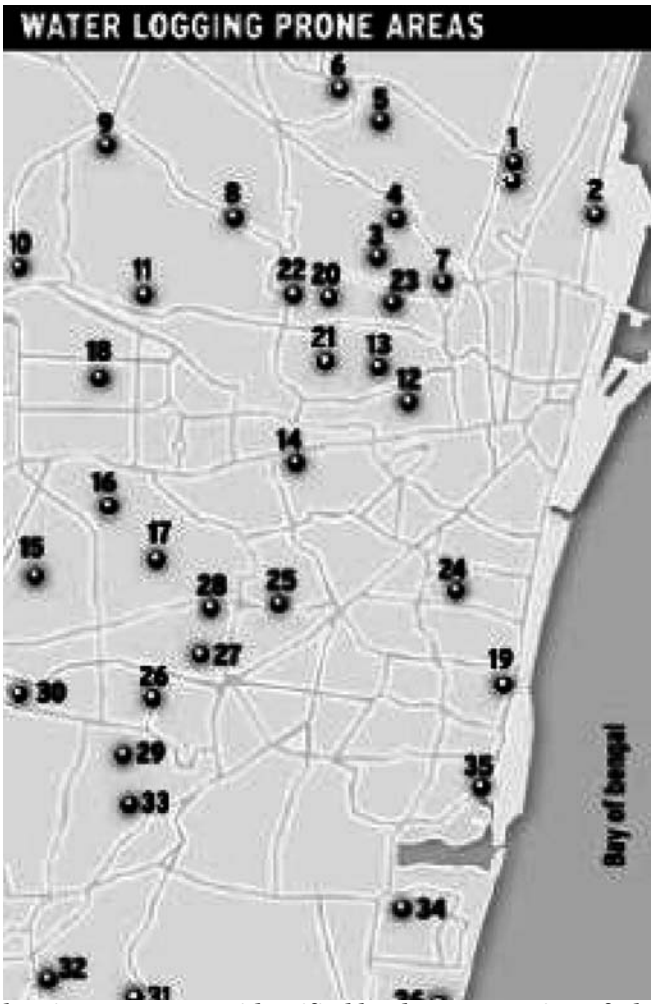
Flood Vulnerability

From the flood hazard map of India, it is seen that no area in Tamilnadu falls in the risk zone. But within a local body area, particularly with reference to an area's proximity to a major drainage system like rivers, canals and other waterbodies like lakes, and further with reference to contour levels / low-lying areas, flood prone areas mapping has to be done.

In Chennai Metropolitan Area (CMA), there are a few areas along the rivers and canals and low-lying areas, which are susceptible to flooding / inundation. The Chennai Corporation has identified 36 localities within the city that are prone to inundation during the monsoon.

The localities identified are: 1. Tondiarpet; 2. Royapuram; 3. MKB Nagar; 4. Sathyamoorthy Nagar; 5. Kannadasan Nagar; 6. Muthamizh Nagar; 7. Pulianthope; 8. Perambur; 9. Kolathur; 10. Villivakkam; 11. Ayanavaram; 12. Choolai; 13. Periamet; 14. T.P. Chathram; 15. Virugambakkam; 16. Arumbakkam; 17. Choolaimedu; 18. Anna Nagar; 19. Ice House; 20. Nammalwarpet; 21. Purasawalkam; 22. S.S. Puram; 23. Kosapet; 24. Mirsahibpet; 25. Valluvar Kottam; 26. Mambalam; 27. Rangarajapuram; 28. Trustpuram; 29. Ashok Nagar; 30. K.K Nagar; 31. East Velachery; 32. West Velachery; 33. Saidapet; 34. Adyar; 35. Foreshore Estate and 36. Tiruvanmiyur.

These parts of the city get inundated each year during the October - January, which is when the north-east monsoons hit the state. Even relatively short bursts of intense rainfall are sufficient to cause local flooding in these parts. .



Water logging prone areas identified by the Corporation of Chennai

(Source: http://www.hinduonnet.com/2007/08/09/stories/2007080955880600.htm)

Factors Responsible for the Floods in Chennai

The analysis of the meteorological data clearly shows that the reason for the increase of floods in Chennai is not based on a long or medium-term trend reflecting increasing precipitation amounts at the eastern coast of India. In fact there is no significant upwards nor downwards trend to identify during the last 200 years. The last 20 years are characterised by a decrease of annual precipitation, although the number of floods affecting the inhabitants of Chennai is increasing.

(A. Drescher et. al, Risg Assessment of Extreme Precipitation in the Coastal areas of Chennai)

Listed below are some factors responsible for floods in Chennai city and its suburbs even under conditions of moderate precipitation.

Uncontrolled Urban Sprawl & Loss of Natural drainage

Uncontrolled urban sprawl has a number of important consequences with regards to urban floods. Out of necessity, spatial development and water were closely interwoven to historic cities. Watersheds were left intact and were often further developed with the objective to harvest rainwater and mitigate floods.

Chennai's natural terrain allowed for floods to drain into the watercourses of north Chennai including the Kosastaliyar, the Buckingham Canal, Otteri nullah and the Captain Cotton Canal. Cutting across the metropolis is the river Cooum and channels that lead into this river. In the South is the Adyar river. Further south is the massive flood plain that stretches from the fringes of Keelkattalai extending into the Pallikkaranai marsh-Velachery Lake, down to the Okkiyam Madagu and Buckingham Canal.

Historically, the growth of the city was also supported by a system of irrigation links and tanks. According to historical records the state had a tank for every 3.3 sq. km area. In Chennai alone, it is estimated that there were 352 tanks though no systematic study has been made.

(*Source: http://www.hinduonnet.com/2003/06/25/stories/2003062508490300.htm)*

Since the beginning of the 20th Century, Chennai has witnessed a steady deterioration of and decrease in water bodies and open spaces. Several people settled down in lake areas and in dry beds of water bodies. The reason being that it is cheaper to buy land and build a small shelter on. Over the years, these houses have been getting bigger. The Government itself, over the years, has built tenements in such areas. For instance, officials concede that the State Housing Board has built colonies on the sites, which were once part of Velachery and Mogappair lakes. Here too, the reason remains the same - less expenditure for government to take over the land.

Natural drainage channels too have been blocked and urban lakes have been filled upon and encroached upon. The rapid growth of the metropolis - planned and unplanned - has resulted in the filling up of substantial portions of this once well-managed water management system.

The Cooum, Adyar and the Buckingam canal today are highly degraded and polluted. They are heavily silted up and narrowed down due to encroachments. The Sludge disposal consultancy study conducted in 1994 has revealed that contamination of waterways and

anaerobic digestion of waste water in the waterways has led to accumulation of sludge causing hindrance to the hydraulic functyionning of the water ways.

The Cooum river narrowed down by encroachments

(Source : http://www.hindu.com/2008/04/21/stories/2008042158880300.htm)

The highly polluted Captain Cotton Canal

Another classic example of degradation of wetlands is the slow disappearance of the Pallikaranai marsh on the outskirts of Chennai. Pallikranai was once a rich wetland spreading over 5,000 hectares, extending from Velachery to Sholinganallur in the east and Jalladampet in the west. It was home to several hundred species of flora and fauna. The marshland also served as an important retention area for strong precipitation during the monsoon.

Garbage being dumped at Pallikaranai

Around the mid-1990s, the Tambaram - Velachery Highway was re-laid. Thanks to this well-laid road, the area has been blessed with enviable development. However, in proportion to this development, the marsh lost its value as a well-balanced ecosystem. Normless constructions and inflow of sewage and other pollutants stripped the swamp of a large extent of land and also of its the fauna and flora.

These constructions, effected without regard for the natural contours of the wetland, have resulted in the clogging of the natural conduits in the marshland. The result, the runoff into the low-lying marshland gets blocked and in the recent times aggravated the frequency and intensity of floods in and around the marshland. Residents in the Velachery - Madipakkam - Nanganallur belt face recurrent floods every year. A number of factors contribute to the inundation. Veerangal Odai, a canal that carries floodwater from areas including Nanganallur and Adambakkam into the Pallikaranai swamp, is not properly linked to the swamp. It terminates abruptly about 2 km before the swamp and this aggravates the problem. Another factor is the lack of enough culverts to enable draining of floodwater from Velachery into the swamp.

The Koyambedu marshland was another wetland that died on the pedestal of development. About 15 years ago the area used to have a lot of wild growth attracting a large number of birds. During monsoon, rainwater used to get stored in the marsh and

it helped in maintaining the groundwater table in the western parts of the city. A few years ago, the marshland was taken over by the Government for housing the vegetable and fruit markets and bus terminus.

Koyambedu wetland converted into the Moffusil Bus Stand

The Adyar creek, originating near the Chettinad Palace, and then meandering through Foreshore Estate and ending at Mandavelipakkam has today been reduced to half its original size - 100 acres. The ingress of the sea through this creek has been arrested because of the silt that has formed at its mouth due to the dumping of garbage and the line of encroachments, especially at the Karpagam Avenue bridge. The fragments that have fallen from a dilapidated footbridge also clog the creek. Due to all these factors, the local fishermen are denied an easy fishing option and the area is also deprived of a natural flood control mechanism.

Satellite Image of the Adyar Creek

Lakes, ponds, canals and tanks have also been encroached upon. The Korattur Lake, a prime source of water for Ambattur Municipality has turned into a reservoir of sullage. Spread over 996 acres with a capacity of 232 million cubic feet, it is one of the largest water bodies in the Ambattur circle. The water body, which was used for irrigation and earlier supplemented the city's drinking water supply, has shrunk in size due to dumping of refuse. It is now partly covered with hyacinth and choked with debris, including industrial effluents.

Storm water drain carrying sewage

During the 2005 floods, Thiruvalluvar Nagar in Mugalivakkam near Porur was submerged under 2 - 3 feet of water. The waterlogging was primarily due to the shrinking of the Manapakkam channel. The channel - once 40 feet wide - drains surplus water from the Porur lake as well as the storm water into the Adyar river at Manapakkam. Due to encroachments and poor maintenance, the flow of water was nil, resulting in the flooding.

(Source: http://www.hinduonnet.com/2005/12/15/stories/2005121518380300.htm)

Temple tanks - a man-made feature in the water management system, are today degraded backyard spaces. The water inlets to the tanks have been completely cut-off - either by constructional activities or with debris and litter. This loss of tanks would result in flooding, as in the case of Vyasarpadi, where 16 tanks were taken over.

Inadequacy of Storm water Drainage System & Lack of maintenance

Chennai City has only about 855 km of storm drain as compared to 2,847 km of urban roads. Besides this inadequacy, the problem of water logging in Chennai gets aggravated every year because drains were not maintained properly. Originally meant to carry rainwater during monsoon period, the drains should remain dry during other seasons. But they are found with water stagnation throughout the year often leading to mosquito menace. Thus, most of the existing ones too have become nothing more than conduits of sewage and solid wastes.

The consumer culture, to which the fast developing Chennai belongs, further adds to the woes of the city. Plastics are often major constituents in the packaging of all kinds of consumer goods. Once the product is unwrapped, the discarded packaging frequently becomes a major contributor to the storm water stream, thereby exacerbating the floods.

Increase in Impermeable Surfaces

Continuous and unplanned growth of the city has covered up open spaces, which have earlier facilitated free flow of storm water. Urban areas including Chennai characterized by high area under impervious surfaces such as roads, pavements, houses and so on. High rates of development along with the loss of soft landscape can lead to high surface water run-off rates. Moreover, there is a tendency in middle and high-class residential areas to pave roads whenever possible. This results in flash floods in low-lying areas even after moderate precipitation.

Lack of Co-ordination between agencies involved in flood control

A number of agencies are responsible for management of storm water in the city. These agencies often blame each other for this lack of maintenance.

Agency	Responsibility
Chennai Metropolitan Development Authority (CMDA)	Project Packaging, Management, Monitoring and Co-ordination
Public Works Department (PWD)	Plan, design and Implementation of Macro-drainage systems (Rivers, Tanks and Surplus Channels)
Chennai Municipal Corporation (CMC)	Plan, design and Implementation of Micro drainage works (Storm water drains)
Tamilnadu Slum Cl;earance board (TNSCB)	Planning, design and construction of storm water in slum resettlement
Tamilnadu Housing Board (TNHB)	Planning, design and construction of storm water on their housing colonies.

The lack of a unified flood control implementing agency that integrates the function of the Chennai Corporation, the CMDA, the CMWSSB and the Slum Clearance Board to carry forward strategies throughout the year, rather than just before the monsoons.

Efforts made to mitigate and manage the Floods

Flood Alleviation Project, 1998

The Government accorded approval for Flood Alleviation Scheme under G.O.Ms.No.321, HUD dated 12/08/1998 for implementing the structural measures in 4 packages with a total cost of Rs.300 crores. The aim of the project was to alleviate the perennial problem caused due to flooding and to improve the environment.

Important Objectives of the Project:

- To ensure and maintain adequate flow in the arterial drainage system
- To prevent and remove impediments to drainage
- To provide safeguards against tidal and fluvial flooding
- To improve all macro drainage networks covering major waterways and canals within CMA and micro drainage network covering storm water drainage network within Chennai City. Improvement measures include desilting of the waterways in the CMA, resectioning and strengthening of the banks, provision of flood protection measures. Structural measures like replacing all old bridges, improvement of existing drains and provision of pumping arrangements and plugging of sewer outfalls into the waterways.

- Further an important component of this scheme was the relocation and rehabilitation (R&R) of encroachers living on the waterways.
- The macro drainage works like structural measures were implemented by Public Works Department and the Resettlement and Rehabilitation works are implemented by Tamilnadu Slum Clearance Board. The CMDA as the nodal agency helps to obtain funding from HUDCO and co-ordinates the implementation of the project. The project is being implemented with 70% of the cost as loan from HUDCO and the remaining 30% from the Government budgetary support as grant. Government will repay the loan through budgetary provisions.
- The macro drainage works were grouped into four packages based on their geographical existence and based on different water courses in CMA and also to obtain loan for better implementation and management.

Package - I

Improvements to waterways in Chennai (Coovum River, Virugambakkam - Arumbakkam Drain and Otteri Nullah) and Resettlement and Rehabilitation;

Package - II

Improvements to waterways in Chennai Buckingham Canal

Package-III

Improvements to waterways in Chennai Adyar & Flood Banks of Kosatalayar

Package-IV

Improvements to waterways in rest of Chennai Metropolitan Area and sandbar removal at the mouth of Coovum River and Adyar River

Cleaning up of the Velachery Lake

Project Progress

The projects have been taken up in phases for execution and up to mid-2005 they have been executed including an expenditure of about Rs.106 Cores.

1. Under R&R Component implemented by TNSCB 3000 tenements had been constructed at Okkiam Thoraipakkam to resettle the slums in the flood alleviation project along 'B' Canal and Adyar river.
2. Desilting of South Buckingham Canal, construction of retaining wall, formation of jeep track along the banks and construction of 10 vents in North Buckingham Canal, repairs to its linings had been completed.
3. Construction of flood defences and resection of the rivers Kosasthalaiyar had been completed.
4. In respect of Adyar river, construction of flood defences and resection works are nearing completion except for the desilting work in the East of the Thiru Vi Ka Bridge.
5. Works in Ambattur Tank Surplus Course, Madhavaram Tank Right Flank Surplus Course and Pallikkaranai
6. 70% of the works in respect of the Red Hills Surplus Course works have been completed; remaining works in this Course and the works in Madhavaram Tank, Chembarambakkam Tank, Korattur Tank Surplus Courses are to be completed after required lands are acquired. Improvements to Otteri Nallah, Virugambakkam - Arumbakkam drain had been completed.
7. Drainage relief works to Velachery area is nearing completion except for the court stayed short stretches.
8. Improvement to the Cooum river from sea mouth to Periyar bridge have been completed and from Periyar bridge to Koyambedu will be taken up after completion of R&R works.
9. The Micro Drainage works to the tune of Rs.43 crores have been implemented by the Chennai Corporation for improvement of the drainage system in Chennai Corporation area integrating with the Macro Drainage System.

Clean up storm water drain in Nanganallur

Chennai City River Conservation Project (CCRCP), 2000

In order to improve the conditions of waterways in Chennai a comprehensive package of projects with an estimated outlay of Rs. 1,700 crores was prepared. The projects proposed included sludge removal and disposal from waterway banks, improvement of macro drainage network in the catchments, improvements of micro drainage network in the the city, improving the water quality of rivers and waterway, strengthening urban drainage network in the city, construction of sewage flow interceptors and treatment facilities. It was posed to Government of India for funding under the National river Conservation Programme. Out of the proposed , the Government of India approved in the year 2000 the schemes for interception, diversion and treatment in Chennai at a cost of Rs. 491.52 crores and it was implemented by Chennai Metropolitan Water Supply and Sewage Board (CMWSSB). In addition, the remaining works to the cost of Rs. 228.63 crores was taken up by the CMWSSB.

Second Master Plan Provisions

Drainage

1. All the structural and non-structural measures recommended in the Madras Metro Flood Relief (MMFR) / Storm Water Drainage (SWD) Master Plan Study Report of 1992-93 should be implemented to alleviate the existing flood problems and also to ensure prevention in future during the plan period (considering more than 50% of

the 2026 population is proposed to be accommodated in the rest of CMA, and the City will also get densified additionally by 35%.).

Structural Measures Recommendations

S. No.	Structural Works	Cost (Rs. in million)
1.	Pallikkaranai Scheme	160
2.	Flood defences and channel improvement on the Cooum	348
3.	Flood defences and channel improvement on the Buckingham Canal	96
4.	Flood defences and channel improvement on the Otteri Nullah	125
5.	Flood defences and channel improvement on the Captain Cotton Canal	20
6.	Flood defences and channel improvement on the Madhavaram Surplus Channel	10
7.	Flood defences and channel improvement on the Red Hills Surplus Channel	215
8.	Flood defences on the south side of the Kosasthalaiyar	50
9.	Manali Township drainage and flood protection	40
10.	Urban storm water rehabilitation and repairs	35

All cost estimates are preliminary - year 1993

Non-structural Structures Recommendations

1. Designated floodways on the North side of the Kosasthalaiyar with associated planning controls and flood warning/evacuation procedures.
2. Design guidelines for drainage systems
3. Planning and regulatory controls to prevent development in old tank beds unless adequate flood defence measures are in place
4. Planning and regulatory controls to prevent encroachment of squatter settlements in old tank beds and watercourses
5. Provision of good facilities (vehicles, communications) for flood emergency management
6. Public education (e.g. to prevent solid waste dumping in urban drains)
7. Flood risk mapping
2. In CMA, all the lakes vested with the departments/agencies (such as Revenue

departments, etc) other than PWD, should be transferred to PWD for its proper maintenance. Further, all these lakes and major drainage system within CMA should be brought under the control of a separate Division/Circle in PWD, which should be, in-charge of continuous planning and implementation of flood alleviation projects and maintenance of these water bodies.

3. The lakes / water bodies should be protected from encroachments and existing encroachments should be evicted by the departments/agency concerned bringing the water bodies to its original state.
4. The lakes may be developed not only as a flood accommodator and for ground water recharge, but also as open space with trees as wooded areas.
5. Drainage system around Pallikaranai area has to be designed taking into account of the I.T. development and also future developments in the area.

Sewage

Under Ground Sewerage Scheme in the Urban Local Bodies

CMWSS Board has been appointed as a nodal agency to implement under ground sewerage schemes in the urban areas adjacent to the city. Under Ground Sewerage Schemes have already been implemented in Alandur and Valasaravakkam municipality and are under various stages of implementation in Ambattur (Part), Pallavaram, Thiruvottriyur and Madhavaram (Phase-I) municipalities. In case of Ullagaram-Puzhudivakkam, the board has prepared the plan and submitted to the municipality for arranging funds under JNNURM.

Detailed Project Reports (DPR) are under preparation for 6 municipalities, namely Maduravoil, Kathivakkam, Madhavaram (Phase-II), Avadi, Ambattur (Left out Area), Tambaram, Porur Town Panchayat and Ramapuram and Manapakkam Village Panchayats.

For the following adjacent urbanized local bodies (5 Municipalities, 17 Town Panchayats, 22 Village Panchayats and one Cantonment) CMWSS Board has invited tenders to prepare Detailed Project Report for providing Under Ground Sewerage Scheme. On finalization of Detailed Project Report the work will be taken up in Phases under JNNURM Scheme.

Municipalities	1. Poonamalle 2. Thiruverkaddu 3.Pammal 4.Anakaputhur 5. Manali
Town Panchayats	1. Chinnasekkadu 2. Meenambakkam 3. Naravarikuppam 4. Thiruninravur 5. Minjur 6. Thirumazhisai 7. Mangadu 8. Nandambakkam 9. Puzhal 10. Kundrathur 11. Perungalathur 12. Peerkankaranai 13. Chitlapakkam 14. Sembakkam 15. Madampakkam 16. Perungudi 17. Pallikaranai.
Village Panchayats	1. Kottivakkam 2. Mugalivakkam 3. Pozhichalur 4. Cowlbazaar 5. Kilkattalai 6. Nerkundram 7. Ayanambakkam 8. Madipakkam 9. Neelankarai 10. Okkium-Thoraipakkam 11. Injambakkam 12. Koilambakkam 13. Medavakkam 14. Karapakkam 15. Iyyappanthangal 16. Ayapakkam 17. Vanagaram 18. Nolambur 19. Kattupakkam 20. Seneerkuppam 21. Mathur 22. Palavakkam.
Cantonment	1. St. Thomas Mount

Construction of Additional Sewage Treatment Plant at IT Corridor

South Chennai is witnessing rapid growth and development especially due to IT and IT-based industries and associated housing projects. The present capacity of Perungudi Treatment plant is not adequate to match the growing needs. Therefore, it is proposed to construct an additional 54 MLD capacity Sewage Treatment Plant at Perungudi. The proposal has been approved by the Government of India under Jawaharlal Nehru National Urban Renewal Mission (JNNURM) at an estimated cost of Rs.31.48 crore by JNNURM. The work will be taken up during the current year and will be completed in 18 months.

Improvements to the sewerage facilities in Guindy Thiru Vi Ka Industrial Estate

Guindy Thiru vi ka Industrial Estate Manufacturer's Association's long-pending request for rehabilitating and upgrading the sewerage system has been accepted and accordingly the project has been sanctioned at an estimated cost of Rs.6.95 crores. The work has been commenced during December 2006 and will be completed.

Strategies for flood control at Chennai

1. Encroachments and obstructions to the waterways are indeed the main causes for floods in the city. The level of encroachment has increased manifold between 1985 and 2005. Clearing the encroachments is essential to provide relief.

2. Identifying lakes, water bodies and their flood channels both inlets and outlets.
3. Shrinking of marshlands are causing floods in Chennai. Clear demarcation of areas where no development or encroachment can be allowed.
4. Revival of temple tanks and other small tanks in Chennai.
5. Detailed Development Plans need to show the pathway of the flood carrier through every neighbourhood. If building a road across a waterway or lake is unavoidable, plan the required number of siphons and their size to carry huge flood levels.
6. Avoid narrow roads in new layouts. The minimum road widths should be a minimum 33 ft., so that there is enough space for storm water drains, and a clearly demarcated and isolated sewage system.
7. The local communities should be involved in the protection to protect lakes, rivers and water bodies. Make them responsible for the lake upkeep. People living near water should be imparted knowledge about water as a natural resource and methods by which water may be preserved and conserved. In short, they should be made water literate. Government should facilitate the process by providing technical assistance and part-funding.
8. Vigorously continue the desilting operations and river water conservation projects so that sewage fallout into water bodies is completely avoided.
9. The use of Geographic Information System (GIS), Global Positioning System (GPS) and Remote Sensing (RS) data to plan drainage for Chennai is essential. Appropriate action should be taken at the earliest.

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Urban Floods: Case Study of Kolkata

Mohit Bhattacharya

Introduction

The phenomenon of urban flood has in recent times engaged the attention of planners and administrators because of its disastrous consequences for the urban settlements in terms of sudden interruption in orderly and productive urban situation, and the human sufferings and damages to life, property, and urban infrastructure. In India many of our large urban agglomerations such as Greater Mumbai, Delhi, Kolkata and other areas have been used to living with flood as a matter of annual routine, and only recently national level discussions are going on to study the ground level reality and intervene in a planned manner in the flood situations in the large mega cities.

Approach to the Study

Generally, the public policy response in regard to `floods' has been basically relief and rehabilitation oriented. Only recently, wider policy implications of floods mitigation and floods control and management have come to the fore, as there is increasing realization at policy levels that `floods' need to be viewed in wider perspective in terms of planned natural resource management and disaster management to avoid resource loss and wastage. This is in sharp contrast to the conventional 'relief' oriented emergency flood management that has been the characteristic response of urban public authorities. It is now being suggested that the concerned public authorities are to adapt their policies to coalesce flood emergency relief operation, and management measures, spatial development planning and innovative strategies on safety standards.

Structural measures such as improved drainage system, installation of new pumping stations and so on are usually undertaken to reduce the probability of flooding. In addition, new approaches need to be developed to mitigate the impact of flood. Proper land use planning and management, zoning, flood insurance, water harvesting are a few examples to modify the susceptibility of the urban environment to flood damages. Equally important in this context are the innovative non-structural measures such as

* Contributed as Kolkata city team under National Coordinated Project of NIDM (Gupta, Anil K. and P.G. Dhar Chakrabarti, *Disaster & Development*, 3 (1):1-14, 2009)

community sensitisation and awareness, and local people's preparedness to face up to the challenges of the flood situation

Nidm Study

A very timely and much desired initiative has come from the National Institute of Disaster Management (NIDM) of the Ministry of Home Affairs, Government of India, to study and analyse `Urban floods' in the large cities that contain the nation's wealth and have large concentrations of urban population. The cities chosen for the study are Bangalore, Bhopal, Chennai, Delhi, Hyderabad, Kolkata, Mumbai, and Surat.

To have a degree of uniformity in presentation of the cases, a broad framework has been proposed focusing on:

- profile of the city
- city infrastructure with special reference to drainage
- floods in the city
- efforts made to mitigate and manage the floods, and
- strategies for the future.

Kolkata: History, Topography, Climate, Demography

The choice of Kolkata as one of the worst flood-affected metro cities has been very appropriate. Kolkata city has been living with annual visitation of widespread floods since, possibly, its birth in the early eighteenth century. Strangely enough, despite acute and large-scale human sufferings and colossal economic losses due to annual flooding, the city seems to have accepted it as annual routine. A city widely known for regular vociferous protests and processions has virtually been used to tolerating monsoon floods as a sort of way of life. The reactions have at best been journalistic with widest possible media coverage of flood scenes in newspapers and television channels. Surely, the civic body - Kolkata Municipal Corporation - girds up its loins as a sort of one-shot job, during emergencies, to ameliorate the sufferings of the citizens. What defies imagination is that a city that has been undergoing bouts of 'planning experiments' since the early sixties of the last century, continues to face flood ravages as a kind of annual 'festival'(?) of human misery; and managerially speaking, there has hardly been any worthwhile and effective longer term policy planning to come to firm grips with this regular cycle of 'natural' calamity. Only recently, as we will have occasion to refer later, a phased programme has been launched to save the city dwellers, to a great extent, from the regular onslaught of annual floods. The 'added areas' of the KMC annexed in the 1980s did not have proper drainage and sewerage

facilities and had been used to annual flooding during monsoon. An ambitious drainage and sanitation programme was launched in August 1998 with ADB fund ($ 220 million) to give the added areas a modicum of sewerage and drainage facility. This programme popularly known as KEIP (Kolkata Urban Improvement Programme) has been going on since then, giving some relief to the residents of these outlying areas. For the core city, the JNNURM programme has come as a god send; a large drainage and sewerage plan has been submitted under the Mission which has since been cleared by the Government of India. We will be discussing both the programmes later under 'strategies for the future'.

History, Topography and Climate

Like all 'Asiatic imperial cities', Kolkata was developed with a dual entity. At south, the 'white' European city had semblance of planned and orderly growth - with clean houses, wide roads and well laid-out pathways and gardens. But at north, the natïve city existed 'with its black, ill-lighted, narrow, slimy lanes'. The cultural divide between the two segments of the city was so deep that even after two hundred years it has not been possible to completely integrate these two halves. Thus, Kolkata suffers from the problems most of which had their historical roots in the city's colonial past. Kolkata's development was different due to its peculiar `land form' pattern as much as to its major communication routes - which run predominantly north-south along the riverbanks. The river Hooghly, over centuries, has deposited large quantities of alluvial silt along its both banks, forming natural levees of high land suitable for human habitation on both banks. Here the land slopes away from the river all along the banks and within short distances - about four to five kilometres away from the river, low-lying areas or swamps begin. Therefore, physical extension of the city towards easterly direction was practically restricted. This peculiar landform characteristics presented great constraint for any compact urban development form around a fixed nucleus.

Thus, in physical growth pattern of Kolkata the inevitable had happened. Rapid demographic growth could not be matched with supply of good quality build-able land for human settlement or with any systematic provision of extension of basic transportation and infrastructure networks throughout the city. Already developed build-able areas steadily got saturated and substantial communities had grown up in the low lying suburbs of eastern and south-eastern fringes. Within the municipal limits of Kolkata, the fastest growths have occurred in those relatively less accessible low-lying, poorly drained, un-sewered areas of Borough VI and XI to XV. (The City has 15 Boroughs as decentralised units of administration.) The urban growth that took place subsequently could not strike any desirable relationship with the existing landform

pattern of Kolkata. Residential growth, in fact, has been occurring in areas of severe geographical constraints where the only lands available for development were mainly those rejected as unsuitable by the earlier generations of Kolkata's residents. These lands are either predominantly low-lying, swampy and immediately flooded by the monsoon rains each year or squatted upon land of railways, canal banks, even dry canal beds, garbage disposal areas and the like. It is not only very expensive to make these areas suitable for decent urban living, it also became highly difficult and expensive for the Kolkata Municipal Corporation to extend all basic utility and civic services to these areas at later dates.

Physical Features

Kolkata is geographically located in the northern hemisphere, between $22^0$30' N to $22^0$37' North Latitude and $88^0$18' E to 88023' East Longitude. The city stands on the eastern or left bank of the river Hooghly, a former mainstream course of the River Ganga - at an average elevation of 6.40 meters from the Mean Sea Level. It is located about 145 km away from the mouth of the Bay of Bengal.

The natural landform characteristics of Calcutta[1] make the city's drainage problem inevitably problematic.[2] The land is more elevated towards the west and is gradually tilted towards the eastern marshy land which has been partly reclaimed and developed into the present Salt Lake City. The highest parts of the city lie along the eastern bank of the Hooghly River, maximum elevation being 9-12m. In the northern side, land slopes downward rather steeply; while in the south, the slope is gradually reaching to a height of 4.2m. The riverside levee is the highest part of the city. At Garden Reach on the riverside, the levee is nearly 7m above the mean sea level. Towards Tiljola on the eastern fringes, the height of the levee comes down to less than 3m. It is to be noted, therefore, that the entire drainage and sewerage network planning of the city is based on this eastern slope of the land.

Kolkata falls within the lower deltaic plane of the Bengal Basin, formed by the Ganga-Brahmaputra River System. General slope of the terrain is from north to south with local variations towards east and southeast. As mentioned above, the high ground on either side of the Hooghly River and areas in close proximity provide the city with a very gentle slope towards east. In the eastern part of the city, large wetlands and marshy areas with extensive swamps - spreading over an area of about 12,000 hectare - provide a unique `urban eco-system' in an environmentally sensitive area. This area has been declared as

1 Calcutta and the later Bengali version of Kolkata mean the same thing.
2 Saswati Mookherjee, 'Problems of Waterlogging in Calcutta', in Subhasranjan Basu (ed.), Changing Environmental Scenario of the Indian Subcontinenent, acb Publications, Calcutta, 2002.

the `East Kolkata Wetland and Waste Recycling Region' and has been recognized as a `Ramsar Site' by the `International Union for Conservation of Nature' (IUCN), a global agency. The East Calcutta Wetlands are widely known for the unique sewage fed fish culture-cum garbage farming system, that has been providing for long a natural demonstration of a wonderful resource recovery and recycling system on a grand scale.

As the city constitutes a part of the lower deltaic plain of the Bengal Delta, its soil is represented by a huge thickness of unconsolidated younger deltaic deposits of Holocene age. The sediments are composed of sand, silt and clay in varying proportions and often associated with angular calcareous concentration (kankar), decomposed organic matters and one or two peat layers. Since there is a close linkage between landform, sediment content and depositional process in deltaic environment, the composition of sediment in different landform units vary considerably. The presence of decomposed vegetative matter, wood pieces and peat layers within the clay silt deposit at shallow depth throughout the area, represents palaeo-tidal flat environment similar to the present- day environment of Sundarban area with mangrove vegetation.

Seismic Vulnerability

The city is located under zone-III or a 'moderate intensity earthquake prone zone' as per "India, Earthquake Hazard Zoning Map" (Vulnerability Atlas of India - Series), and IS 1893-2002, part-I. However the city borders very close to zone-IV towards the east, and therefore seismic activity is not very uncommon in this part of Bengal Basin. In the past, a number of earthquakes of high to moderate intensities (V-VI) have rocked Kolkata and its surrounding areas.

Climate

Kolkata's climate is essentially a tropical one. Further the presence of a large river and abounding swamps in very close proximity to this city makes Kolkata's climate characterized by high humidity and relatively higher temperature, but the city does not experience the extremes of temperature or humidity. The average diurnal temperature remains high for about eight months in a year - that is from the month of March to October. The highest maximum temperatures in a year are recorded in the months of May or June, when in some days the mercury touches around 40 to 42 degrees Celsius mark. During this time the nights are also very warm and sultry. A few Nor'westers occasionally relieve this uncomfortable weather conditions during evenings.

Rainy Season

The rains are generally preceded by cloudy weather condition with southerly winds from the sea. With onset of rains from mid-June, the city experiences sporadic showers with occasionally heavy downpour. In wet season, there can be prolonged periods of rain, which can last for three to four days at a stretch. The period from July to September is the rainiest when the city receives as much as 1000 to 1200 mm of rainfall due to intensive monsoon activity. During these three months the city receives nearly three fourth of its average annual precipitations. The adjoining graph gives a vivid picture of monsoon rains in the city over a twenty-year period. In 2007, there has been an unprecedented rainfall of 410 mm in the first week of July itself. When the weather clears after the rains, from early October onward, there is only a marginal drop in the temperature level though humidity remains very high even then, as may be seen from Table 1.

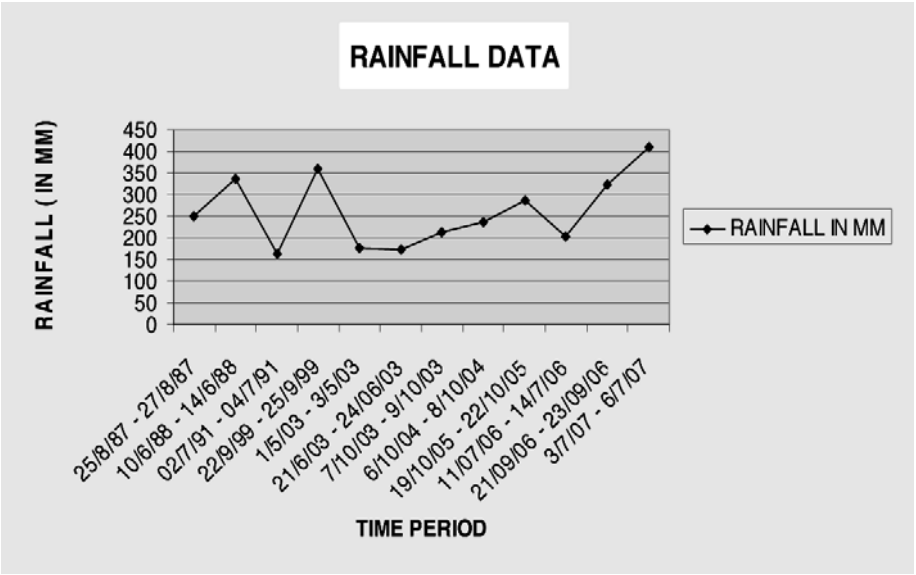


Table 1: Average Temperature, Relative Humidity & Rainfall in Kolkata

Month	Temperature (°C)				Relative Humidity (%)		Average Precipitation(mm)
	Average		Record				
	Min	Max	Min	Max	Max	Min	Total in a month
Jan	13	27	7	32	85	52	10
Feb	15	29	8	37	82	45	31
Mar	21	34	10	40	79	46	36
April	24	36	16	42	76	56	43
May	25	36	18	42	77	62	140
Jun	26	33	21	44	82	75	297
Jul	26	32	23	37	86	80	325
Aug	26	32	23	36	88	82	328
Sept	26	32	22	36	86	81	252
Oct	24	32	17	36	85	72	114
Nov	18	29	11	33	79	63	20
Dec	13	26	7	31	80	55	5

The cool weather sets in by the middle of November and lasts until mid-February. During this period the average temperature remains moderate around 25 degrees Celsius. December is the driest month of the year. However the dampness of climate manifests itself in frequent fogs over the river and water bodies including low surrounding areas. From around the end of February the days again begin to be clearer and appreciably warmer and in March - April the temperature rises rapidly during the day times.

Population

The population of Kolkata Municipal Corporation stood at 45.728 lakhs on 31March, 2001. The city has registered only a very marginal growth of 3.93 percentover its base population of 1991. Kolkata is one of the slowest growing cities among most metropolitan cities of India. The table below indicates that during last forty years the decadal growth rates of population have been steadily declining. Since 1991, Kolkata has been reporting a single digit growth rate on a diminishing basis, as could be seen from Table 2.

Table 2: Population Figures of Kolkata Municipal Corporation During 1951-2001

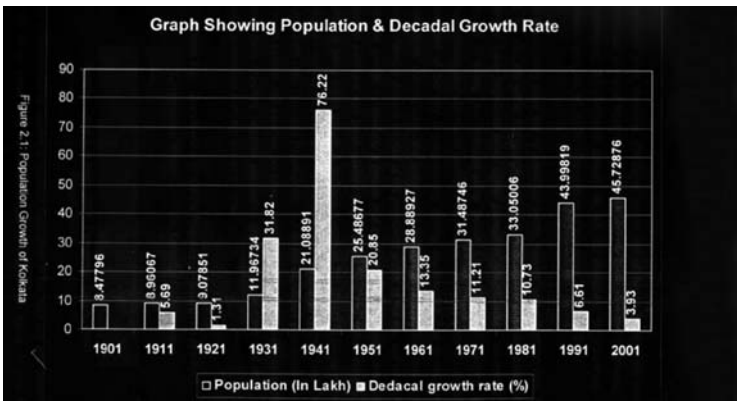
Census Year	Population (in thousand)	Growth Rate (in percentage)
1961	2889	…
1971	3149	11.21(61-71)
1981	3305	10.73(71-81)
1991	4400	06.61(81-91)
2001	4572	03.93(91-01)

Source: Census of India volumes, Population Tables

Note:

(1) There has been a major jurisdictional change in the area of Kolkata Municipal Area after the enactment of KMC Act, 1980. Accordingly all previous population figures of Kolkata have been readjusted to same physical area.

In real terms, growth rate figures for last two decades indicates depopulation in terms of the original city. Detailed ward-wise examination of census data reveals that out of 141 municipal wards as many as 60 wards have returned negative population growth rate during 1991-2001, and out of these there are at least 12 wards that have recorded negative growth rates during last three successive census operations. The wards, which have registered such declining population trends are all located within the dense residential areas of North and South Kolkata, for example wards 23 (Posta), 24 (Jorabagan), 37 (Amherst Street), 40, 48, 50 (Sealdah), 68 (Gariahat), 72 (Bhawanipur), 84, 85, 86, 87 (Gariahat and Lake area).



On the contrary, there are 18 municipal wards, located under Borough Nos VII, Xl, XII, XIII, XIV within Tollygunge, Jadavpur, Thakurpukur and Metiabruz police stations, that have registered much higher population growth rates - exceeding 25 percent - during the corresponding period i.e. 1991-2001. Judging from this phenomenon, one conclusion seems obvious - while the original congested core area of the city is progressively getting depopulated due to residential populations' out-migration and commercial invasion to residential areas, some new residential districts located at the peripheral wards of the city are absorbing this new growth. Locationally it seems that most such new growths are taking place in southern and southeastern fringes of the core city. While there is no record of comparable growth in the northern fringes, there is definite evidence of growth taking place in suburban municipalities outside the limits of KMC like Bidhan Nagar, South Dum Dum, North Dum Dum and Rajarhat. But for the significant population growth in south eastern and southern peripheral wards of the KMC, the city as a whole would have reported negative population growth rates in 1991 and 2001, as could be deciphered from the figures in Table 3.

Table 3: Distribution of KMC's Population Growth - 1991-2001

Corporation Wards	Av. Decadal Growth Rates (in %)
1-100	1.34
101-141	+23.89

Source: Census of India: 2001. Population Tables: West Bengal (S-20)

This phenomenon of relative population stagnation in the core city and dispersal to the fringe areas is by no means unique for Kolkata city alone. All over the world, growth of metropolitan cities shows similar trends. With increase in size of the city and consequent expansion of various tertiary and service sector activities, land prices increase in core city leading to replacement of low value land uses like low income residences by high value, economically remunerative land uses. Further, higher rental structures squeeze out the low-rent accommodations to give way to high-rent commercial activities or luxury residences.

Kolkata Urban Agglomeration (KUA)

Kolkata Municipal Corporation, along with Howrah city forms the core of the second largest urban agglomeration of the country, only next to Greater Mumbai. In 2001, the

Kolkata Urban Agglomeration (KUA) had a population of 13.20 million. It appears that with rapid urbanization of rest of the metropolis, the share of Kolkata city with respect to the entire KUA has been slowly going down over the decades. Even then Kolkata held about 34.6 percent of total KUA's population in 2001 as it can be seen from Table 4.

Table 4: Urban Population in West Bengal and KMA: 1971-2001
(Population figures in million)

Year	West Bengal: Urban	KMA (Urban)	KMA's Urban share in West Bengal urban (%)	Kolkata City	Kolkata's share in KMA's Urban (%)
1971	10.97	7.42	86.18	3.14	50.13
1981	14.33	9.19	87.61	3.30	44.94
1991	18.71	11.02	87.18	4.40	39.92
2001	22.43	13.22	89.81	4.57	34.57

Source: Census of India, 2001: West Bengal, Series 20, and other Population Tables.

Migration Pattern

Kolkata's economic and cultural dominance over the entire region of eastern India, containing a quarter of India's total population, is overwhelming. Its attraction for migrants in search of employment and services is unrivalled by any other urban centre in the region. Thus the city has grown and perhaps suffered also, as its physical infrastructure and urban services have failed to cope with the mounting demographic pressure. The close interdependence of the city and its vast hinterland makes it imperative that the development of the region and that of the city be viewed as parts of a combined process. To understand the growth of the city, it is essential to consider the urbanization pattern of the hinterland. The crucial demographic fact about Kolkata is that the city had received substantial volume of migration in search of employment during the last hundred years. Kolkata had the misfortune of receiving two streams of migration from two different sources - one from the relatively poverty stricken rural hinterland of the eastern regional states and the second, when the city received a sudden

surge of displaced persons following the trauma of partition of the subcontinent. In this process, the city has overgrown along with its fringes, blurring the statutory boundaries of the local bodies - both urban and rural - in the fringes.

Though data on migration into the KMA as a whole over the period 1991-2001 are not available from the census, population growth figures of the city of Kolkata reveal that the streams of migration are no longer affecting the recent composition of the city. During the last fifty-year period, an additional ten million people - were reported to have come into the city from neighbouring Bangladesh as refugees, following the 1947 partition and subsequent events. Migration figures to the city since 1921 are given in Table 5.

Table 5 Migrants to Kolkata Municipal Area during 1921-91

Year	Total Population (in lakh)	Migrant Population (in lakh)	Percentage of Migrants
1921	10.31	3.25	31.52
1931	11.41	3.57	31.29
1941	21.09	6.64	31.48
1951	25.49	13.45	52.76
1961	29.14	7.58	26.01
1971	31.36	10.62	33.86
1981	33.05	9.28	28.08
1991	33.8	7.12	21.06

Source: Vision 2025 Perspective Plan of KMA: 2025: Draft Final Report, December 2005, KMDA (Table-3.18, pp 3-29)

Density of population is an important indicator in urban planning for the estimation of requirements of utilities and community facilities. Density also affects the environmental condition of a human settlement. Also, in accommodating future population growth and prospective commercial uses of land, assessment of optimum density is important. In 2001, the gross population density of Kolkata city stood at 24718 persons per sq. km, registering only about 4 percent growth over the 1991 figures. Looking at the density map of the city, it becomes clear that the central business districts

witnessed highest densities. Ward no. 23 has a very high density of 144,000 persons per sq. km, followed by Wards 24, 28, 39, 41, 62 and 134 - where the density figures range from 120,000 to 150,000 persons per sq. km. The density falls rather sharply at the peripheral Wards - for example, at Ward 57 near Dhapa, where the density is only 9357 person per sq. km or about one third of Kolkata's average. The gross population density of the city is shown in Table 6.

Table 6: Gross Population Density in Kolkata - 1961-2001 (pop. /sq. km.)

Year	KMA	Kolkata
1961	3817	16740
1971	4651	18813
1981	5666	22308
1991	6826	23782
2001	7950	24718

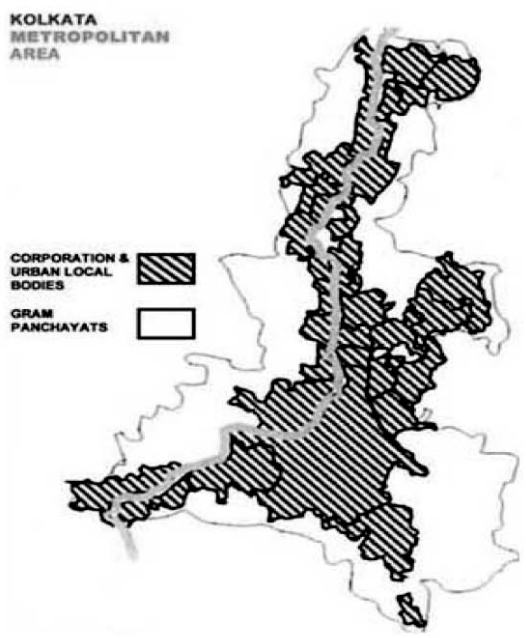
Source: Compiled from Census Data

The core city seems to have already reached near saturation point in terms of its population holding capacity. Indeed some of the municipal population growth figures during last three successive decades are due to out-migration of their resident population. As more and more residential areas near Central Business Area (CBA) are being converted into commercial or similar higher remunerative uses, the people are moving out of these wards, being pressurized by `rent squeeze'. In contrast, the peripheral wards, notably the added areas of Kolkata Municipal Corporation, are witnessing a positive growth in population - sometimes higher than the KMA rates even due to fresh population consolidation -resulting in population equilibrium at around little higher than the existing level. As per the Perspective Plan for KMA for 2025, the most likely resident population estimate for Kolkata city in 2025 is 4.682 million - a meagre addition of 1 lakh (100,000) in next two decades. Nearly 3 million additional people from KMA and beyond enter or use this city every working day for jobs, education, medical attention, service delivery or transport. The anticipated figure for future years would definitely be much higher when more and more tertiary sector jobs would be created in the city - a fact that city planning has to seriously reckon with.

Planning Interventions

Urban planning and development came to be nationally recognised as a focused area of governmental attention only towards end of the Third Five Year Plan in 1961. This was the time when Kolkata was not only exhibiting massive demographic growth but also was beset with the worrying problem of inadequacy of civic infrastructure and services. The cholera epidemic of 1958 drew the attention of the national government and the international agencies like the World Health Organization (WHO). This led to the creation, for the first time in 1960, of an urban planning organization in West Bengal - the Calcutta Metropolitan Planning Organization (CMPO), as a sequel to the WHO Report on Calcutta's environmental health and sanitation. The Basic Development Plan (1966-86) published by CMPO in 1966 presented a fairly detailed and well-researched Perspective Plan - no doubt a pioneering effort of its kind in India. This was followed by two sectoral Master Plans, namely, `Comprehensive Traffic and Transportation Plan' and the `Master Plan for Water Supply, Sewerage and Drainage'. The Basic Development Plan suggested for Calcutta a massive dose of infrastructure improvement, primarily with a view to arresting further deterioration in public utilities and services.

The national Fourth Five Year Plan recognized for the first time the need for special attention to urban infrastructure development. But due partly to overall economic recession in the country and partly to other factors, financial support was not readily available at that juncture. As the civic infrastructure facilities deteriorated further and reached almost a point of total collapse, the Government of India stepped in to bring about institutional change to arrest further deterioration and to work out planned intervention in the city's civic infrastructure and facilities. That was the historic moment in 1970 of the creation of the Calcutta Metropolitan Development Authority (KMDA). The objective was to study the urban



situation and to come out as quickly as possible with a definitive rescue plan that would be implemented with assured fund support. With great speed, the KMDA prepared several key planning documents having bearing on the phased development of the city. More important among these were the `Development Perspective and the Action Program' (1976), and the `Plan for Metropolitan Development: 1990-2015' in 1990. The State Planning Board in 1991 published the draft of `A Perspective Plan for Calcutta: 2011'. The KMDA thereafter in 1992 published the `Development Needs of Calcutta Metropolitan Area: 1992-2002', the `Calcutta Mega City Program: Project Profile and Investment Plan' in 1994, and `The Vision and Perspective Plan for Calcutta Metropolitan Area: 2025'. Besides, the sectoral Master Plans for Water Supply, Sanitation & Drainage; Traffic & Transportation; and Environment and Bustee Improvement were published in 2006.

Under the West Bengal Town and Country (Planning and Development) Act, 1979, KMDA was designated as the Planning and Development Authority for the KMA and it prepared the `Land Use and Development Control Plans (LUDCP) for Kolkata Municipal Corporation Area in 1996. Presently the KMC is carrying out development control functions in terms of LUDCP, as required under the Act. In 1997, the Environment Department, Government of West Bengal, with assistance from the DFID, U.K. prepared the `Calcutta Environmental Management Strategy and Action Plan' (CEMSAP) for the KMA (see attached map). The Kolkata Municipal Corporation, with international assistance (from Asian Development Bank) has since been engaged in the planning and implementation of a massive environmental improvement programme called the `Kolkata Environmental Improvement Programme' (KEIP).

Municipal Management Set-Up

Historically, Calcutta Corporation had grown up during colonial times as a highly centralised and bureaucratically controlled civic body. Despite democratization of the Corporation Council by fits and starts, it had basically been a Commissioner (the chief executive)-dominated municipal organisation. This basic set-up remained unaltered even after independence. So the legacy of a strong professional executive has lingered on, and the KMC's professional wing continues to be headed by a senior IAS officer as Commissioner.

Mayor-in-Council System

Under the Kolkata Municipal Corporation Act, 1980, a cabinet-type Mayor-in-Council

was introduced which marked a revolutionary change in municipal management - a quantum jump from the age-old colonial system of Commissioner-dominated bureaucratic management to a new political executive system headed by a Mayor along with his team members in the Mayor-in Council. The salient features of the present Mayor-in-Council in the KMC are:-

- After a general (Municipal) election, the Mayor is elected by the elected members of the Corporation from amongst the members (141 councillors are elected from as many Wards).
- The Deputy Mayor and other members of the Mayor-in-Council (Mayor's Cabinet) are chosen by the Mayor from among the elected members, all of whom function during the pleasure of the Mayor.
- The Mayor distributes charges (port-folios) among members of the Mayor-in-Council (12 members in all including Mayor and Deputy Mayor).
- The Mayor-in-Council is jointly accountable to the Corporation (the whole body of elected Councillors)

On the lines of the cabinet system, the Mayor is the head of the political executive called the Mayor-in-Council which consists of 12 members including the Mayor and the Deputy Mayor. Each member of the Mayor-in Council, like a minister in the cabinet system, holds charge of specific municipal functions (see Mayor-in-Council chart). Each member of the MIC looks after the functioning of specific departments of the KMC. The concerned departmental officers, as shown under KMC's Professional Wing, serve and report to their respective MIC Members.

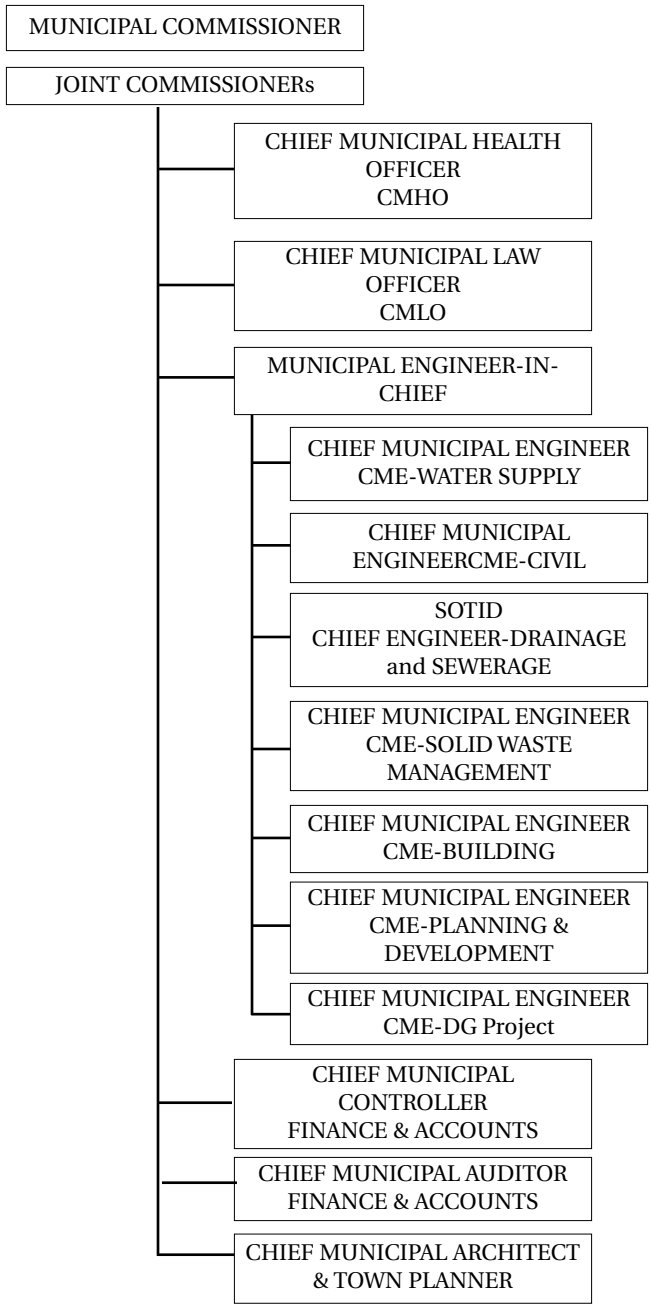
The relevance of certain departments, from the perspective of flood planning, mitigation and management, is quite obvious. For instance, the departments in charge of drainage and sewerage, and solid waste management would be directly involved in flood management activities. KMC's civil engineer would be having major responsibility in respect of building collapses and clearing roads of uprooted trees.

Mayor - in - Council

Sl. No.	Name	Port Folios
1	MAYOR	General Administration, Finance & Accounts, Internal Audit, Personnel, Assessment - Collection, Planning & Development, Vigilance, Municipal Secretary's Department, Law, Records, Market, KMDA and other agencies' works, ADB, World Bank, DFID and other externally aided projects and any other work not covered under this allotment.
2	DEPUTY MAYOR	Water Supply to Shipping and Stores.
3	MMIC(WATER SUPPLY)	Generation and distribution of water.
4	MMIC (IPR and P&G)	Information and Public Relations, Parks & Gardens and Sports
5	MMIC (BUILDING)	Building and Licence.
6	MMIC (BUSTEE)	Bustee Development and Welfare Services and SSEP
7	MMIC (R & E)	Roads & Engineering, Asphaltum, Footpath, Sewer, Nikashi.
8	MMIC (EDUCATION)	Education.
9	MMIC (SWM)	Solid Waste Management and Entally Workshop.
10	MMIC (Ltg.)	Street Lighting & Electricity, Environment, Training Institute.
11	MMIC (HEALTH)	Health, Disinfection Services, Vaccination, Vector Control, Epidemic Control, Hospitals, Maternity Homes, Dispensaries, Chest Clinics, Analysts, Ambulance, Slaughter Houses, Burning Ghats and Burial Grounds, Registration of Birth & Death, Prevention if Food Adulteration, Central Medical Stores and T.B.Hospitals.
12	MMIC (S & D)	Drainage Pumping Stations, Mechanical Sewer Cleansing and Man-entry sewers.

Note: MMIC stands for Member of the Mayor-in-Council.

KMC's Professional Wing



Borough Committees

The KMC has 141 wards that are, for decentralization purposes, formed into 15 Boroughs each having a Borough Committee consisting of the elected members of the Wards falling within the Borough limits. The formation of Borough Committee introduces a kind of municipal federation, as powers and function are divided between the Central Municipal Office and the Borough Committees. Under the Regulation framed under the KMC Act, a Borough Committee has been given responsibility for the followed functions:

- Provision of supply pipes
- Sewerage and drainage connection to premises.
- Removal of accumulated water on the streets or public places due to rain or otherwise,
- Collection and removal of solid wastes
- Disinfections, provision of health and immunization services,
- Bustee services,
- Provision of lighting,
- Repair of locality-level roads (categories IV, V & VI)
- Maintenance of parks
- Drains and gulleys, and,
- Such other functions as may be delegated to the Borough Committee by the Corporation.

There is a Borough Officer (usually an Executive Engineer) who coordinates the work at the Borough level and executes the decisions of the Borough Committee. All resolutions of the Borough Committee are forwarded to the Mayor whose decision (in regard to acceptance or rejection) is final. Not all the Officers located at the Borough level are accountable to the Borough Committee, nor are they placed under the control of the Borough Officer. The Assistant Engineers in charge of water supply, drainage and sewerage, and roads report to the Borough Executive Engineer. But the decentralised solid waste management set-up has its own old 'District' based organisation which has hardly any relationship with the Borough administrative set-up. Interdepartmental financial relations have not been dealt with either in law or regulations, so there are no definite assigned revenue sources on which the Borough Committee could rely. Abject financial dependence on the Central Office coupled with the independent functioning of many of the field offices of headquarter departments has stood in the way of harmonious working of the decentralised Borough system and has naturally weakened

KMC's decentralization plan. Currently, attempts are being made to mend matters and strengthen Borough administration by placing almost all the field functionaries under the control of the Borough Committee.

Ward Committees

The need for decentralization and participative local management is now constitutionally recognized. The formation of ward Committee at the level of the locality or the electoral Ward has been mandated by the Constitutional (74th) Amendment Act, 1992. KMC Act has accordingly been amended providing for the formation of Ward Committee in each electoral ward. A ward committee consisting of the councillor elected from the ward (who acts as the Chairperson) and the nominees of the Corporation and the Councillor, is to help the Borough Committee and the Corporation in the following activities:

a. Identification of the problems of the ward and prioritizing them,
b. Overseeing the proper execution of various municipal works and services in the word,
c. Development and maintenance of civic services by enlisting people's participation and receiving feedback from the people from time to time,
d. motivating the people of the ward in making timely payment of tax and non-tax revenue,
e. planning and execution of various obligatory and discretionary functions as laid down in the Act,
f. detection of violation of various provision of the Act such as unlawful construction, encroachments on municipal and public properties, public nuisance, evasion of taxes, unlicensed activities, and the like,
g. arresting wasteful use of various municipal services like tap-water, street hydrant, street light, parks and playgrounds, community centres and libraries and the like
h. organization of greater civic participation by holding periodical meetings,
i. Listening to the grievances of citizens and, making arrangement for their redressal, and
j. Any other functions entrusted to the committee by the Borough Committee/ Corporation from time to time.

In sum, the Borough Committees and the Ward Committee are designed to introduce and sustain a participatory mode of civic administration. Both the devices are expected

to bring about a deepening of democracy as well as efficient and effective delivery of civic services. Strong ward committees, if and when these would be really functional, would go a long way to mobilise local civic energy in aid of normal municipal administration. In an emergency situation like flood control, the ward committee would be of immense help to organise and orchestrate local citizens' support for flood relief operations.

Unfortunately, the KMC's record in constituting ward committees has not been up to the mark, and special efforts at the political level are urgently called for to set up ward committees through out the KMC.

Flood Stuation

Turning to the flood situation in the city, during monsoon, the city is used to facing severe waterlogging for days together at many pockets every year. In 2007 the flooding had been quite extensive and damaging. A vivid pen-picture of the city's location-specific flood situation is portrayed here based on KMC's official report on 'Natural Calamities on 30th June, 2007.

1. Big trees were uprooted at the following points:
   In front of Basanti Devi College, Rawdon Street, Indian Museum, 40 N.S. Road, Middleton Street, Medical College, Elgin Road, Garcha Road, 1 Humayun Kabir Avenue, Gurusaday Road and Surawardy Road.
2. Three cases of electrocution reported; CESC has taken appropriate action.
3. At Choubhaga Point, the State Government's Irrigation & Waterways Department has 30 pumping machineries. All the pumps remained inoperative since 7-30 am to 12-00 hours due to non-availability of CESC power. After intervention, power was made available at about 12-15 hours and 20 pumping machineries were put into operation.
4. There was 105 to 120 mm rainfall all over the city, while the drainage capacity of the core city is only 6 mm per hour.
5. The water level at Palmer's Bazar rose to 17 ft. high while the normal level is 10 ft.
6. Water level at Choubhaga point rose to 8 ft. (2.7 meter) while the normal level is 2 ft.
7. The tidal effect of River Ganga was at high level from 7-30 am to 12-00 hours.
8. Building collapses at the following places have been reported. No report of death, however, was received:
   - 5 Girish Avenue, Borough-IV: part of existing two-storied old building has collapsed. Owner of the premises removed the debris.
   - 98 Manicktala Main Road: Existing single-storied Nut-Mandir has collapsed.

KMC has engaged labourers to demolish the remaining portion of the structure.

- 20/8/1, Brindaban Basak St.: Old two-storied vacant buildings attached with the adjoining premises in three sides have collapsed. KMC had earlier served notice declaring 'dangerous building' status. Demolition work has now been started to pull down the remaining portion.

9. Water Supply: Normal. Disinfection of water supply line will be undertaken in the afternoon.
10. Health: Borough Health Officers placed at 15 Boroughs of KMC have been alerted.
11. SWM: Normal activities are on.
12. The situation started improving since 12-00 hours.

Operation of Pumping Stations

The 'pumping stations' stationed at discrete locations of the city become the life-line of the city during the floods. An important report released regularly by the KMC authorities relates to ameliorative measures, particularly with reference to the draining out of flood waters through the operations of the pumping stations located in different parts of the city. The situation of the pumping stations as these were being operated at different locations is presented in Table 7.

Media Reporting & Citizens' Responses

Area-wise flood situation, as reported in the important Calcutta dailies, is presented below to give a first-hand impression of the crisis situation obtaining in different parts of the city.

General Post Office (9am)

The stretch in front of the GPO, which is just a stone's throw from Writers' Buildings - Government Headquarters - was under knee-deep water as office-goers were found struggling to make their way to work. The ongoing repair work on the pavement and a fallen trees made it a mess. "BBD Bag (former Dalhousie Square) has been badly hit. The knee-deep water is making it tough for cars and pedestrians," said a sergeant on duty.

Table 7: Pumping Stations: From 6 am to 9 am on 13.6.2007

Name of the Drainage Pumping Station	Cumulative Rainfall (in mm)	How many pumps in total	How many pumps under repair	How many pumps running condition	Outfall channels
1. Palmer Bazar	117	13	3	10	Town Head Cut Canal + DWF Channel
1a. Manicktala	75	5	1	4	Relay (PBPS)
1b. Belgachia	-	2	-	2	Relay (PBPS)
1c. Thanthania	107	2	-	2	Beliaghata Canal
2. Pagladanga	-	3	1	2	Town Head Cut
3. Kulia Tangra	-	2	-	2	Town Head Cut
4. Ballygunge	105	12	2	10	Suburban Head Cut Canal
4a. Mominpur	129	8	3	5	Boat Canal + Relay(BDPS)
4b. Chetla	79	3	-	3	Relay (BDPS)+ Tolly's Nullah
4c. Kalighat	72	2	-	2	Tolly's Nullah
4d. Jodhpur Park	51	5	-	5	Relay (BDPS)
5. Dhapa Lock	31	8	2	6	Central Lake Channel
5a(i). Ultadanga	70	11	2	9	Kestopur Canal + Relay of Dhapa Lock
5a(ii) Ultadanga Siphon	-	2	-	2	Kestopur Canal + Relay of Dhapa Lock
6. Topsia	48	7	2	5	SWF Channel
7. Birpara	2	2	-	2	Bagjola Canal
8. Nimak Mahal	-	2	-	2	River Hooghli
9. Southern Avenue	-	4	-	4	Tolly's Nulla
TOTAL		**93**	**16**	**77**	

Park Street (10am)

The food-and-fun street resembled a river during first half of the day. The cars swam and the food shops were flooded. McDonald's declared a rainy day and downed shutters, while Music World could not open before 1.30pm.

Ultadanga(11am)

The traffic junction at Ultadanga was thrown completely out of gear as the knee-deep water refused to recede. The ripples/waves were felt from VIP Road to Salt Lake and all the way down the EM Bypass.

Chittaranjan Avenue, up to Girish Park (noon)

The entire stretch was under water and vehicles were just not moving. All the arterial roads leading to and from Chittaranjan Avenue were also under water.

"It took me close to an hour to come from Girish Park to Medical College and Hospital," grumbled Rajesh Jhajharia, behind the wheel of his car.

Mahesh Agarwal blamed the civic authorities: "We were told last year by the civic engineers that the stretch opposite Mahajati Sadan would not be waterlogged. But look what has happened on Day One of the monsoon. We could not open our shops because they were all flooded."

Amherst Street (12.30pm)

If Park Street was a river, Amherst Street was more like a sea. Waist-deep water made the cycle van the only means of transport. Students of Shri Shikshayatan College, desperate to get to City College (North) for their Part II exams, did not mind paying Rs 50 each for a place on the submerged van rickshaw.

Most shops and establishments were shut. "An hour's downpour has exposed the inefficiency of the civic authorities even before the monsoon has set in properly," said Joy Sengupta, a resident.

College Street (1245pm)

It was no better for students arriving at Presidency College for admission tests. "Only we

know how we managed to come here from Baruipur - a suburban town. The train services were hit and there was no public transport available. When we got here, we were told that the exam had been postponed from 9am to 11am. There was no electricity and no drinking water on the campus," alleged Chaitali Banerjee, whose daughter was appearing for the test. All the bookstalls and shops were shut. College Street was a no-entry zone.

Elgin Road (1.30pm)

The mall-and-multiplex street of south Calcutta was practically out of bounds till 2pm. Till then, the knee-deep water made it a road to avoid for cars and shoppers alike. Rickshaws were the only wheels that turned. "Forum was almost deserted till 2pm," said an official at the Elgin Road mall.

Topsia Road (2.30pm)

Residents say the water-logging begins as soon as clouds gather. So, it was no surprise that Topsia Road drowned on Wednesday. Said resident Mohd. Atif: "Not only is the area flooded, it is flooded with such filthy water that it makes living here a serious health hazard. But the civic authorities won't bother. They should come here and see how we live."

- Srabani Roy Karmakar of Maharani Indira Devi Road, in Behala, has been living in knee-deep, filthy water since the downpour on July 3. She has no clue when the water will recede.
- Samir Sen, of Nibedita Sarani, is not just marooned; he is reportedly being forced to share space with snakes and poisonous insects.

Scenes such as these will greet visitors to several Behala pockets - the southwest fringes of the city.

A week had passed since the deluge, but Kshudiram Pally, Green Park, Adarsha Nagar, Mahendra Banerjee Road, Motilal Gupta Road, Hemanta Mukherjee Road, Subhas Marg, Airport Road, Pally Sree, Anandanagar and Joyrampur had still remained waterlogged.

"Aamra Shobai jole bondi (We are all imprisoned in water),"said Timir Bose, of Motilal Gupta Road, summing up the situation.

"We had never faced such a crisis," said Ratna Sur, the chairperson of Borough XIII of the Kolkata Municipal Corporation. She blamed the situation on the "negligence" of the engineers who are supervising the drainage revamp work, under the Calcutta Environment Improvement Project (CEIP) in Behala.

These are just some selective snippets of the widespread urban floods that, as earlier pointed out, have been a regular annual feature of the city's living design.

Municipal Administrative Response

Recent records of dealing with this kind of flood emergency (June, July 2007) reveal KMC's fairly prompt response to the stress situation. The Mayor held rounds of meetings with key officials of the KMC to review the flood situation from time to time. The canal system that serves as the main outfalls of KMC is under the management of State's Irrigation and Waterways Department. The Mayor held special meetings with the concerned officers of the I&W Department to ensure orchestration of the KMC's flood relief activities and the canal system operation by the State Department. Even the Minister in charge of Municipal Affairs took personal interest and held meetings with the key officers of the KMC to make an appraisal of the situation and work out short and long term plans for the city's flood mitigation. At the operational level, the Commissioner, Joint Commissioner (Development), the Engineer-in-Chief and the departmental heads of drainage and sewerage, solid waste management, civil engineering works, lighting, and health teamed up as an emergency operational group. The Mayor and the Commissioner used to review the overall situation through video conferencing which had been a very effective mode of tracking and monitoring the area-wise condition in the different boroughs of the Corporation. The field situation was being constantly monitored via the control room. The operations of the pumping stations including their electricity supply position were being constantly monitored. Supplementary arrangements were made for deployment of portable pumps in different boroughs. As many as 266 pumps were deployed out of which 46 were in operation in Borough VII alone.

Action Plan for Health, Water supply, Civil Works

During floods, apart from attending to immediate calls like electricity line repairs or removal of uprooted trees, emergency relief operations need to be mounted to give succour to affected people particularly in respect of food, water, and health related matters. From the recent experience, it transpires that relief materials for food and shelter had to be rushed to the families marooned in worst affected localities. In July, at the height of the crisis, the supply position in different boroughs had been as shown in Table 8.

Table 8: Item-wise Relief Materials Supply

Items	Qty.
Tarpaulin	550 pieces
Chira	30 Qtls
Gur	6.5 Qtls
Sugar	2.25 Qtls
Rice	4 Qtls
Dal	5 Qtls

To ensure effective and quick supply of relief materials, a special ad hoc arrangement was made for the procurement and supply of these essential items to the citizens in the worst flood affected areas of the city, particularly in the poorer localities.

The Health Department of the KMC had sprung into action by mobilising field workers, nurses and medical officers who had been working in full swing to ensure that the city did not get affected by public health hazards and vector borne diseases. At the borough level, the health establishments were alerted and asked to maintain adequate stock of emergency medicine and allied items. Individual councillors in their respective constituencies were charged with the responsibility of distributing ORS packets and Halogen tablets among the people in their areas. As many as 38,510 ORS packets and 1.13 lakhs Halogen tablets were thus distributed locally which possibly had yielded good results, as there was no report of widespread epidemic either during or after the flood.

The other important measure taken was disinfection work jointly with the SWM Department. Door-to-door surveillance had been intensified to track and monitor cases of fever and diarrhoea syndromes. Also, the department took prompt anti-malaria measures, particularly through anti-larval measures and early diagnosis and treatment. Important IEC activities had been the spread of awareness about general public health issues - particularly awareness against acute diarrhoeal diseases in the flood-affected areas. One mobile medical unit was set up to rush to affected areas on emergency call.

Precautionary measures through installation of extra submersible pumps were taken to prevent water logging within the water supply generating stations as well as the booster pumping stations. Through water tankers, water had to be supplied to water logged areas - 44 tankers making 334 regular trips supplied 1,76,000 litters on a single day (July 5, 2007). Besides, 6.150 stand posts and 738 small dia tube wells had to be disinfected in specific water logged areas.

During flood, building collapses and uprooting of trees are common occurrences. During June-July (2007) floods affecting extensive areas of the city, the civil engineering section had to respond to quite a few calls of building collapses in older parts of the city. From about 67 locations reports had come in of uprooting of trees that needed to be cleared promptly to restore traffic. Extensive road damage is another episode during floods. In 2007, as many as 84 roads had been badly affected due to heavy showers and consequent submerged condition. A moderate estimate was that KMC would be requiring about Rs. 1.60 lakhs for repair of potholes and damaged patches at different part of the city.

Ad hoc Response

Every year KMC wakes up to the flooding problem of the city during monsoon. Despite regular annual visitations and the attendant human misery and infrastructural damage and dislocation, KMC has not been able to develop a regular system of municipal flood management set-up. The response has always been ad hoc and instantaneous. Nor has the urban flood mitigation plan (since none exists) been integrated with the city's holistic urban planning. Kolkata has now been included as one of the Mission cities, under JNNURM, for which purpose the city has to have a comprehensive city development plan (CDP) as a funding conditionality. So, it is to be expected that water-logging issues and the city's larger problem of planned flood proofing would find a definite place within the CDP. The other aspect that deserves careful consideration is the preparation of a well-thought-out Flood Management Manual to consolidate the numerous ad hoc measures taken from time to time to cope with the city's flood problem. Once the Ward Committees would be in position, citizens need to be taken in confidence to develop in each ward, particularly in the most affected wards, participative local flood mitigation plans.

Need for Coordination

In the present Mayor-in-Council set-up, two members have almost overlapping portfolios - one holding charge of 'solid waste management', and another holding charge of 'drainage pumping stations, mechanical sewer cleansing and man-entry sewers'. Even in normal times, they need to coordinate their functioning; and in times of emergency, like meeting the flood situation during the rainy season, they have to coalesce and integrate their working both at headquarter and in the boroughs. In fact the two members of the Mayor-in-Council should form a kind of nodal point for data-based advance planning for flood warning, and prevention and mitigation. The

Member holding charge of 'health' has a major role to play during and after the flood to prevent epidemic outbreak and keep the municipal public health management system in a state of readiness.

The Control Room which functions round the clock even in normal times assumes a major role during flood emergency in terms of information collection and dissemination among the KMC departments. A senior officer, usually of the rank of Deputy Commissioner is placed in charge of the Control Room during emergencies along with a group of two to three supervisory staff to support him. It is time to think of developing a regular blue print for the organization and functioning of the Control Room during emergency operations.

Major Areas Of Water-Logging

There are clearly identifiable areas in the city which are prone to flooding each year. Details of some of the badly affected flood prone areas of the city are indicated below to give a first hand account of the flood situation in these areas. The descriptive account portrays (a) the site characteristic, (b) major reasons for flooding, and (c) the mitigation measures already taken or being proposed for the area in question.

1. College Street area

The college street area bounded by Sukea Street on the North, Kolutola Street on the South, Central Avenue on the West and Amherst Street on the East is a chronic water logging area within KMC that suffers from stagnation of water for hours together during every Monsoon in any heavy or even short duration rainfall. The whole area is at relatively much lower elevation than the surroundings and water from all sides of the area rushes to this part. The drainage of the area is served by the network of sewers leading to the trunk sewers along Kolutola Street and Mechua Bazaar Street and partly through the Sukea Street sewer and finally goes to the terminal pumping station (PBPS). The rate of storm runoff accumulation in the area is more than the rate of disposal of storm water through the sewer network. This can be attributed to two factors: 1) the reduction in hydraulic capacity of the sewer network due to heavy silting and 2) the existing gully pits being completely choked and not being sufficient in number. Cleaning of the gully pits to enhance the proper inflow of water to the sewer and cleaning of the sewer network and lining of them to enhance the hydraulic capacity of the system may partially solve the problem of water logging. This requires further study for a planned approach to the area's problem. To reduce the water logging problem in the area CMC has installed a pump house in this area at Hrisikesh Park in the last year

with an idea to discharge the accumulated water in this area to the near by Circular canal through force main. Water intake to the pump house is being done by connecting some lateral sewers in the area by an inlet sewer leading to the pump house. Water heads up in the sewer network and finally leads to the sump of the pump house through the connecting inlet sewer and is pumped to the Circular Canal through the force main. The problem of water logging is reported to have been reduced in respect of duration of inundation after installation of this pump house but this may cause malfunctioning of the sewer network in the long run as the direction of flow in the sewers has become reversed against the slope of the sewers that may cause more siltation in the sewers. Detailed recommendation is possible after further study.

2. B.B.Ganguly Street and Central Avenue Crossing

The water-logging at the junction of the B.B.Ganguly Street and Central Avenue Crossing is a localized problem. The sewer along the B.B.Ganguly Street was intercepted by the Metro Railway tunnel across the direction of the sewer. The invert of the sewer is slightly elevated due to the Metro Tunnel below the sewer. This location of the sewer requires regular maintenance so that silt does not deposit, allowing free flow of water through the sewer.

3. B.B.Ganguly Street near Writers' Building

Immediately after the formulation of 1966 Master Plan, CMWSA laid storm drainage network along Netaji Subhas Road, in-front of Writer's Building, Hare Street, Koilaghat Street and Clive Street and then along Strand Road and ultimately having three outfall sewers to the River Hooghly (Ganges) through the Calcutta Port Trust Area. Flap shutters were provided at the outfall ends.

Advantage of that storm sewer can be taken and additional gully pits may be constructed for quick entry of the storm water into the drain. The alignment of the sewer route has to be surveyed and revived and penstock gates with new flap shutters may be installed for operation.

4. S.N. Banerjee Road near Moulali

The problem of water logging along S.N. Banerjee Road, particularly in front of Calcutta Boy's School, was due to inadequacy of the existing sewer to take care of storm water flow along this road. Recently KMC has laid higher diameter RCC pipe sewer along the length of the road replacing the old one discharging to the AJC Bose Road Trunk sewer, and in consequence, the problem of water logging in this area reportedly has since been successfully solved.

5. Free School Street Area

The Free School Street area is comparatively lower than the surrounding area which stretches over North of Lindsay Street junction to the South of Kyd Street junction. This stretch gets water logged during heavy shower, especially in front of the Fire Brigade. The area drainage is served by the sewer along Free School Street that discharges to the trunk sewer of Lenin Sarani. The sewer itself is reduced in hydraulic capacity due to heavy silting. Structural condition is bad. Collapse at 3 or 4 places has already been reported, and similar collapses at two new places are under repair. The sewer crosses the S.N.Banerjee Road pipe sewer where there is a reported obstruction, causing restriction to the free flow of water down to the Lenin Sarani trunk sewer. The situation at this junction point needs to be investigated. The gully pits along this road may be choked or insufficient in number.

6. Elliot Road Area

Elliot Road sewer discharges the runoff of its catchment basin to the sewer along AJC Bose Road. The elevation of Elliot Road is less than the elevation of the AJC Bose Road and thus water first flows along reverse direction over the surface. Moreover there is no flow observed in the Elliot Road sewer where it discharges to the AJC Bose Road trunk sewer, which is suggestive of some obstruction at the junction. Cleaning of the sewer, revival of the junction and keeping the gully pits clean will solve to a large extent the water-logging problem of this area.

7. Park Street–Camac Street Area

Park Street and Camac Street area suffers from frequent water-logging during monsoon despite having extensive sewer network in the area. The sewer network in the area discharges partly to the southerly direction to the AJC Bose sewer and partly to the northerly direction to the Park Street sewer. A new sewer along Park Street in addition to the old one was laid by KMC according to the recommendation of the 1966 Master Plan, but the problem of water-logging was not solved. The capacity of the sewer network and the trunk sewers, where the area drainage is disposed of, is estimated to be adequate to cater to the runoff of the catchment. Despite adequate provision of sewerage network, water-logging problem in the area is still prevailing. The reason can be attributed to inadequate slope in the sewers/improper implementation/inadequate inlets/inadequate maintenance/improper operation of the pumping station either singly or in combination. This problem of the area therefore requires detailed investigation.

8. Waterlogging in Suburban System due to problems related with BDPS

There are two pumping stations in the BDPS. The old pumping station is comprised of 8 pumps, namely Pump No. B to Pump No. 1 whereas the new one is comprised of 4 pumps namely Pump No. 1 to Pump No. 4. The capacity of the Pump B is 75 cfs, Pump C, D, II and I are 50 cfs each; Pump E and F are 175 cfs each and Pump G is 130 cfs. In the new pump house the Pumps No 1 and 2 are 75 cfs each and the Pump No 3 and 4 are 200 cfs each. In general, the water level is kept at (+) 8.00 KODS[3] in the sump of the pump house by operating the pumps. The invert levels of all sewer lines entering into the BDPS are lower than this level. As a result, even in dry season free flow of water cannot occur in the sewers leading towards BDPS. Ground level of this area is around (+) 19 KODS, and hence in dry weather a water-logging problem does not arise in these areas even though the sewers cannot maintain a free flow of water. This does cause damage to the service condition of the brick sewers. Moreover, no regular desilting operation is possible in the sewers at these areas as they are always surcharged. This causes constant silt deposition in the sewers. This may also cause major damage to the system in the near future. The BDPS therefore must maintain the water level in the sump below a certain point that would allow all the incoming sewers to flow freely to the pump station. This requires further analysis of the sewers and the pumps in BDPS as well as the operation of sequence of pumps.

There is a bypass arrangement between the silt pit and the discharge channel for Pumps No. 3 and 4. The by-pass outlets are at level (+) 13.00 KODS and at (+) 10.0 KODS. There is a gate in this by pass arrangement to control the flow and is kept closed generally. The by-pass was constructed with an idea to avoid station inundation in case of occurrence of power failure. The gate of the by-pass should be kept in operable condition to serve its original purpose.

9. Waterlogging in Hide Road Area/problems with Nimak Mahal Pumping Station

As the existing sewer along Hide Road appears to be completely defunct, a new scheme for improving the sewerage and drainage situation at this area is badly needed. Total sewage generated in this area may be estimated in the following way:

The area covers ward No. 79 and 80.

Population in ward No. 79 is 42,725

Population in ward No. 80 is 36,305

(Population of 1991 is considered, as the increase in population since '91 is negative. The slum population density ratio with respect to total population is negligible as recorded in the 1981 population data.)

3 KODS stands for Khiddirpore Old Dock Sil. This is a local hydraulic engineering standard related to the Dock's water level.

With water consumption @ 40 gpcd and @ 35% of domestic demand as ICI demand and @ 5 gped as other demand, total usage of water amounts to 4.66 MGD. Assuming 80% of the water usage entering the sewer, waste water generated is 3.7MGD.

Under the existing situation the Nimak Mahal Pumping Station pumps the DWF of the Nimak Mahal Road area through a 9-in diameter force main to the Hide Road sewer. The Hide Road sewer, which was laid at a considerable depth from road level, (invert at 18 ft below ground) varies in size from 18-in. to 27-in.; after following a route below the dock yard and along Mayurbhange Road, it reaches to Mominpur Pumping Station. This sewer is almost non-functional as mentioned earlier. During a field visit, no manhole could be seen as they were covered by the road surface and it appears that the sewer has remained unattended for several years. The surface drains on both sides of the road are connected to the underground sewer at a certain distance apart and slope to either side of the road. One side of the road surface drain slopes towards north and discharges to the 5ft diameter RCC pipe along Nimak Mahal Road leading to the Hooghly River and the other side of the road surface drain slopes south leading to the tank beyond the Budge-Budge railway line. These surface drains are not adequate to carry the storm run off of the area resulting in water logging during rain.

10. Waterlogging in Swinhoe Street

Water logging in and around Swinhoe Street is a perennial problem of the area. The area, bounded by Gariahat Road on the west, Eastern Railway line on the east, Broad Street on the north and Rashbehari Avenue on the south, is a relatively low-lying area. The eastern end of Swinhoe Street is the lowest point of the area, almost 4-ft. below the surrounding land. During heavy showers, rainwater from the whole area drains toward this point. The water level would be about 5-ft above the road level.

The drainage of the area finds its outlet through the roadside open Nikashi along Swinhoe Street along with some sewers in other parts of the area leading to this Nikashi. This Nikashi conveys the water to the Rash Behari Avenue sewer at the other end of the Eastern Railway line through a culvert. The Railway embankment forms a barrier of the area on its eastern side and the water of the whole area gets accumulated at this point and passes through the culvert. The discharge rate through the Nikashi and the culvert is much less than the rate of accumulation of water in the area causing severe water logging. The open Nikashi itself is heavily silted. Moreover the Rashbehari Sewer, where the Nikashi discharges, is silted by more than half its depth. The terminal pumping station, i.e. the Ballygunge Drainage Pumping Station (BDPS) cannot keep the water level sufficiently low so that water from the sewers can have free flow to the pump house.

An extensive storm sewer network with RCC pipes of 15-in to 18-in diameter has since been laid along Ballygunge .Place, Ballygunge Place East, and Swinhoe Street that discharges the storm runoff of the area to the Bondel Road sewer. These newly laid sewers cannot cope with the water logging problem properly either due to their alignment along the reverse direction of the natural slope or inadequate slope of the sewers. However, these sewers together with proper operation of the pump house (BDPS) have reduced water logging problem of the area considerably.

The necessity of a pump house at the Eastern end of the Swinhoe Street in between Bhartia Electricals and Mackintosh Burn at the side of the Railway Embankment has been under consideration by the KMC since 1962 to pump the accumulated discharge to the R B Avenue sewer. This aspect needs to be looked into for further relief.

11. Waterlogging problem in Ballygunge Phanri Area

This area is the crossing of Gariahat Road with the Ballygunge Circular Road, Hazra Road, and Broad Street. The junction of the roads is the lowest point of the area causing water accumulation from all sides of the area through the link roads. Moreover, the Hazra Road sewer that carries the combined flow of the area to the terminal pumping station (BDPS) is severely inadequate against two-month frequency storm. In fact the Suburban system is designed against a rainfall of 4 mm/hr. Providing sufficient inlets to the sewers and increasing the capacity of the Hazra Road sewer may allow the free flow of surface runoff to the sewers. Increasing the hydraulic capacity of the Hazra Road sewer beyond Ballygunge Phanri may be achieved by linking this sewer with the Bondel Road sewer at the Broad Street and the Bondel Road junction. This sewer is mostly unutilized under design condition. Diversion of storm water toward western side of the Tolly's Nallah carried by the Hazra Road sewer may reduce the load on the Hazra Road sewer. The feasibility of these proposals requires further study.

12. Water-logging problem in Bhawanipur, Chakraberia and Elgin Road Area

The water-logging in this part of the area is purely a localized problem. The inadequate hydraulic capacity of the sewer system due to heavy silting and the silted up gully pits are the main reasons of water-logging in the area. Increasing the hydraulic capacity either by desilting or increasing the size of the sewer and proper maintenance of the sewer and the gully pits seem sufficient to solve the problem of the area.

13. Waterlogging problem in Baker Road and Gopal Nagar Area

This area is located at the close vicinity of' the Tolly's Nallah. The water-logging problem

is mainly due to the improper disposal of' storm water to the Nallah during heavy showers as the water level in the Nallah does not permit the free flow discharge within the sewers. The defunct penstock gates over the Nallah at the outlet in the sewers cause mal-controlling of water flow in between the sewers and the Nallah. The problem has been studied in detail earlier by the World Bank team during their field visit at the time of high tide in the Nallah. Their report needs to be carefully examined and their recommendations should be implemented without delay.

14. Waterlogging problem at junction of National Medical College, Lady Brabourne College and Darga Road

The junction of Darga Road, CIT Road near National Medical College is a chronic water logging area during monsoon. The area drainage is served by the two parallel trunk sewers, one along the CIT Road and then along Darga Road, it discharges to the terminal pumping station (BDPS) and the other along Dihiserampur Road that also discharges to BDPS independently. The sewer along Dihiserampur Road is completely silted up and defunct as reported. The 1966 Master Plan recommended an additional storm drain along the CIT Road to link across the Dihiserampur Road sewer to this proposed new sewer so that combined flow of the Dihiserampur Road area can be disposed off properly to BDPS via the CIT Road sewer. Inspite of laying a new sewer CMC connected the Dihiserampur Road sewer across to the exiting CIT Road sewer causing overloading of the CIT Road sewer. Under two-months frequency storm, the CIT Road sewer is found to be inadequate to cater the discharge of the vast area under this basin. The recommendations have since been made after proper study and these need to be implemented at the earliest.

15. Waterlogging Problem of Southend Park and Panchanantola Area.

The location of South-end Park and Panchanantola is at the extreme southern end of the suburban system boundary. The areas are comparatively lower than the adjoining areas; as a result storm water rushes to these areas at a faster rate that the existing gully pits can cope with.

Sewerage and drainage of this area finds its outlet through pipe sewer network leading to the Brick Sewer of Gariahat Road south and Ballygunge Station Road respectively. Extensive storm network has been laid but had not yielded desired result. Due to heavy silting of the BS of R.B Avenue and improper operation of Ballygunge drainage pumping station, water-logging in the area persists for hours. Complete removal of water logging from the areas will probably not be feasible. Rather it is not desirable also as it helps the flushing of the sewer system.

The recommendation for construction of a storm pump house to force the water into an existing system of network deserves careful consideration from long-term solution point of view. The solution would have been easier had there been a separate outfall channel available nearby. Existing roads are not wide enough to accommodate all utilities. To reduce the period of' water-logging, storm water may be allowed to accumulate in a sump in Panchanantola near the bridge approach and then to pump it out either to the sewer of Ballygunge station through the delivery sewer of Jodhpur Park Pumping Station or to pump it to the box drain of Raja Subodh Mullick Road through force main under the railway track. In that case addition and alteration of Jodhpur Park Pumping Station would be necessary.

16. Waterlogging Problem in Southern Avenue and Rabindra Sarobar area.

The area bounded by R.B. Avenue on the north, Rabindra Sarobar on the South, Sarat Bose Road and Lake Road on the west and south west and Southend Park on the East, is prone to water logging from heavy precipitation during monsoon. The crossing of Lansdowne Road and R.B. Avenue in front of Deshapriya Park, Lake Road, Southern Avenue and Southend Park get water-logged. The sewerage network in this area is inadequate in capacity to take care of rainfall more than 6 mm/hr. Although the area does not drain into the lake, Southern Avenue often gets inundated due to entry of over flow water from the lake into Southern Avenue sewer through the existing connection.

Water-logging in this area can be minimized by desilting and cleaning sewer system of R.B. Avenue where Southern Avenue sewer finally discharges. There are also inadequate inlets along the Southern Avenue. It has been recommended to provide additional inlets to Southern Avenue Sewer. Road surface gradients leading to these inlets need also to be checked for proper drainage.

The 1966 Master Plan, when considering flooding of this area, recommended constructions of a trunk drain between Dhakuria Lake and Tolly's Nullah that includes the lakes and part of the RB Avenue trunk sewer system. Very little drainage from the adjacent area enters the lakes unless the rainfall exceeds the design capacity of the system. The Master Plan also suggested construction of an overflow west on the south-westerly end of the lake thus permitting the area to drain into the lake and thence through a trunk drain to the Tolly's Nullah.

A pump house would be required in a suitable location in or around Rabindra Sarobar area to pump out storm water through a force main to Tolly's Nullah. The head and capacity of the pumps are to be considered carefully so that the pumps can discharge freely into Tolly's Nullah even during high tide. Cost effectiveness in terms of

permanent liability and recurring expenses for having a pumping station should also be investigated in detail.

It has been reported that KMC has prepared a storm drainage scheme for construction of a pumping station having a capacity of 140 cfs in Rabindra Sarobar area as suggested by the Calcutta Improvement Trust for disposing the storm water to Tolly's Nullah through a force main.

17. Waterlogging in Ultadanga area

Dhapa Lock Pumping Station (DLPS) receives the combined discharge of entire Maniktala Basin. The DWF and storm water of Kankurgachi and Ultadanga area lead to Ultadanga new pumping station through a 10ft diameter brick sewer. Combined flow, after having been pumped at the station, discharges to a common chamber from which the flow finds its outlet through a high-level 10-ft diameter brick sewer leading to DLPS. Before DLPS, this 10-ft diameter sewer meets with the 8-ft 6-in diameter brick sewer from Beliaghata Main Road in a Junction Chamber near the buildings of C.I.T. The two sewers lead into a 14-ft x 13-ft 3-in 'horse-shoe' type brick sewer that siphons below the Beliaghata canal and enters into DLPS.

It can be seen that the invert level (IL) of the 14-ft x 13-ft 3-in horseshoe type sewer at its starting point is (-) 4.4 KODS and the I.L at the entry to the siphon is (-) 4.76 KODS. The IL beyond siphon i.e., after crossing the canal is (-) 3.5 KODS. The ideal siphon action cannot occur with the outlet side higher than the inlet side, although in this case the siphon is reported to be functioning properly as adequate water is found to be entering into the sump for pumping. Moreover, there is no silt deposition reported in the siphon chamber as well as in the silt chamber of the DWF channel just before the sump. Silt is found deposited in the silt pit of SWF entry at the upstream of the screen gate. The 14-ft x 13-ft 3-in-horse-shoe type sewer through out its length up to the inlet of siphon chamber is heavily silted. Although the existing twin barrel siphon is working well, its capacity appears to be less than the full bore capacity of horseshoe type inlet sewer.

There are two storm water box drains laid by CMWSA, one along Maniktala Main Road from Kankurgachi (9-ft x 5-ft RCC twin box) leading to Keshtopur Canal and the other along Narkeldanga Main Road from Phoolbagan (11-ft x 5-ft RCC box) to Beliaghata Canal. There are two cross-over structures at the junction of these RCC boxes with the 10-foot diameter delivery sewer from Ultadanga Pump House. The twin boxes along Maniktala Main Road after crossing the 10-ft. diameter sewer runs parallel to it but in reverse direction and finally discharges to Keshtopur canal near Ultadanga. The RCC box along Narkeldanga Main Road after crossing the 10-foot diameter sewer runs

parallel to 10-foot diameter delivery sewer along same direction and discharges to the Beliaghata Canal near DLPS. There is an interconnection between the twin box along Maniktala Main Road and the10-ft diameter delivery sewer near Purbasha Housing complex. The IL of the discharge point of this storm drain in the canal is reported to be + 7.76 KODS whereas the prevailing water level in the canal in monsoon is about + 14.00. Moreover the discharge point of the storm drain is almost silted. This is causing obstruction to the free discharge of water from the box to the canal even if the water level in the canal is low. If the full supply level (F.S.L) becomes excessively high i.e. + 14.00 there is a chance of water to flow back to the box. This obstructed storm water or water from the canal may lead to the 10-ft diameter delivery sewer of the Ultadanga pump house through the interconnection point near Purbasha housing and finally lead to the sump of the pump house. This will cause overflow, flooding and water logging. The water-logging problem of Ultadanga area, therefore, needs to be carefully studied to work out appropriate solution.

18. Waterlogging problem in Maniktala Main Road

Ghose Bagan area on the North of Maniktala Main Road and the areas under M/s Bengal Chemical and Pharmaceutical Works are comparatively lower than the surrounding areas as a result of which storm water from the adjoining areas rushes to the spot causing water logging. Storm drain has already been laid at Maniktala Main Road but arterial drains have not been developed. Besides thorough cleaning of the box drain right from Kankurgachi gyratory to Keshtopur Canal is necessary. Desilting of the Keshtopur canal and maintaining the F.S.L at +10.25 need to be confirmed by the State Irrigation and Water Ways Department. Alternatively the storm water could be disposed off through pumping by construction of a storm pumping station at the tail end of the box drain. As a second alternative, Ultadanga siphon pumping station can be renovated, and by installing high head pumps for pumping the storm water may be discharged through a force main to the canal.

19. Waterlogging in Narkeldanga, Kankurgachi and Beliaghata Area

The problems are local in nature, and can be removed if the full use of the storm drains which have been already built by CMWSA including construction of the additional inlets and branch storm sewers is done by linking to the main storm drain. The problem will be solved provided the main box drains are kept clean during the monsoon. Beleghata canal also requires desilting. Box drain led along Narkeldanga Main Road to the west of Railway line has a size of 8-feet x 5-feet with IL 8.76 and FDL 13.76 KODS discharging

into the canal, where the ruling FSL should be maintained + 12.25 to have a free discharge of the canal. If the FSL of the canal cannot be maintained to allow gravity discharge, there is no other alternative than to pump storm water into the canal by constructing the pumping station at the tail end of the box drain. Unless FSL is maintained at +12.25 KODS, free flow is not possible. The only alternative would be to have a pump house at the end, with the flow being pumped to Dhapa Lock Pumping Station through a siphon of 8-inch diameter to be constructed under the canal.

This detailed account of the city's known pockets of waterlogging has been presented along with the reasons for water logging and suggestive measures that need to be taken to substantially reduce the acute flooding problem of the respective areas. Lack of funds coupled with lack of a longer term vision has stood in the way of taking a planned approach to this massive problem of reducing considerably (not completely) the annual flood risks that continue to plague city life in Kolkata. Only now, as can be surmised from the suggested ameliorative measures cited above, attempts are being made (with JNNURM fund) to deal with this scourge (flood) in a phased and planned manner.

Drainage & Sewerage System

The problem of waterlogging of Calcutta city is intimately connected with the city's original drainage system which had been designed as a 'combined' system for the disposal of storm water as well as sewerage and dry weather flow in 1855, sanctioned in 1859, and laid down between 1860 and 1875. A brick sewer with a height of 8 feet and a width of 6 feet was constructed beneath the city's principal streets subsequently linked to small underground cross-sewers. The drainage system designed and built during Colonial times could take care of storm water flow from 6mm litres of sewerage per inhabitant per day. The system had thus its in-built inadequacies, and it never took note of heavy intensity rainfall and sewerage generated due to tremendous population explosion in subsequent decades. The old sewerage system could cover only about 55 per cent of the city. Part of the remaining portion is covered by septic tank system and the existing storm sewer network is being used to carry sewage as well. The system has adequate conveyance capacity during dry weather flow, but does not have enough capacity to handle storm flows. The city does not have any conventional facility for wastewater treatment. There are a total of 815 km of sewer, of which there are about 645 km of pipe sewer and about 170 km of brick sewer. About 88 km of the brick sewer is man-entry sewer, i.e. sewers above 42-in in diameters.

At present the City of Calcutta (CMC area) can be broadly divided into six catchment basins (Table 9) having independent sewer networks and terminal pumping stations.

Table 9: Catchment Basin Data

Sr. No	Name of Basin	Area of the Basin (Sq Km)	Terminal Pumping Stations
I	Town System	19.13	Palmer Bazar Pumping Station (PBPS)
2	Suburban System	25.69	Ballygunge Drainage Pumping Station (BDPS)
3	Maniktala System	8.91	Dhapa Lock Pumping Station (DLPS)
4	Topsia-Tangra System	5.17	Topsia Pumping Station & others
5.	Tollygunge-Panchnnagram System (i) Tolly's Nallah Basin (ii) Panchannagram Basin	 4.00 32.00	Chowbhaga Pumping Station
6	Bagjola Basin	6.07	Bagjola Pumping Station

1. Town System

The oldest part of the sewer system, which is more than 100 years old, is called the Town System. The southern part of the sewer system, called the Suburban System, is about 80 years old. The Town System was designed for l /4-in. rainfall per hour, whereas the Suburban System was designed for I/6-in. rainfall per hour with 100 per cent runoff. Three large and 22 smaller pumping stations are used to pump combined wastewater from the sewer system to a canal system and, ultimately, carry wastewater to the creeks of the Bay of Bengal.

Deficiencies of the existing system are:

- Lock gates control the whole canal and discharge system. The coincidence of high tides with heavy rains makes satisfactory drainage difficult.
- Hydraulic capacity of City's sewerage system and discharge canal system has been reduced significantly due to heavy siltation.
- Due to lack of proper maintenance of the age-old pumps and unavailability of

spare parts, pumping stations are inefficient and unreliable, resulting in frequent failures.

- Many gully pits are covered with debris and polythene bags, making it difficult for storm water to enter the sewer system.
- Outfall structures are inoperable for long periods of time due to lack of spares, and storm water-pumping stations cannot discharge freely into the canal system due to heavy siltation.
- Many canal banks have been encroached upon by squatter settlements. The growth of aquatic vegetation also decreases the carrying capacity of canals.
- There are still some dairy farms in the area that discharge wastes directly into the sewer, causing siltation of sewers.
- Rapid, uncontrolled urbanization, indiscriminate real estate development, and destruction of wetlands (Salt Lake city being a glaring instance) have aggravated the flooding problem.

The primary goal of KMC is to keep the city's sewerage and canal system clean and pumping stations operable and efficient to reduce the frequency of flooding of the city streets during heavy rains. This can never be a solo affair of the KMC. Besides KMC's own efforts, integrated approach is necessary by synergizing the efforts of agencies like the State Irrigation Waterways Department, the Calcutta Port Trust and others.

General Description

The inception of Calcutta sewerage and drainage system dates back to the year 1859 when the Town System sewerage network was commissioned. At the time, Calcutta was limited by the area bounded by the River Hooghly on the west, today's Circular Road or the then Maratha ditch on the east and south, Cossipur-Chitpur on the north covering an area of 19.13 sq. km. The City expanded over time and the sewer network has also been gradually extended. At the end of nineteenth century, the Suburban Sewer System network was built covering the southern part of the City, and in the second quarter of the twentieth century the Eastern part of the City called the Maniktala system started to take some form which was later fully developed as a separate sewerage & drainage network known as the Maniktala system.

Out of the 141 Wards of the city, the present study area covers Ward No. 7 to Ward No. 100, and the drainage basins coming under the scope of the study are (I) Town System, (2) Suburban System, (3) Maniktala System, (4) Topsia-Tangra System and (5) part of Tollygunge Panchannagram System.

General Gradient and Flow of Sewage

The general elevation of Calcutta above Khidderpore Old Dock Sill (KODS) is between 19 and 22 ft. as revealed in the existing reports. The average slope is in general from west to east from the east bank of the Hooghly River to the Salt Lakes. The Salt Lake City is at (+) 18.5 KODS and the Netaji Subhas Road is at (+) 22.0 KODS. The trunk sewers laid along the East-West direction carry the wastewater and storm runoff from the western part of the City east to the different pumping stations like Palmer's Bridge Pumping Station (PBPS), Ballygunge Drainage Pumping Station (BDPS) and Dhappa Lock Pumping Station (DLPS). From DLPS, water is pumped to the dry weather flow (DWF) channel and storm water flow (SWF) channel for disposal into the Kulti River almost 36 km away from the City. The major part of the sewer network carries combined flow, whereas in few areas partially separate drainage systems are present. There is no sewage treatment plant in the city at present. In the Town system the average invert level of the trunk sewers near the Hooghly River is (+) 13.5 KODS and at the pumping station end is (+) 3.61 KODS producing a 10 ft. fall approximately.

The Calcutta Town System sewerage network is comprised of following trunk sewers:

	Sewer	**Shape**
1.	Lenin Sarani Sewer	Egg shape
2.	Kolutola Street Sewer	Egg shape
3	Nimtolaghat Street Sewer	Egg shape
4.	Grey Street Sewer	Egg shape
5.	Bagbazar Road sewer	Egg shape
6.	A.J.C Bose Road Sewer	Egg shape
7.	A.P.C. Roy Road Sewer	Egg shape

The trunk sewers along Kolutola Street, Nimtolaghat Street, Grey Street, and Bagbazar Street - running west to east - are intercepted by APC Roy Road Trunk Sewer running along North-South direction. The APC Roy Road Trunk Sewer is inter-connected with another sewer along Canal West Road running parallel to APC Roy Road by means of overflow connections at five different locations. Prior to the construction of' the sewer along Canal West Road the overflow discharge from the APC Roy Road sewer was disposed off to the Circular Canal directly through penstock gates; those are now all defunct except the one at Maniktala Main Road. The storm runoff from the above-mentioned trunk sewers along east-west direction is finally shared by the intercepted sewer along A.P.C. Roy Road and the Canal West Road. The A.P.C Roy Road trunk sewer, A.J.C Bose Road trunk sewer and Lenin Sarani trunk sewer meet at

the Moulali junction and then flow onwards through a special section trunk sewer of 20 ft. x 15 ft. This is known as the 'Town outfall' that leads to the Palmer's Bridge Pumping Station. Apart from these, there are branches and lateral sewers made of brick masonry of size's ranging from 3 ft. x 2 ft. to 6 ft. 6 in x 4 ft. 4-in. All these brick sewers are egg shaped.

The Maidan Area is separate from the Town System. The water from this area finds its outlet through surface drain to the Hooghly River. Recently a part of this area's drainage has been included in the Town System network through an inter-connection between the Town System and Maidan Drainage.

Other pumping stations within this system of sewer are Belgachia Pumping Station and Maniktala Pumping Station. The Belgachia Pumping Station with 9-cfs discharge capacity receives wastewater from the R.G. Kar Medical College Hospital area and a small portion of the area outside the hospital campus. The combined flow is pumped to a sewer along Raja Dinendra Street through a force main and it finally discharges to Maniktala Pumping Station. The Maniktala Pumping Station, having a total discharge capacity of 108 cfs receives the discharge from the Raja Dinendra Street Sewer and from Sukia Street Sewer and pumps the discharge to PBPS through a high-level delivery sewer along Dinendra Street. PBPS receives 94% of the discharge of the Town System directly through the sewer network and only 6% of the discharge from the intermediate pumping station at Maniktala.

The Thantania Pumping Station has been commissioned in the year 2000 and is located within the Town System boundary. To remove the chronic waterlogging problem in the College Street, Amherst Street and Sukhia Street areas, this pumping station was built with a total pumping capacity of 30 cfs.

The total area covered under the Town System sewer network is 19.13 sq. km. The total storm runoff produced in the system is 1172 cfs with two-month frequency rainfall (6mm/hr over a period of three hours or more). The average daily DWF generated in this system is 268 cfs. Total combined flow in the system thus becomes 1440 cfs. The total sewer capacity against this flow is 1425 cfs and the total pumping capacity (installed capacity) of Palmer's Bridge Pumping Station (PBPS) is 1720 cfs. This suggests that the sewerage system is sufficient to take care of the DWF, but with two-month frequency rainfall the overall sewer capacity of the system is marginally less under design condition. The problem of frequent water logging occurs due to local bottlenecks of the system. There is sufficient pumping capacity under installed condition. Under existing condition, the sewer sections are filled up to the extent of 40% to 50% with silt thus causing further reduction in the sewer network. The age-old

pumps are also reduced in their efficiency by 30% to 40%, and thus the net pumping capacity has been reduced to almost 1100 cfs. This suggests a gross inadequacy of the capacity of the system to carry storm flows. Also, due to siltation and inadequate pumping ability, even the dry weather flow capacity is compromised.

2. Suburban System

The Suburban System area is bounded by A.J.C Bose Road and Convent Road on the north, Eastern Railway Line on the south and east, and the dock area on the west, covering an area of 25.69 sq. km. There are three trunk sewers running west to east carrying the combined flow of the area and finally discharging to Ballygunge Drainage Pumping Station (BDPS). The trunk sewers and their shapes are as under: -

Sewer	**Shape**	
1.	Rashbehari Avenue Trunk Sewer	Circular.
2.	Hazra Road Trunk Sewer	Circular
3.	Poddapukur Road trunk Sewer	Circular
[Two other trunk sewers running north to south in direction carry the discharge from CIT Road area and Tiljala area and discharge to BDPS.]		
4.	CIT Road Trunk Sewer	Circular
5.	Tiljala Road Trunk Sewer	Circular
[Another trunk sewer brings the storm discharge from a part of Town System and discharges to BDPS]		
6.	Park Street Trunk Sewer	Circular

The total storm runoff produced by this drainage system is 1574 cfs at a two-month frequency storm (6 mm/hr over a period of three hours or more), and total average daily DWF generated is 175 cfs. The total sewer capacity against this flow is 1236 cfs and the total pumping capacity of BDPS is 1275 cfs. This suggests that there is a deficiency in the overall system under design condition for storm flows, apart from the local bottlenecks. In fact, the Suburban System sewer network was designed for l/6inch per hour rainfall, i.e. 4.17mm/hr rainfall, and thus the runoff flow becomes 1100 cfs. Under the existing condition with more than 50% sectional area of' the sewers silted and 30% to 40 % reduction in efficiency of the age-old pumps in the pump house, the capacity reduces to approximately 600 cfs in the sewers and 800 cfs at the pumping station with no standby. This is suggestive of gross inadequacy of the system against seasonal storm flows.

3. Maniktala System

The Maniktala Sewerage and Drainage area is bounded by E.M. bypass on the east, Circular Canal on the west and south and Keshtopur canal on the north, covering an area of 8.91 sq. km. At the time of the inception of the sewer network in the early thirties, the Cossipur-Chitpur area was also considered as part of this sewerage basin but later these areas were separated from this system. Circular brick sewer laid along CIT road from Kankurgachi and sewer along Ultadanga Main Road or Bidhan Nagar Road cover the Kankurgachi and Ultadanga areas and lead to the Ultadanga Pumping Station which lifts the combined flow. It pumps to high-level delivery sewer along E.M bypass leading to Dhapa Lock Pumping Station (DLPS). The Phoolbagan and Beliaghata areas are served by two trunk sewers, one along CIT Road from Kankurgachi following CIT Road and Hem Naskar Road and the other along Beliaghata Main Road from the western side of Eastern Railway Line crossing. These two sewers meet at the CIT Road junction. The combined flow goes along Beliaghata Main Road through a sewer discharging to the high level delivery sewer of Ultadanga Pumping Station and finally to DLPS. A network of lateral and collection sewers is also there to feed these trunk sewers. Apart from these, CMWSA has installed a few box drains to meet the deficiency of the sewer network capacity against storm. Box drains along Maniktala Main Road receive storm runoff from Kankurgachi area in between Kankurgachi Island to Bengal Chemical near E.M bypass and finally discharge to Kestopur canal. Box drains along Narkeldanga Main Road receiving storm runoff from the Phulbagan area in between Phulbagan Island to E.M bypass crossing and finally discharge to Beliaghata Canal. These storm sewers carry the runoff from west to east. There are three other box drains on the western side of the eastern Railway line that drain from East to West and finally discharge to the Circular Canal. These boxes are laid along Narkeldanga Main Road, Maniktala Main Road and along Barin Ghosh Sarani. All these box drains were laid in a very mild slope, and at the discharge ends in the canals they are almost choked by silts deposited in the canal beds causing flow obstruction in the boxes.

Total storm runoff produced by the Maniktala drainage system area with two-month frequency storm (6 mm/hr over a period of three hours or more) is 546 cfs. The capacity of the sewer network leading to the DLPS is 542 cfs, and the pumping capacity of DLPS is 480 cfs. This suggests that the pumping capacity is just short of the runoff produced. Additional box drains laid by CMWSA had brought about improvement in the system to handle the storm runoff. The 468-cfs capacity Ultadanga Pumping Station was designed to accommodate the Cossipur-Chitpur area drainage in addition to Ultadanga area, but after exclusion of this area from the Maniktala system, the additional pumping capacity of the station may be considered as standby.

4. Tangra-Topsia System

The Tangra-Topsia sewerage and drainage system area is bound by Eastern Railway Line on the west, E.M. Bypass on the east, Park Circus connector on the south and the Circular Canal on the north, covering an area of 5.17 sq. km. Basically this is a low-lying area and a part of it is below the full supply level of SWF Channel from Palmer's Bazar Pumping Station that passes through this basin, resulting in frequent water logging. The very poor sewer network of the area aggravates the situation. The storm pipes laid in this system are incapable of discharging to the pumping station due to inadequate gradient. The roadside Nikashis, which serve the purpose of carrying the DWF, are not kept properly clean, and they are linked with the storm pipes. The area is mainly inhabited by poor people with a sprinkling of Railway quarters near by. Recently, some high-rise buildings have come up - indicative of possible future changes in land use pattern of the area. Drainage of the whole area is dependent on the operational efficiency of four different pumping stations:

(1) Topsia Pumping Station of 221-cfs capacity
(2) Chingrighata Pumping Station of 34-cfs capacity
(3) Pagladanga Pumping Station of 40-cfs capacity
(4) Kulia-Tangra Pumping Station of 100-cfs capacity.

5. Tollygunge Panchannagram System

It is a relatively larger system of the south and southeastern part of the city covering an area of about 36 sq. km. For storm drainage disposal, this area has been divided into nine sub-basins of which three southwesterly basins drain into Tolly's Nallah, whereas storm drainage from the rest of the area is transported to Panchannagram Canal directly through a system of lead canal. From Panchannagram canal, the water is lifted and discharged into the storm water flow channel through three pumping stations at Chowbhaga with a combined discharge capacity of 1450 cfs. Unplanned and indiscriminate building activities in the area in recent years have created problems of drainage in general and storm drainage in particular.

Outfall System

The combined flow produced by the different systems as mentioned above is finally pumped by the terminal lifting pumping stations and discharged into the Storm Weather Flow (SWF) channel and Dry Weather Flow (DWF) channel. .

PBPS and BDPS pumps the DWF from the Town System and Suburban system area

respectively into two high-level delivery sewers leading to a common chamber at Topsia known as point 'A', and thereafter the flow gravitates to the River Kulti through open DWF channel via Bantola. The excess flow, however, is discharged into the storm water channel through a by-pass. BDPS pumps the combined flow of Suburban System into two high-level delivery sewers leading to point A with the excess flow discharged into the SWF channel known as Calcutta Storm Water Flow Channel. SWF Channel from PBPS and SWF channel from DLPS meet at a point near Makalpota; thereafter it becomes a single much wider channel and meets the Calcutta Storm Water Channel through Bantola regulator. The SWF channel beyond Bantola to Kulti is known as Calcutta Storm Water Channel.

Admittedly, the sewer and pumping capacities within the Suburban and Maniktala Systems are inadequate. The pumping capacity in the Panchannagram System is also inadequate. Factoring in the effect of siltation and reduced pumping capacity due to age and wear in the pumps, it is evident that neither the sewers nor the pumping stations throughout Calcutta have sufficient capacity for dealing with the storm water flows.

Existing conditions of the individual trunk sewers reveal structural deterioration in the case of more than century old trunk sewers, and substantial reduction of the hydraulic capacity of the sewers for a variety of reasons.

The CCTV and video photography of the man-entry/non-man entry sewers conducted recently reveals that the sewers are reasonably in shape with loss of mortar from the sidewalls and longitudinal cracks along the crown in certain places. Collapse repair work at the junction of Moulali has been undertaken. All the tie-rods of the arch of town outfall sewers have been found damaged. Tree-root intrusions have also been noticed at places.

SOLID WASTE MAGEMENT

Kolkata Municipal Corporation has to provide services to 8 million people every day, out of which daytime population (floating) constitutes about 3.4 million. The total number of households of about 4.25 lakhs and population living in slums of about 15.24 lakhs need to be served by KMC through its "District"-based "conservancy" services. By any standard, it is a massive operation that requires adequate organization and management.

Present System of Waste Handling

Within KMC area, the generated waste is stored within the premises in commercial and industrial areas, whereas in residential areas occupants take it out and throw either on the streets or transfer to community bins.

Availability of storage space for collection:

(i) Total no of container points and vat points: 662

(ii) Other small bins & trash bins: 435

Collection: Table 10 shows the existing status of collection from different points. The average daily accumulation of garbage is of the order of 3000 MT. The field staffs commence their work at 5 am and continue till 12.00 noon with a break of half an hour in between.

(i) **Street sweeping and cleaning:** After the first mastering, conservancy workers carry out sweeping and cleaning of roads and pavements and thereafter remove the collected garbage to the assigned vat/containers. This task is expected to be completed by about 7.30 am.

(ii) **Residential commercial, slums and office complexes:** From 7.30 am onwards the conservancy workers move on to their assigned areas with their hand carts giving whistle signal, calling the residents to bring their garbage. This process continues till 10.30 Am. Garbage thus collected is taken to the nearest vat / container from where vehicles pick up the garbage and transport the same to the disposal ground. Presently this process of house-to-house collection of garbage is practiced in all the 141 wards.

(iii) **Hotels & Restaurants:** Big hotels have their own vats wherefrom garbage is collected and transported regularly by KMC / Private vehicles on charge basis. Others dispose their waste on the road or nearby vat with the help of KMC / own sweeper. In case of KMC's own markets, wastes are collected regularly. In case of roadside and unauthorized markets, the waste from these markets is dumped on the road and collected by KMC street sweepers.

(iv) **Hospitals (Bio-medical wastes):** KMC was earlier collecting the waste from those bio-medical generators who did not have the treatment facility and disposing the same at Dhapa landfill site by deep burial method. From 1st April 'O4, collection and treatment of bio-medical wastes of KMC and other areas, have been entrusted to a private organization and the processes used in this connection are (i) Autoclaving (This is a process of steam sterilization under pressure) and (ii) Incineration.

Table 10: Status of present collection points at Kolkata

Borough Nos.	Total Collecti-on points	Type of Collection points			Category wise assessed solid waste generation (MT/d)		
		DL * points	Open Vat/ Space	Container Points** (B/N)	Domestic & Street Sweeping	Market & Commercial	Silt & Debris
I	58	3	35	20(12B, 16N)	140.90	52.00	16.00
II	19	0	12	7(14B)	92.50	70.00	7.00
III	33	0	16	17(30B, 2N)	173.80	40.00	14.50
IV	22	0	14	8(19B)	180.00	85.50	14.00
V	22	0	17	5(9B)	110.90	197.00	10.00
VI	20	1	13	6(12B)	131.20	180.00	25.50
VII	57	7	27	23(34B)	194.70	116.00	46.00
VIII	34	3	11	20(36B)	155.00	45.00	15.00
IX	53	6	31	16(23B)	181.10	40.00	23.00
X	81	18	53	10(11B, 6N)	166.30	30.00	20.00
XI	52	2	19	31 (33N)	45.80	9.00	4.50
XII	48	5	11	32(33N)	40.20	11.00	8.00
XIII	63	0	43	20(4B, 18N)	57.80	22.00	7.00
XIV	52	1	38	13(13B, 2N)	48.30	28.00	10.00
XV	48	9	48	0	56.80	15.00	10.00
TOTAL	662	46	388	228(217B, 110N)	1775.30	940.50	230.50

* Direct loading ** Big (7m3) / Normal (4.5m3)

Total category wise assessed solid waste generation is 2946.30 MT/d and may be considered approximately 3000 MT/d

Source: ADB Report, 2005

Transportation: There are five main vehicle garages and three subsidiary garages from where conservancy vehicles operate to transport garbage from their assigned areas to the disposal ground. Currently private carriers transport nearly 60% of daily-generated garbage. Of the remaining 40%, three main systems are in vogue viz. manually loaded vehicles, pay loader loaded vehicles and containerized vehicles. An average of 330 nos @ 4.9T/trip garbage trips, 54 nos. @6T/trip silt / rubbish trips are performed by the hired lorry vehicles, and 320 nos. @ 3.3T / trip garbage trips are performed by KMC lorries daily to remove the garbage from the city to the disposal ground.

Deficiencies of the present collection & transportation system

(i) About 58 - 60% of collection points are in the form of open vat, and the waste is lifted daily. However no of collection points remains in bad condition due to citizens dropping the waste haphazardly at the collection point after the clearance is done.

(ii) At present there is no source segregation system in KMC area.

(iii) Dumper placer containers and KMC vehicles are not washed daily or periodically even once a week. This results in heavy corrosion giving ugly appearance and reduced life of the vehicles.

(iv) 70% of KMC vehicles are more than 8 years old. The operational efficiency is less than 50%.

(v) In added areas large quantity of waste is disposed of in open canal and drains or dumped into low-lying areas instead of collecting and transporting to Dhapa waste disposal site.

In Kolkata the disposal ground is in the eastern fringe of the city with an average distance of 20 km from the collection points. Computerized weighbridges with capacity of 20T & 30T have been installed at the Dhapa Check Post where all vehicles are checked and recorded. Area of the Dhapa land fill site is 21.47 ha where, on an average, 1100 MT of wastes per day are disposed by the departmental vehicles within an area of 8.125 ha, and remaining 1800 MT of wastes per day are disposed by the private vehicles within an area of 13.345 ha. Another land fill site is situated at Garden Reach area of 3.52 ha where approximately 100 MT of wastes are disposed of by open dumping daily.

Deficiencies in the present Disposal system:

- Maximum balanced life of Dhapa is less than a year if the land presently used by cultivators is not taken over and developed for 'engineering landfill'.

- The method of operation of Dhapa waste disposal site is uncontrolled without providing earth cover, liner and leachate collection and treatment.
- No studies have been carried out to determine the effect of landfill operations on the surrounding environment and ground water.
- Rag picking carried out at Dhapa site for recycling and reuse of recyclable waste is most unorganized, hazardous and unhygienic, affecting seriously the health and safety of rag pickers.

Solid waste management is basically dependent on how the ground level staff functions and how they are supervised. The role of the Block Sarkars in their respective areas of operation (an electoral ward will be having a number of blocks) along with their gang of workers is of crucial importance in this context. During heavy rains in 2007 from 13 June to 3 July, the garbage from vats and polythene bags was a major problem - blocking gully pits at many places. Lack of timely collection, transportation and disposal of solid waste was identified as one of the major reasons for choked drainage and consequent flooding at many locations. Night-time collection and disposal, it has been suggested, might be useful. Kolkata's floods mitigation plan must take into account the proper management of solid waste in terms of frequency of collection and prompt collection, transportation and disposal.

Task Force Report

Recently, a high power Task Force was appointed, under the KEIP, to examine the sewerage and drainage problem of the city with special reference to the city's chronic flooding problem. The problems were studied, very rightly, in the broader context of urban planning. The Task Force has come out with a number of major recommendations which are of far reaching consequences.

Uncontrolled Urbanization

One issue that is seen as hampering any attempt at rational planning of the sewerage and drainage system is uncontrolled urbanization in various areas - which has been evident in some parts of Kolkata in the past 15 years.

A number of new residential apartments for NRIs are springing up in a number of areas in Kolkata. There is a requirement that high rise apartment complexes need to provide their own sewage treatment plants if there are no KMC sewers nearby. There is anecdotal evidence that this requirement is not always complied with and apartment complex sewage treatment plants are sometimes switched off to save power. This situation needs to be better policed and regulated by KMC.

The experience gained in implementing the KElP project in the Added Areas reveals that streets are generally small and narrow and there is insufficient room for separate wastewater and drainage systems -e.g. 2 m dia sewer being laid in 4 m wide road. This highlights the difficulties of constructing sewer networks in highly congested, unplanned neighbourhoods.

The other issue encountered when extending the sewerage system in the Added Areas is that most houses do not have separate discharge systems for sanitary sewage and grey water on the one hand and storm water on the other.

Separate sewerage systems are therefore difficult to implement in crowded existing areas. Separate sewerage systems should however be planned for if possible in the development of housing in any new areas, where streets can be sized to accommodate utility corridors. This should be spelt out in new regulations to be promulgated.

A high priority for Kolkata is therefore an improvement in the system of sewerage and drainage planning and the links it has to urban planning in general. To really improve the standard of sewerage and drainage in Kolkata a more comprehensive approach to planning and utilities is desirable, encompassing all urban services including roads, traffic, water supply, electricity, telecommunications, public space, green areas, sewerage systems etc. The urban plan might include off-channel storage areas for storm water which would be used to attenuate and help confine any initial flooding to pre-designed open areas. These areas might normally be used as parks or playing fields for example.

An integrated urban planning approach is required based on an updated Urban Plan that clearly spells out in which areas of Kolkata future development should take place and where high rise apartments may be built. Also required is a review of the KMC Act, new regulations to be promulgated for wastewater disposal from new houses and high rise apartments (to include on site treatment for new high rise apartments if necessary), industrial premises to be required by regulation to have on-site treatment of wastewater as part of an KMC-wide Industrial Pollution Control Action Plan and town planning is required to incorporate off-channel storm water storage in open areas and basins (e.g. parks) to attenuate storm flow peaks.

Sewer Desilting

Siltation of the trunk sewer system is seen as the biggest issue facing Kolkata at present. It has been assumed for the purposes of the Master Plan Study that 60% of the sewer capacity is filled with silt, and this will need to be removed as a priority.

As a result of the Metro works, an amount of bentonite was accidentally pumped into the trunk sewers adjoining the Metro alignment. This bentonite and other cemented

mounds of silt in the central part of sewers that are difficult to reach by manual methods will be cemented hard and difficult to remove with conventional jetting methods. Compressed air tools will likely be required in places for full silt and hard material removal.

The removal of the silt is essentially an under-ground mining application, that requires special equipment and technique in a hazardous, dangerous environment, and it will need to be planned and managed in that light.

Alleviation of Flooding

Along with the urgent need for sewer desilting, the alleviation of flooding has a high priority for the Master Plan. Sewer desilting will, however, assist but will not totally solve some of the waterlogging issues, which are also caused by undersized sewers in certain parts of the city such as in Camac Street. Undersized sewers are also found extensively in the Suburban system, where the sewers were designed for 4 mm/hour rainfall rather than the 6 mm/ hour used in the Town Area. This will require introduction of an extensive programme of upgrading of small sized sewers over a long period.

Other Sewerage System Issues

The siphons need a special study. The siphons being referred to are the twin compartment steel siphon under Tolly's Nullah; the twin siphons under Beliaghata Canal and the series of siphons under APC road to Canal East Road.

The construction of the Metro system caused damage to the existing sewers west of the Metro line in the Barabazar and Mahatma Gandhi Road areas. The hydraulic modelling will look at the feasibility of constructing Combined Sewers Overflows (CSOs) to transfer storm water (SWF) originating in the Town area west of the Metro line to the River Hooghly.

The limited hydraulic capacity of the trunk sewer along Hazra Road and the capacity of the discharge sewer from Mominpur PS have been highlighted in all Master Plans completed to date. The hydraulic modelling will examine what improvements can be made to the sewers particularly at the upstream ends of these sewers, and whether some of the SWF can be diverted to Tolly's Nullah, which was also recommended in earlier Master Plans.

Gully pits and storm water entry manholes in various locations are blocked with solid waste or have inadequate hydraulic capacity to quickly admit storm water to the sewers during the monsoon. Gully pits should be provided at the rate of 100 1/ sec/ ha in built up areas and this requirement is not met.

The identification and replacement of the poorly performing gully pits is required, together with the construction of new gully pits to allow storm water to quickly drain to the drainage system.

Pumping Stations

Most of the major pumping station buildings are in a state of disrepair and require upgrading. The building fabric is old and dates from pre-independence time. Some of the pumps in the pump stations are old. Old pumps should be replaced with a modern, efficient design of pump preferably VSD controlled, and preferably of a standardised make throughout the KMC area for ease of maintenance. Spare parts for the old pumps are not available any more and spares therefore have to be manufactured locally. The 2035 DWF and SWF flows have been compared with the capacities of the major Drainage Pump Stations. Whilst DWF pump capacities are adequate the SWF pumps have inadequate capacity for 2035 SWF flows in all cases. Additional capacity is also required at BDPS to improve the flow of sewage to the pump station. The installation of a deeper pump sump is required to allow incoming sewers to be desilted.

Old and inefficient pumps along with lack of proper maintenance consume high energy. A programme of replacement of pumps older than 30 years is recommended. At all major pump stations, the electrical switchgear and pump control panels require replacement and upgrading. Pump station silt pits need to be re-designed to facilitate the removal of silt from both sewers and pump station.

The silting up of the outfall canals require the SWF pumps to pump to a higher level, reducing the volume of water pumped. Therefore, it has been recommended that better coordination of the entire pumping system functioning and introduction of a SCADA control system from a central control room need to be ensured early. At all pump stations, mechanical screens should be installed at secondary screen chambers and primary screens replaced by new stainless steel screens to protect the mechanically raked screen downstream. Another recommendation is that at all pump stations, penstock/ sluice gates need to be renovated, ventilation needs to be improved and a monorail arrangement with 2T capacity is needed.

Canals

The hydraulic capacity of the outfall canal system has been reduced due to siltation and deposition of solid waste. Due to paucity of funds, periodic maintenance is not undertaken - the DWF canal was last maintained in 1999 and the SWF canal was last maintained in 2003-2004.

Responsibility for maintenance of the canal system lies with the state Irrigation and Waterways Department. The maintenance of the trunk sewers and pump stations is the responsibility of the KMC - this separation of responsibility for different parts of the drainage systems leads to problems.

Control structures have been installed at various places including the outfall at Ghusighata. Due to paucity of funds these sluice gates and outlet structures have not been maintained, and up to 40-50% of the gates require repair.

Canal banks have been encroached by informal dwellings within the KMC limits. Access to the canals for maintenance is made more difficult. Resettlement of the canal dwellers should be given a high priority.

The budgets for canal maintenance are inadequate. In 2003/2004, only 7.7 Iakh was spent on canal maintenance in the KMC area and on outfall canals.

l &WD have estimated the minimum amount of funding required per annum for canal maintenance as 190 lakh. Separately, PMC have estimated that 2,021 lakh rps is required per annum for 10 years to bring the canals back to their designed condition.

A pumping station at Ghusighata has been recommended in previous Master Plans. The need for a pumping station at Ghusighata will be reviewed as part of the hydraulic modelling work being undertaken for this Master Plan and is reported on in section 11.

The need for dredging in the Kulti River to accommodate the continuing discharge from the Kolkata outfall canals - a major issue in flood proofing of the city - requires further detailed study and cost estimation.

Institutional Issues

Kolkata Corporation

The Constitution (74th) Amendment Act provides the KMPC to prepare a development plan for the larger metropolitan area. (Vision 2025).Each municipal body within the larger area will need to prepare short-term and long-term development plans.

There should be clear provision within the KMC Act conferring the responsibility of preparing development plans for the city on KMC. The responsibility for land use and development control should also be given to KMC.

Traditionally, KMC employed a large number of unskilled staff for the purposes of sewerage and drainage maintenance. A major 0&M issue has arisen with a directive from KMC management placing a ceiling on labour recruitment (hence freezing of manual

labour engagement); also, there is the recent directive from the Supreme Court that unskilled labourers should not be used for the removal of silt from sewers by manual means. Thus, henceforward sewer desilting will have to be undertaken primarily by mechanical means. KMC have only 10 jetting machine trucks; so, more need to be purchased for sewer desilting.

Due to division of work, KMC (Hd. Qtr.) is responsible for sewer maintenance for sewers greater than 600mm dia., and the Boroughs for sewers less than 600 mm dia. There are problems of coordination due to this sort of division of responsibility.

State I&W Department

There have been no overflows from canals within the KMC area. However at the moment the canals are not being maintained regularly. Water hyacinth should be dredged and removed from canals at the time of hyacinth growth and before the onset of the monsoon each year to improve canal carrying capacity. Every year there should be a post - monsoon survey of the canals at the same place each year to assess the amount of siltation. Repair of the flap shutters and sluice gates at the Ghushigata lock gates is required urgently. Land use is changing on the banks of the canal, the storm water and wastewater flow is therefore increasing and the smaller channels have inadequate capacity.

The Kulti River is considered to have adequate capacity for drainage discharge based on cross sections and observations of I&WD staff since the 1950s. The environmental condition of the Kulti River at the outlet sight is poor.

It is accepted by l&WD that there is a paucity of funds for canal maintenance. Standing arrangements need to be worked out to ensure functional coordination between the staff of I&W Department and the KMC's concerned departmental staff, particularly before the onset of monsoon every year.

Kolkata Metropolitan Development Authority

KMDA has broad responsibility over the entire KMA area for urban planning, urban drainage, transportation and the Ganges Action Plan (GAP) sewer construction system. Its activities within the study area of the KMC area are currently limited to maintenance of assets created earlier and some GAP Phase II work. Within the KMC area the GAP Phase I works are completed and were located in Borough I at Kestopur area and in Borough XV in South Suburban East and Garden Reach Service areas. The GAP Phase II system within KMC area is currently under construction and involves the construction of interceptor sewers on the north bank of Tolly's Nullah and discharge

to the KMC trunk sewer system. There is also work underway as part of GAP Phase II at the Circular Canal. A problem is the low number of households actually joining onto a newly constructed sewerage schemes. KMDA trunk sewer assets within KMC area are currently being transferred to KMC. Since KMDA functions now as the technical secretariat of the KMPC, any worthwhile flood mitigation plan of the KMC, both technically and financially, needs to be integrated with the planning and executing responsibilities of the KMDA.

The KMWSA, now functioning within the overall umbrella of the KMDA, is charged with the responsibility of construction and operation of water supply and sewerage systems outside the core KMC area. A key issue for KMWSA was the clarification of responsibilities for an improvement in the maintenance of the canal outfall system. This problem needs to be worked out in consultation with the State's I&W Department.

Long Term Goals

The following section sets out a list of goals that should be aimed for in 30 years time. These goals arise from the list of issues set out above and, if implemented, would result in an efficient and modern sewerage and drainage system for Kolkata with much-reduced flooding incidence in the core area of the city.

Integrated Urban Renewal

A very high priority for Kolkata is seen as an improvement in the system of sewerage and drainage planning and the links it has to urban planning in general.

Difficulties encountered in the implementation of the KEIP project in the Added Areas - e.g. 2 m dia sewer being laid in 4 m wide road - point to the difficulties of constructing sewer networks in highly congested, unplanned neighbourhoods.

To really improve the standard of sewerage and drainage in Kolkata a more comprehensive approach to planning and utilities is desirable, encompassing all urban services including roads, traffic, water supply, electricity, telecommunications, public space, green areas, sewerage systems etc.

The urban plan would include off- channel storage areas for storm water which would be used to confine any flooding in the monsoon to particular open areas- which could otherwise be used as parks or playing fields for example.

An integrated urban planning approach is required based on an updated urban plan. This would result in real upgrades of entire areas and with it an increase in land and housing values and increased revenue from property taxes.

Particular urban planning goals include the following:

- Integrated urban renewal approach
- Land Use plan to be prepared for KMC area and updated regularly
- Review of the KMC Act
- New regulations to be promulgated for wastewater disposal from new houses and high rise apartments, to include on site treatment for new high rise apartments if necessary
- Industrial premises to be required by regulation to have on-site treatment of wastewater as part of an KMC-wide Industrial Pollution Control Action Plan
- Separate sewerage systems should be planned in new areas as part of integrated planning of transportation, water supply, sewerage, gas, electricity, telecommunications etc
- Town planning is required to incorporate off-channel storm water storage in basins to attenuate storm flow peaks

Sewerage System

The goals for the sewerage system are primarily to attend to deferred desilting and maintenance of the trunk sewer system, and once the backlog of desilting has been cleared to implement a regular system of sewer maintenance. An additional important goal is the alleviation of flooding in the monsoon, particularly in the CBD area of the Town Basin.

Particular sewerage system goals include the following:

Desilting of Trunk Sewers

- Desilting of the trunk sewer system undertaken by specialist contractors using specialist vacuum trucks
- Backlog of desilting work to be undertaken by coordinated approach by the letting of a number of contracts to run concurrently
- Once sewers are desilted, regular sewer maintenance programme to be instituted to keep them desilted

Alleviation of Waterlogging

- Alleviation of waterlogging in the core area, by specific measures at identified locations
- Increase number of catch pits and gully pits and improve the process of storm water entry to sewers.

- Sluice Gate Structure to be constructed across Tolly's Nullah at Hastings. These sluice gates to be closed in the monsoon against tidal lock to aid drainage to Tolly's Nullah

Construction of additional trunk sewers

- From hydraulic modelling, construction of additional trunk sewers in areas where hydraulic modelling shows existing capacity is insufficient.

Extend Sewerage System to Unsewered areas

- Extension of sewerage system areas to areas currently unsewered or not covered by KEIP Phase 1. These additional sewerage systems would be constructed mainly in Added Areas Boroughs I and Xl-XV but also in Boroughs IX and X.

Storm Water Drainage

Particular storm water drainage goals include the following:

- Separation of DWF and SWF achieved over entire KMC area
- Peak storm flows in monsoon to be accommodated by discharging SWF to Tolly's Nullah and River Hooghly
- Off channel storm water storage and attenuation basins to be included in system design

Pumping Stations

The pumping stations are old and inefficient and have a history of breakdowns. Pump station upgrades will increase their efficiency and reduce the energy cost.

The recommended approach is for complete rehabilitation, including upgrades for all mechanical equipment, improvements in electrical, control and ventilation systems and general repair of the pump station structures.

Particular pump station upgrade goals include the following:

- Complete pump station upgradation, including electrical upgradation
- Introduction of latest synchronization system (SCADA system) to improve pump station and sluice gate operation coordination.
- Separation of DWF and SWF as part of pump station upgradation.
- Construction of deep pump sumps at major pump stations to aid in improving trunk sewer hydraulics and in desilting inlet sewers
- Installation of mechanically raked screens at all pump stations
- Sustainable system of maintenance introduced at all pump stations

Canals

The hydraulic capacity of the outfall canal system has been reduced due to siltation and deposition of solid waste. Due to a paucity of funds, periodic maintenance is not undertaken. Siltation of canals leads to reduction in hydraulic capacity. Control structures, sluice gates and outlet structures on the canals have not been maintained. Canal banks have been encroached by informal dwellings. The budgets for canal maintenance are inadequate. Adjoining municipalities also used the canal system for discharging wastewater and the responsibility for improving re outfall canals is not only KMC's.

Particular outfall canal goals include the following:

- Implementation of an institutional arrangement which guarantees the outfall canals are regularly maintained for all municipalities using them in the future
- Canal desilting programme
- Setting up of an O&M system to ensure that canals are regularly maintained in the future
- Rehabilitation of sluice gates and lock gates
- Resettlement of informal dwellers living on canal banks
- The DWF and SWF canals separated and not mixing together upstream of Bantala Lock
- Review of need for dredging of Kulti River
- Receiving water discharge standards to Surface Waters set by the Central Pollution Control Board fully complied with
- Industrial wastewater discharges must be either controlled at their source or provision made at a central treatment facility to accept such wastewater.

Private Sector Participation

A few examples in this context are:

- Sewer maintenance including desilting sewers.
- Canal desilting and dredging.
- Residuals removal from pump stations (screenings) and sewage treatment plants (sludge, screenings).
- Pump Station Electrical Maintenance.
- Pump Station SCADA Instrumentation Maintenance.
- Independent Water and Sewerage Authority set up, independent of KMC.
- Engineering Design and Construction Supervision.
- Client/Consultant partnership in undertaking projects and sharing risk (of The New Engineering Contract, Institution of Civil Engineers, UK).

Mayor's Vision

At the height of the latest flood in June-July, 2007, the Mayor of KMC, faced by severe media criticism and public outcry, had come out with an unusually candid and detailed explanation of the city's recurring annual floods along with suggested concrete measures to mitigate (not eliminate) flood havoc to give the citizens much sought after relief. The following excerpts from the Mayor's article published in an important local daily (Anandabazar Patrika, July 17 and 18, 2007) reveal as much his anxiety as his determination to save the city from the annual deluge:

The upshot of Mayor's argument is: On one side is the unprecedented, huge rainfall and on the other is the city's choked drainage system. Since the British days, the combined drainage system has been such that domestic sewers and rainwater are drained through different sizes of pipes into outfall channels via a number of pumping stations. The brick sewers are of two types - man entry sewers and non-man entry sewers. As the name suggests, the former used to be cleaned by 'man', and the latter by natural flooding during high tide of the river Ganges. For the last several decades, the humdrum task of regular cleaning of these sewers has somehow not received the attention it deserves. Successive surveys have revealed that through years of sedimentation the 'man entry' brick sewers - the lifeblood of the city - have virtually turned into solid impervious stone slabs. As regards the non-man entry sewers, steady loss of navigability of the River over the years and appearance of sand bars have rendered the old process of natural flooding of these sewers inoperable.

As the Mayor has written, on emergency basis the KMC engineers have visited cities like Mumbai and Delhi, as also some of the cities of South-East Asia, to see at first hand the advanced system of 'micro-tunnelling'. Detailed project report has since been prepared and submitted to the Government of India for approval. This would cost nearly Rs.5oo crores. The project is now under implementation in phases. To quote the Mayor, "We have now embarked upon working out a fundamental solution - an exceedingly difficult task where every body's help is needed."

Commenting on the problem of the 'added areas', the Mayor has said, "Contrasted with the old city, the newly added areas have hardly any drainage structure. Starting from Cossipore in the North (Ward Nos. 1-6) and the extensive areas of Garden Reach-Behala-Jadavpur in the South, at no point of time there has been any planning and construction of durable structure of drainage and sewerage for them. After a great deal of thought, the State Government and the KMC have jointly launched the Rs. 2000-crore project called the KEIP (Kolkata Environmental Improvement Project) with loan fund from the Asian Development Bank. The project has been under implementation for the last one and a half years".

Referring to problem of the drainage outfalls, the Mayor observes that the city's sewers and storm water drain out to two main outfalls: the river Ganges in the west and Bidyadhari in the north. Regarding the main canals at the south-west fringes of the city - Tolly's Nallah, Monikhal, Bagor khal, Churial Khal etc., his observation is that the reason why Behala gets flooded during the monsoon is due to the fact that all these canals are then in spate. Similar is the situation with the river Ganges. To make things worse, during high tide the river water rushes into the canals and the neighbouring areas. There is back flow of water from the pumping stations. The story is much the same with the canals at the eastern fringes of the city - Tollygunge-Panchannagram Canal, Bhangor Katakhal, Kestopur Canal, Bagjola Canal etc.

The role of these canals in managing urban floods in Kolkata is of crucial importance. These canals are looked after by the Irrigation and Waterways Department of the State Government. Hence, the Mayor has taken up the issue of desilting and excavation of these canals with the concerned Minister of the Department as well as the engineers of the Department. For this purpose, a substantial amount - Rs. 200 crores - has been allocated, and the work has just commenced.

The Mayor has made special mention of the East Kolkata wetlands in this context, which he has likened to the 'kidney' of the city. As he has rightly pointed out, most of city's sewerage flows through the wetlands and drains out to Kulti-Bidyadhari Gang. Since the 1950s, as the Mayor makes a caustic remark, 'there has been a lot of torture on the wetlands in the name of spread of civilization'! Currently, however, steps have been taken to save the wetlands (now declared as a Ramsar Site) in the interest of wider environmental considerations.

Acknowledging the gravity of the problem, alongside the big investments, provision has been made for phased desilting of the sewer pipes throughout the year out of the limited revenue budget of the KMC.

As the Mayor concludes, 'spending Rs. 2,500 crores is a huge and time-consuming task. It will take quite some time to see results flowing from these investments.

Action Plan Under Execution

Meanwhile, multi-pronged ameliorative measures have been planned, and these are already under execution at selected sites. To the great relief of the citizens of Kolkata, quite a few areas have since been made relatively free of water-logging through planned and appropriate interventions. These areas are:

Borough VI: Junction of APC Road & S. N. Banerjee Road - new sewer along S. N. Banerjee Road leading to Circular Road, Brick sewer laid including construction of additional gullypits

Borough VI: Free School Street in front of Fire Brigade to Market Street - Existing brick sewer reconstructed enhancing capacity, and hard silt within brick sewer (80% silted) removed successfully. Also, additional gullypits constructed

Borough VII: Circus Avenue and Lower Range - existing sewer on Circus Avenue leading to new Park Street - brick sewer was damaged during construction of AJC Bose Road flyover. Difference of invert level between lateral sewer on Lower Range and invert of new sewer laid by HRBC (flyover construction agency). New sewer now laid along Circus Avenue leading to sewer at Shakespeare Avenue

Borough VII, Ward 66: Swinhoe Lane & Adjoing Areas - New drainage system developed on Swinhoe Lane leading to BDPS. Originally, drainage system was leading to TP Channel through DD-I Canal, causing water logging for a longer period

Borough VIII: Southern Avenue & Adjoining Areas - New lifting pumping stations commissioned beside Nazrul Stadium to cater to storm water on Southern Avenue & adjoining areas - same being discharged in Tolly's Nullah.

Besides these interventions, KMC has been able to access the JNNURM fund recently and this has greatly facilitated KMC's longer term planning to ameliorate the flood situation at critical locations in the city. A list of such areas (other areas are being taken up in phased manner) along with planned measures to bring relief is presented below:

Project Sites and Ameliorative Measures

- Suddar Street: Rehabilitation of non-man entry Brick Sewer
- Kyd Street: : Rehabilitation of non-man entry Brick Sewer
- Free School Street Part-A: Rehabilitation of non-man entry Brick Sewer
- Free School Street Part-B: Rehabilitation of non-man entry Brick Sewer
- Free School Street Part-C: Rehabilitation of non-man entry Brick Sewer
- Jhawtolla Road: Rehabilitation of non-man entry Brick Sewer
- Samsul Huda Road: Rehabilitation of non-man entry Brick Sewer
- Baker Road: Rehabilitation of non-man entry Brick Sewer
- Gopal Nagar Road: Rehabilitation of non-man entry Brick Sewer
- Mominpur Road: Rehabilitation of non-man entry Brick Sewer
- Dehi Srirampur Road: Rehabilitation of non-man entry Brick Sewer
- Dehi Srirampur Part-A Road: Rehabilitation of non-man entry Brick Sewer
- Gora Chand Road Part-B: Rehabilitation of non-man entry Brick Sewer

Other measures under implementation are (a) canal desiltation to improve the outfall system, (b) survey and planned maintenance of water bodies within KMC area,

(c) planned improvement of the pumping stations including new constructions, (d) strengthening Borough administration to enhance its capacity to cope with local level ameliorative measures, and (e) strengthening of KMC's planning function to ensure coordinated approach (as against stand alone approach) to floods mitigation.

The Way Ahead

Kolkata, as can be surmised from the elaborate presentation above, has a very extensive and complicated drainage system, a chain of pumping stations and an age-old outfall system. Hence the technical aspects of floods mitigation are of formidable nature. These need to be scientifically studied, and the situation needs to be constantly watched for timely upgradation. It is not merely KMC that has to look after the system; it is a whole network involving the KMC, Government departments, parastatal organizations and even private agencies.

On the planning front, floods mitigation and city planning need to be dovetailed to evolve an integrated vision and action plan. It has been our experience that intensity of flooding has a certain relationship with 'unplanned' growth of the city under situations of tremendous demographic pressure. Two of the familiar responses, have been to permit house building activities without much thought to zoning and land use regulations, and the sprouting of unregulated squatter settlements in any area of the city, particularly in the low-lying areas. As the Calcutta experience bears this out clearly, the first phenomenon - the real estate boom - increases the housing stock no doubt but in most cases at the cost of the urban environment especially the urban open spaces, the water bodies and the greeneries. As regards the squatter settlements, these unplanned growths along rail lines and canals, and in the midst of low-lying areas create sanitation hazards and act as barriers to natural egress of storm water flow. Structures that come up haphazardly encroach on the flood plain. Unplanned land use and other human activities influence the peak discharge of floods by modifying how rainwater is stored on and run off the land surface into streams and low lying areas. The permeable soil is replaced by impermeable surfaces such as roads, roofs, parking lots and side walks that store little water, reduce infiltration of water into the ground, and accelerate run off to ditches and streams.

Under these circumstances, it is now dawning on the planners and policy makers and urban managers that what is needed is an integrated and comprehensive urban planning and not just the conventional ad hoc fire-fighting approach. Coping with urban flood has to be integrated with the overall planned development effort as in the case of the nationally sponsored JNNURM for the large mission cities. As the upgradation plan for city's infrastructure is taken up and the urban poor are assured of

improved access to urban civic services and a decent livelihood, such planned efforts must take into account the flood hazards that need to be mitigated and removed within the broader framework of comprehensive planned city development. Special mention needs to be made in this context of 'urban water harvesting plan' which is now being strongly advocated in many cities for flood proofing as well as water retention for drinking, fire-fighting and other urban water uses.

Based on weather forecasting data and information by the meteorology department, a fairly precise early warning system on flood occurrence can be developed. Such a system would be alerting the municipal authority including the citizens of the relatively vulnerable areas in the city so that the municipal organization and the citizens might be put on high alert about the impending heavy showers and consequent flooding of specific localities. From this point of view, intra-municipal communication system is as important as municipality-citizen communication.

As things stand now, KMC has prepared a comprehensive floods mitigation plan that has to be steadily implemented in a phased manner and monitored under close supervision. Alongside these measures, KMC has to develop mechanisms to involve the citizens in floods mitigation planning and implementation. This would call forth a full-throated effort to invigorate the 'ward committees' that have so far remained either moribund or non-existent. Particularly, the worst sufferers - the bustee dwellers - need to be organised and made conscious of their own innate strength to combat flood ravages. SJSRY set-up may be mobilised and tied up with KMC's disaster management plan for the purpose with appropriate training and resources support. Popular participation, particularly the participation of the poor and the marginalized, has not so far been a strong point of the KMC.

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