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Editorial Note

Flood is the most common and recurrent natural disaster in our country. Every year, on an average, we are losing well over thousand five hundred people, hundred thousand animals, hundred and fifty thousand houses besides standing crops over eight million hectres of land. It is estimated that goods and assets worth more than thousand crores are lost every year due to the furies of floods.

Over the years the country has invested hundreds of thousand crores on flood protection and mitigation measures. Many of these measures have protected lands and assets in many places, but the overall impact of such investments are not seen in reducing the risks of flood. In fact, the risks of flood seem to be increasing every year.

A number of factors are responsible for these developments. First, carrying capacity of our rivers are getting reduced due to increasing silt loads. Even normal to heavy rains are swelling rivers to flood the banks. Secondly, increasing demand of water have reduced the capacity of reservoirs to store excess water and spill off even during normal rains, thereby creating manmade floods in many places. Thirdly, the rainfall pattern itself is changing breaking past trends and records, as demonstrated during the unprecedented rainfall in Mumbai in July 2005 when a single day rain exceeded the annual average. Last, but not the least, pressures of population, particularly in the urban areas, have resulted in unplanned and even planned settlements in flood panes that have exposed more people to the risks of flood.

In fact, urban flood has emerged as an important issue of disaster management in our country. As we are passing through the peak process of urbanization, when about 300 million people are expected to be added to our cities during the course next two decades, we have the challenging task to ensure that the risks of flood in our cities are reduced.

The National Institute of Disaster Management had conducted a series of coordinated studies on urban flood. The last issue of our journal had published four such study reports. We are happy to publish the remaining four reports in the current issue.

(P. G. Dhar Chakarbarti)

Urban Floods: Case Study of Bangalore

T. V. Ramachandra and Pradeep P. Mujumdar

Profile of the City

Bangalore is one of the fastest growing cities in India and is branded as 'Silicon Valley of India' for heralding and spearheading the growth of Information Technology (IT) based industries in the country. With the advent and growth of IT industry, as well as numerous industries in other sectors and the onset of economic liberalisation since the early 1990s, Bangalore has taken lead in service-based industries fuelling substantial growth of the city both economically and spatially. Bangalore has become a cosmopolitan city attracting people and business alike, within and across nations. This profile notes the urban setting and provides an overview of the urban fabric, while discussing various prospects related to infrastructure and governance (Sudhira, et al. 2007).

Bangalore

Bangalore[1] is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka. Greater Bangalore[2], an area of 741 square kilometres agglomerating the city, neighbouring municipal councils and outgrowths, was 'notified' (established) in December 2006 (Figure 1.1 and Figure 1.2). A tiny village in the 12th century, it grew to become one of the fastest growing cities in the world by the 21st century and to figure among the million-plus cities in India[3]. Bangalore has grown spatially more than ten times since 1949 (Table 1.1).The city enjoys a pleasant and salubrious climate throughout the year. Its tree-lined streets, numerous parks and abundant greenery have led to it being called the '*Garden City*' of India. It has also been identified as the country's *'Silicon Valley'* and it is one of the technological innovation hubs with a technological achievement index (TAI) of 13[4]

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

* Data compilation Analysis: Uttam Kumar, Sudhira H.S., Chitra S. Raju and Ranjini V.

1 *The name, Bangalore has been proposed for renaming to 'Bengalooru' by the State government following suit of Bombay to Mumbai, Madras to Chennai and Calcutta to Kolkota. However, we use Bangalore all through.*

2 *The Urban Development Department, Government of Karnataka has issued gazette notification vide No. UDD/92/MNY/2006, dated 2.11.2006 for constituting the Bruhat Bangalore Mahanagara Palike (Greater Bangalore City Corporation) merging the existing area of Bangalore City Corporation, 8 Urban Local Bodies (ULBs) and 111 Villages of Bangalore Urban District.*

3 *PTBangalore is the fifth largest metropolis in India currently with a population of about 7 million.*

4 *Almost on par with San Francisco, USA, while Silicon Valley, USA is number 1 with TAI of 16.*

according to the Human Development Report (United Nations Development Programme, 2001). However, with all the hype about growth in IT and IT based industries, Bangalore also houses numerous other leading commercial and educational institutions, and industries like textiles, aviation, space, biotechnology, etc. As an immediate consequence of this growth in the last decade, apart from creating a ripple effect in the local economy, there has also been great pressure on infrastructure and resources like water supply, energy, public transportation, land, etc. The local body and other parastatal agencies responsible for delivery of basic services are facing stiff challenges in catering to this demand.

Table 1.1: Bangalore City Corporation limits over the years

Year	Area (sq. km)
1949	69
1963-64	112
1969	134
1979	161
1995	226
2007	716

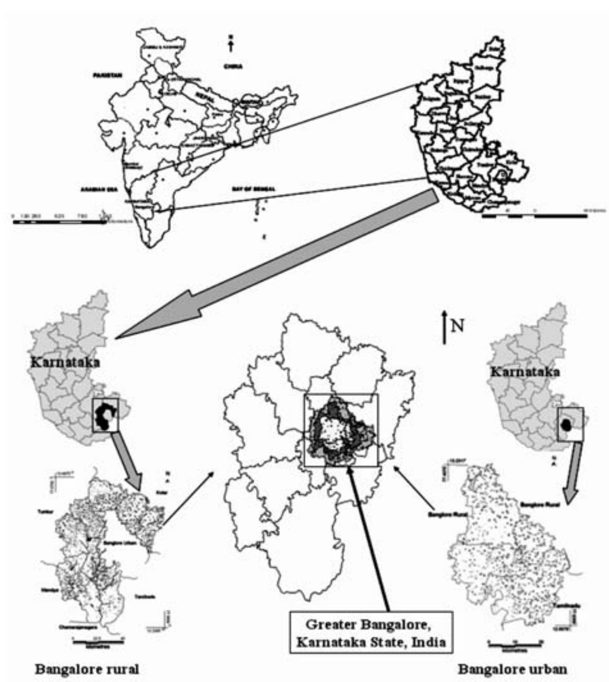

Figure 1.1. Location of Creator Bangalore

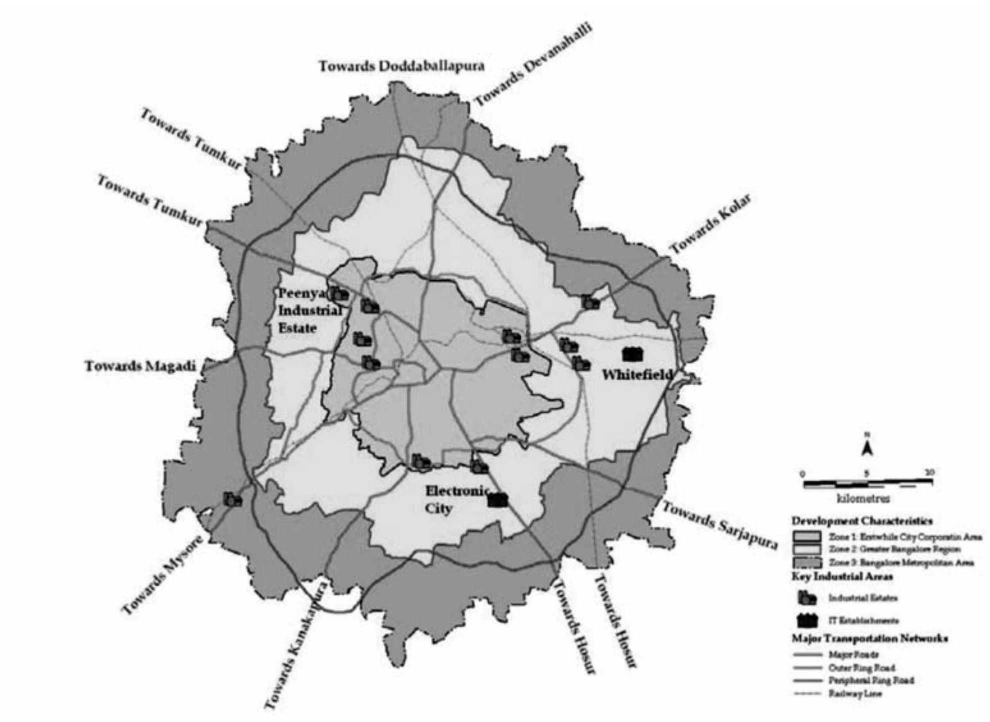

Figure 1.2: Map depicts Development Characteristic over Bangalore with the erstwhile City Corporation limits, Greater Bangalore region and Bangalore Metropolitan area and noting some of the prominent industrial areas.

Quite recently there have been serious attempts by sociologists and urban planners to characterise the city. Heitzman (2004) has analysed the nature of growth that the city experienced with the emergence of the information society, while bringing out the ingredients that led to the transformation of planning methodologies and spatial planning tools for the city. Nair (2005) has exemplified Bangalore as 'the promise of the metropolis' while illustrating the urban fabric of Bangalore over the last century. In this profile, an attempt is made to bring out the status of current infrastructure and various facets of planning and governance.

The next section deals with the origin and history of the city followed by a description of climate, geography and environment. The subsequent section considers culture, demography and economics. Lastly, the urban agenda addressing governance and infrastructure discussing the stakeholders involved, challenges in managing urban infrastructure and issues in planning and development are elaborated.

History and Culture

The earliest reference to the name, in the form '*Bengalooru*', is seen in a ninth century Ganga inscription (hero-stone) from Begur , referring to a battle that was fought in that place. The present name of the city, Bangalore is an anglicised form of *Bengalooru* which according to the popular belief is derived from *Bengaalu* - synonymous of *Benda kaalu* or boiled beans and *ooru* meaning a town. Tradition associates Hoysala King Vira Ballala (12th Century) with the origin of this name. Vira Ballala, during one of his hunting expeditions in this region, lost his way and after hours of wandering reached the hut of an old woman. This woman is believed to have offered cooked beans to the king. Pleased with her hospitality, the king named the place as '*benda kaala ooru*' (town of boiled beans). But it is interesting to note that there was already evidence for name of the place much before Hoysalas. Kamath (1990) notes that Bangalore is said to have got its name from *benga,* the local Kannada language term for *Pterocarpus marsupium*, a species of dry and moist deciduous tree, and *ooru*, meaning town. However, the founding of modern Bangalore is attributed to Kempe Gowda, a scion of the Yelahanka line of chiefs, in 1537 (Kamath, 1990). Kempe Gowda is also credited with construction of four towers along four directions from *Petta*, the central part of the city, to demarcate the extent of city growth (Figure 2). By the 1960's the city had sprawled beyond these boundaries (Asian Development Bank, 2001).

Figure 2: The Kempe Gowda Tower at Lalbagh – one of the four towers Kempe Gowda built to demarcate the extent of city growth in four directions [Photo: H. S. Sudhira]

Later on, the city was administered by the Wodeyars, rulers of Mysore, until it was given as *Jagir* (with rights for general administration and collection of taxes) to Hyder Ali during late 18th Century. Hyder Ali and later, his son, Tippu Sultan, were responsible for growth and development of Bangalore in a significant way with the construction of summer palace and Lalbagh. Indeed, Bangalore was already the commercial capital during Tippu's time and the second important city after Srirangapatna, Tippu's capital. During the early nineteenth century, the city was known to have almost all coins in circulation from different places and kingdoms, thus evidencing a flourishing trade and commerce (Buchanan, 1870). The fall of Bangalore in the Second Mysore War of 1792, may also have led to the fall of Tippu Sultan in Third Mysore War of 1799, after which Bangalore became a base for the British troops and saw the establishment of the Cantonment in 1802. British control over Bangalore was initially established indirectly through the Maharaja of Mysore. By 1831 the administration of the city was taken over by the British, and in 1862 two independent municipal boards were established: Bangalore City Municipality (in the older areas), and Bangalore Civil and Military Station Municipality. At Independence, Bangalore was notified as the capital of Mysore (now Karnataka) State. In 1949, the two municipalities were merged and the Bangalore City Corporation was formed. Subsequently, to keep up with the pace of growth and development, there have been reorganizations with respect to the zones and wards within the corporation, rising from 50 divisions in 1949 to 95 wards in 1980s, 100 wards in 1995 and now about 150 wards. With the 2006 notification, the Bangalore City Corporation is now reorganized as Greater Bangalore City Corporation (Note 2).

Bangalore, in spite of the buzz around IT-based and related commercial activities, has retained much of its unique cultural ties keeping its date with its history, culture and tradition. The city is known for historical temples such as the Someshwara temple in Halasuru (neighbourhood of Bangalore) built during 12th – 13th century by Cholas, Basavanagudi (Bull Temple) built by Kempe Gowda during 16th century, Kaadu Malleshwara temple built during 17th century in Dravidian architecture, and Gavi Gangadhareshwara temple, all nestle in the middle of the city. Apart from the numerous temples that have mushroomed around the city, Bangalore also has one of the six basilicas in the country, built during the 17th century, St. Marks Cathedral built during 1808, the oldest mosque, Sangeen Jamia Masjid built by the Moghuls during the 17th century, and the popular Jamia Masjid near the City Market built during the 1940s. The 'Bengalooru Karaga' is a major annual fair associated with the Dharamaraya temple, is considered to be the actual fair of the erstwhile city, and is still persistent in the older central parts of the city. Karaga, a five-day festival of Tigalas, a community who migrated from Tamil Nadu, has many unique features such as intense religious fervour, strict rituals, unchanged traditions over centuries, a fixed route and stops for the procession, welcome and respect shown at all the temples on route. The annual groundnut fair, '*Kadalekai Parishe*' takes place in a part of old city, Basavanagudi during November-December. More recently, an annual cultural fest called '*Bengalooru Habba*' ('*habba*' in kannada means festival) is held during the first week of December hosting various cultural programmes like music, dance and drama. The involvement of all sections of people and the unique communal harmony displayed by the special prayer at Tawakkal Mastan Darga (mosque) are also remarkable (Chandramouli, 2002).

Geography and Environment

Bangalore is located at 12.591/4 north latitude and 77.571/4 east longitude, almost equidistant from both eastern and western coast of the South Indian peninsula, and is situated at an altitude of 920 metres above mean sea level. The mean annual total rainfall is about 880 mm with about 60 rainy days a year over the last ten years.. The summer temperature ranges from 18^{o} C – 38^{o} C, while the winter temperature ranges from 12^{o} C – 25^{o} C. Thus, Bangalore enjoys a salubrious climate all round the year. Bangalore is located over ridges delineating four watersheds, viz. Hebbal, Koramangala, Challaghatta and Vrishabhavathi watersheds (Figure 3). The undulating terrain in the region has facilitated creation of a large number of tanks providing for the traditional uses of irrigation, drinking, fishing and washing. Their creation is mainly attributed to the vision of Kempe Gowda and of the Wodeyar dynasty. This led to Bangalore having hundreds of such water bodies through the centuries. Even in early second half of 20th century, in 1961, the number of lakes and tanks in the city stood at 262. These, and open spaces generally, were seriously affected however with the enhanced demand for real estate and infrastructure` consequent to urbanisation. Temporal analysis of waterbodies indicate sharp decline of 58% in Greater Bangalore attributing to intense urbanisation process, evident from 466% increase in builtup area from 1973 to 2007. Figure 4.1 provides the distribution of wetlands in 1973, 1992, 2002 and 2007 based on the respective years' remote sensing data. The analysis revealed that there were 51 wetlands (321 ha) in 1973, 38 (207 ha) in 1992, 25 (135 ha) in 2002 and dropped down to 17 with an extent of 87 ha in 2007 in the Bangalore city limits. The corresponding number of waterbodies and their areas were computed and are listed in table 1.2 (Ramachandra and Kumar, 2008). There were 159 waterbodies spread in an area of 2003 ha in 1973, that reduced to 147 (1582 ha) in 1992, which further declined to 107 (1083 ha) in 2002 and finally there are only 93 waterbodies (both small and medium size) with an area of 918 ha in the Greater

Bangalore region. Waterbodies in northern part of greater Bangalore are in a considerably poor state compared to the waterbodies in southern greater Bangalore. With the city's unprecedented growth, the large number of public open spaces diminished over the years. Much of the loss in green cover is due to the rapid change in land use. As the city grew over space and time, inner areas got more crowded and congested. Initiatives to ease congestion on road networks have led to axing numerous road-side trees. Many lakes have been converted into residential layouts, bus stands, play grounds and stadiums, etc (Figure 4.2).The built-up area in the metropolitan area was 16 % of total in 2000 and is currently estimated to be around 23-24 %. The rest of the area is occupied by either agriculture lands, quarries or other vacant land.

In the aspect of nurturing flora and fauna, the situation in Bangalore is quite complex, with prominent green spaces like Lalbagh and Cubbon Park almost at the city centre and a few water bodies, such as Ulsoor, Sankey, Lalbagh, Yediyur and Madiwala, scattered across city's landscape, the remaining green spaces in the

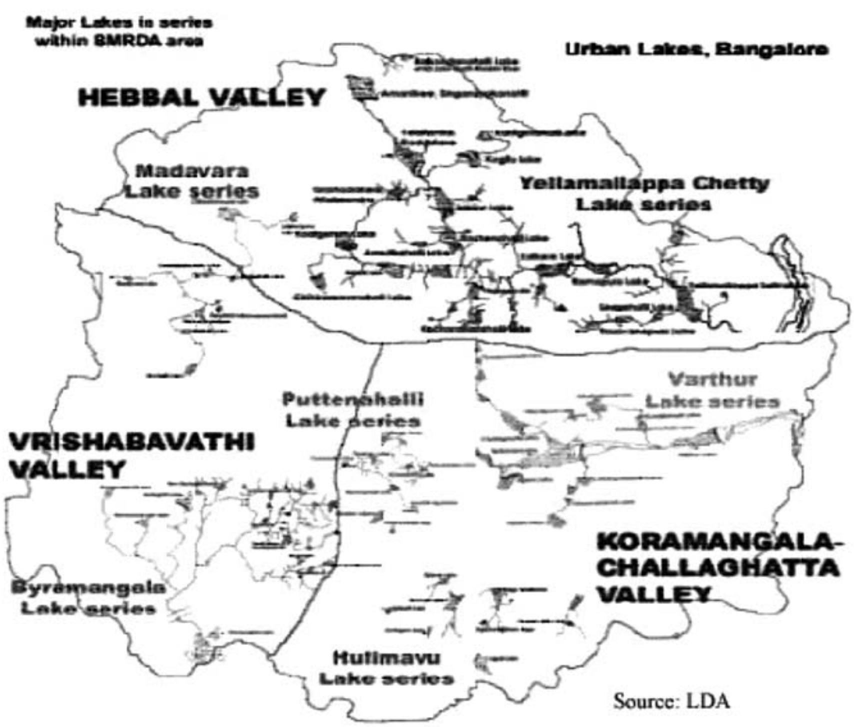

Figure 3: Cascading Lake series of Bangalore (Source: Lake Development Authority)

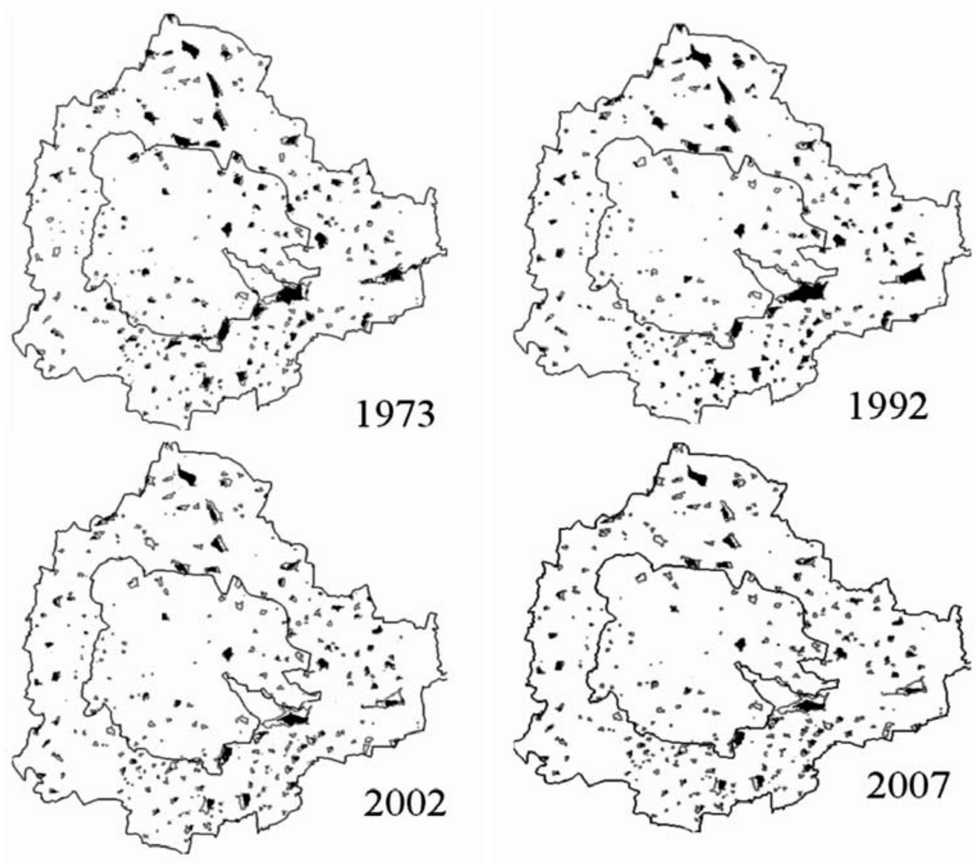

Figure 4.1: Temporal (1973-2007) changes in number of waterbodies in Greater Bangalore

periphery harbour a great number of species. In a compilation of fauna present in and around Bangalore within a radius of 40 km from city centre (Karthikeyan 1999), about 40 species of mammals, more than 340 species of birds, 38 species of reptiles, 16 species of amphibians, 41 species of fishes and 160 species of butterflies have been recorded. A new 'ant' species, *Dilobocondyla bangalorica*, was discovered in Bangalore recently (Varghese, 2006). In another study, Sudha and Ravidranath (2000) have investigated the floral assemblage in different land-use categories and the changes in vegetation over Bangalore City. About 164 species were identified in different residential areas, of which 149 were recorded within compounds and 87

Figure 4.2: Bangalore, once boasted of 81 lakes in the city limits, while now about 34 show some signs of existence. High-rise buildings sprouting across Bellandur lake.

Table 1.2: Changes in number of waterbodies during 1973 to 2007

	Bangalore City		Greater Bangalore	
	Number of Water bodies	Area in (ha)	Number of Water bodies	Area in (ha)
SOI	58	406	207	2342
1973	51	321	159	2003
1992	38	207	147	1582
2002	25	135	107	1083
2007	17	87	93	918

were avenue trees. The rich diversity speaks for the volume of life still persisting in spite of rapid urban growth.

In recent times, the increase in vehicular traffic (see section on Urban Agenda Addressing Infrastructure) has increased suspended particulate matter and other oxides of carbon, nitrogen and sulphur in the environment. Air pollution and the reduction in tree cover have induced the urban heat island effect resulting in variations in local temperature and sudden unanticipated showers during late afternoon.

Demography and Economy

The state of Karnataka was carved out in 1956 based on linguistic boundaries, with regions dominated by Kannada speaking people. Bangalore was retained as the capital of the state, with Kannada as the official language while accommodating other languages like Tamil, Telugu, Malayalam, English and Hindi, true to its cosmopolitan status,. The census of population in Bangalore has been recorded every decade since 1871, during the colonial times, the most recent census being carried out in 2001. Figure 5.1 shows the growth of population in Bangalore from 1871 to 2001 (5.7 million), along with an estimate for 2007 (7 million). Now, Bangalore is the fifth largest metropolis in India currently with a population of about 7 million. Population growth and population density changes during 1871 to 2007 is given in Figure 5.2. It is notable that since the first census, Bangalore was already the most populous city in Karnataka. This urban primacy has been retained consistently for more than a century now. After Independence, Bangalore, now a State capital, saw an influx of population migrating to the city, although it should be noted that the steep population rise in the decade 1941-1951, while due in part to this migration, also reflects the amalgamation of Bangalore Civil and Military Station Municipality with the Bangalore City Corporation. Population growth during the 1970s could be ascribed to numerous public sector industries and other defence establishments that came up during the period and fuelled significant immigration. By this time, incidentally, Bangalore had lost its tag of 'Pensioners Paradise', gained before Independence. Although the advent of IT is attributed to the late 1980s, major growth and expansion of this industry happened only during the late 1990s. Still, population growth in Bangalore in the last census decade, 1991-2001 (38%), was substantially less than in 1971-1981 (76%). Nevertheless, the physical growth of the city has been phenomenal over the last few years, and the glaring evidence of this is increased travel-times and the escalating real-estate prices.

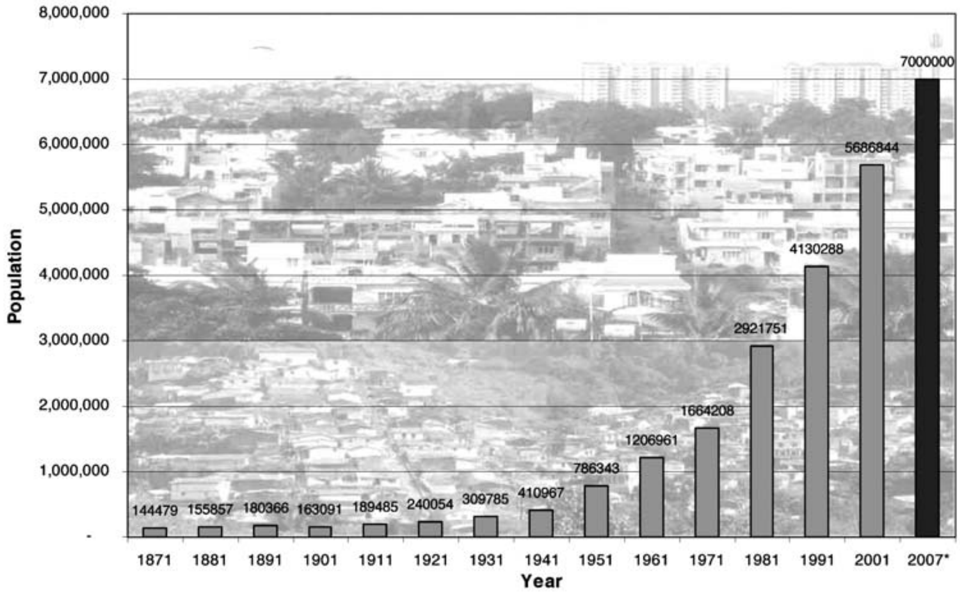

Figure 5.1: Population Growth of Bangalore City 1871 – 2007* (* The population for 2007 is an estimate) Source: Census of India (2001b)

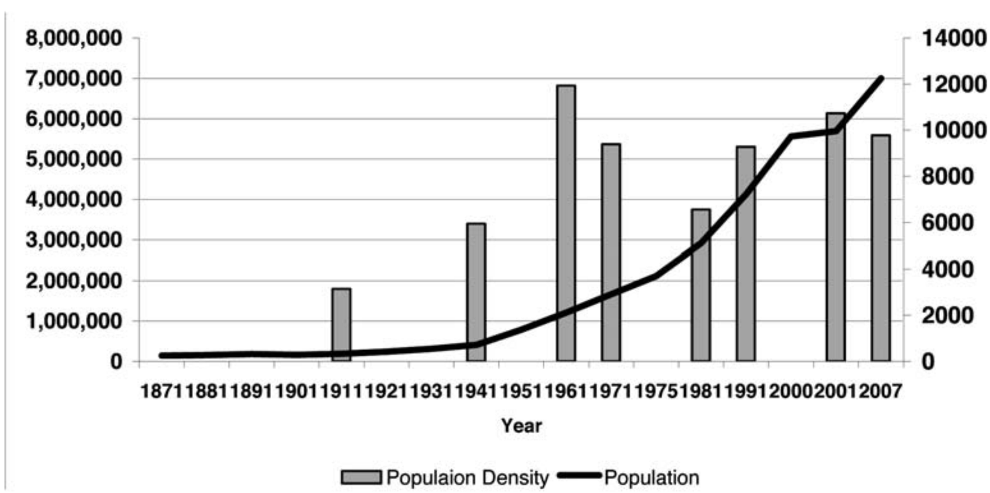

Figure 5.2: Population growth and population density

According to the latest census (Census of India, 2001a), the urban agglomeration had an overall population in 2001 of 5.7 million, including a workforce of 2.2 million, within an area of 560 sq. km, and a literacy rate of 75.1 %. The hype over the IT industry is underlain by Bangalore having about 30 % of all IT workforce in the country and a personal disposable income greater than the Indian city average. This has also resulted in a trickle down effect within the urban economy. Further, investments in industries (not only IT), infrastructure and other services, have significantly increased purchasing power among the people and have nurtured real estate with consequent land market dynamics, apart from creating numerous secondary employment in services. Interestingly enough, of the 5.7 million population in the urban agglomeration in 2001, about 2 million were migrants (Census of India, 2001b). About 1.2 million of these were from Karnataka state, mainly from the rural parts, while the remaining 0.8 million were from outside the state, the majority of these from urban areas. It is further noted that people have migrated chiefly for employment or moved with household or for education. The large number of migrant population from other parts of India explains the multitude of languages spoken and understood in Bangalore.

Bangalore is home to numerous high-tech knowledge hubs evident from the establishment of premier centres like Indian Institute of Science (IISc), National Institute of Advanced Studies (NIAS), Tata Institute for Fundamental Research (TIFR), Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Indian Space Research Organisation (ISRO), National Aerospace Laboratories (NAL), Defence Research and Development Organisation (DRDO), Indian Institute of Management (IIM), Institute for Social and Economic Change (ISEC), Indian Institute of Information Technology (IIIT) and several professional engineering and medical colleges at undergraduate and graduate levels. In tune with recent trends, Bangalore now has numerous malls and multiplexes that are swarmed during weekends. With an active night life and Bangaloreans penchant for fast-food, a large number of restaurants, pubs and 'eat-outs' throng the city.

The economic fabric of the city, although at times masked by the IT-based industries is varied, being also characterised by textile, automobile, machine tool, aviation, space, defence, and biotechnology based industries. In addition, numerous services, trade and banking activities mark the city's economic landscape. An important feature of the economic activities of Bangalore is the huge concentration of Small & Medium Enterprises (SMEs) in diversified sectors across the city. Bangalore has more than 20 industrial estates/areas comprising large, medium and small enterprises. Of these, Peenya Industrial Estate located in the northern part of the city comprises about 4000 SMEs and is considered the largest industrial estate in South and South East Asia (PIA, 2003). A majority of the SMEs function as ancillaries/subcontractors to large enterprises in the field of engineering and electronics industries, among others. The industrial estates sprung up mostly in the periphery of the erstwhile city and gradually as the city grew became part of its sprawl. Notable among these are the Peenya Industrial Estate just mentioned, Electronic City and Whitefield (Figure 1.2). The proliferation of SMEs in residential and commercial areas, in addition to the industrial areas, has added to the chaos and congestion in the city. Thus, the thriving economy of the city has resulted with a net district[5] income of Rs. 262,592 million (approx. US $ 5.8 billion) and a per capita income of Rs. 39,420, a little more than twice the State's average per capita income of Rs. 18,360 (Government of Karnataka, 2005). Despite higher per capita income within the urban district than in the rest of the State, and with significant migrant population, the number of urban poor has been on the rise and the slum settlements in the city have not been contained. The escalating costs of land prices coupled with rise in cost of living has pushed the urban poor to reside in squatter settlements with inadequate amenities and services (Figure 6). Some of these settlements have speckled the city's landscape garnering immediate action from civic authorities. According to BMP (2006), the number of households in the urban agglomeration defined as poor was 0.22 million, housing approximately 1.1 million people out of 5.7 million population (Table 2). Noting the importance of the matter, the State Government has set up a special agency, Karnataka Slum Clearance Board (KSCB)[6] specifically to address the redevelopment of slums in partnership with various stakeholders like the Housing Board, Local Bodies, Water Supply Boards, etc. The initiatives taken up by the local body addressing redevelopment of slums are noted in the section on Issues in Planning and Development.

Table 2: Distribution of Slums across Greater Bangalore (BMP, 2006)

Agency / Authority	No of slums	No of Households	Remarks
Karnataka Slum Clearance Board (KSCB)	218	106,266	Declared
Greater Bangalore City Corporation	324	110,991	310 Undeclared & 14 Declared
Grand Total	542	217,257	

Note: Estimates are based on 2001 Census

5 *In the Indian federal system, each state is divided into districts (which are further divided into taluks) for administrative purposes, including decentralised implementation of developmental programmes. The State of Karnataka has 27 districts, of which Bangalore Urban is one, comprising Bangalore East, Bangalore South and Anekal Taluks. Taluk boundaries dissect the city and extend beyond the Bangalore Metropolitan Area. Thus the 'net district income' refers to the entire district and not to the city alone.*

6 *Karnataka Slum Clearance Board is responsible for slum improvement, clearance and rehabilitation of the slum dwellers.*

Figure 6: The plight of urban poor in Jayanagar 9th Block [Photo: BMP]

Urban Agenda: Governance and Infrastructure

An important aspect of a city is how well it is planned, managed and administered, activities which form the core part of an urban agenda – governance. However, appropriate state mechanisms through organisational structures, procedures and policies are needed to enable these. Also, apart from the formal administrative structures, the presence and involvement of civil society significantly drive the urban agenda.

Organisations and Stakeholders

Greater Bangalore City Corporation (Bruhat Bengalooru Mahanagara Palike) is now the key 'Urban Local Body' (ULB), that is, the local governmental structure representing and responsible to the citizens) for the city and outlying areas. Notified in December 2006, the new Corporation replaced the erstwhile local bodies, Bangalore City Corporation (Bangalore Mahanagara Palike), 8 neighbouring councils (7 City

Municipal Councils and one Town Municipal Council) and 111 outlying villages. Independently of the Corporation[7], which is governed by locally elected representatives, parastatal bodies controlled by the State government are responsible for many essential services (see Table 3).

Planning in the form of land use zoning and regulation are vested with Bangalore Development Authority (BDA), a parastatal agency, in spite of the he 74th Constitutional Amendment Act, passed by the national parliament in 1993. This Act requires that the planning function be vested with the (elected) urban local body and not with any parastatal agency. But, in the case of Bangalore, the Corporation have not been granted adequate powers by the State to plan, decide and administer their city! Furthermore, the State has created numerous other organisations of its own to manage various services such as water supply, law and order, energy, etc. The result is the existence of many parastatal organisations, each acting in its own geographic area, leading to complication and confusion in coordinating different activities. Apart from the issue of a common geographical unit and the lack of coordinated effort, even basic information related to different sectors is extremely difficult to collect, collate and to correlate. For effective planning it is imperative that all the basic information is gathered across a common geographical unit with the effect of creating a robust city information system. In addition to the official bodies, civil society of Bangalore is known for its vibrant community participation. The spectrum of their activities ranges from literacy and green brigades to urban governance, ensuring continuous interactions with the local administration. Notable spheres of activity of these Non-Governmental Organisations (NGOs) include: improving urban governance by Citizens Voluntary Initiative for the City (CIVIC) and *Janaagraha*; improving living conditions in slums by *AWAS*, *APSA*, *Paraspara*, etc.; addressing child literacy by *Prerana* and the India Literacy Project; taking on environmental issues by the Environment Support Group, *Hasiru Usiru*, etc. Apart from the NGOs, there are numerous resident welfare associations, trade and commercial organisations, and professional organisations that have played a major role in some of the important activities of local bodies and influencing their decision-making. Civil society has contributed considerably in shaping the policies and governance structures and has always intervened whenever there has been any apathy on the part of the administration towards activities of interest to society at large. An experiment to promote public private partnership and bring together citizens, NGOs, industry representatives and the erstwhile local bodies resulted in

7 *'Corporation' refers to the recently notified Greater Bangalore City Corporation unless otherwise stated.*

"Bangalore Agenda Task Force (BATF)". This experiment was about to be benchmarked as one of the 'best practices' in urban local governance, when it faced strong criticisms from several civil society groups for setting aside priorities favouring the urban poor and was accused of making a back door entry towards policy making (Ghosh, 2005). In the event, the activities of BATF came to a standstill with the change of guard at the State government two years ago and it is currently dormant. Another instance of strong action by civil society groups, was seen when the local government started tree felling and pruning for road widening. Members of the green brigade, *Hasiru Usiru,* staged protests, held an all night vigil, stormed the Commissioner's office and also moved to High Court and finally got the actions stayed. The High Court also ruled later that *Hasiru Usiru* members should inspect the trees along with the designated Tree Officer from the Forest Department (TOFD) before any tree felling and pruning of branches was begun.

Challenges in Managing Urban Infrastructure

Urban activities require the support of infrastructure. Broadly, urban infrastructure can be divided into social and economic infrastructure. Social infrastructure encompasses facilities like health care, education, housing, commercial (shops, markets and hotels), sports, recreation and entertainment. With mixed land use being practiced in most parts of Bangalore, shops and markets are the most commonly found amenities (approximately 1 shop per 100 persons) in the urban agglomeration[8] (Karnataka Urban Infrastructure Development & Finance Corporation, 2006). The provision and maintenance of primary health care, elementary education, sports, recreation and entertainment are administered mostly by the Corporation, while BDA also facilitates some of the social infrastructure like shopping complexes, with provisions for private participation. Economic infrastructure encompasses water supply, wastewater treatment, storm water drainage system, solid waste management, telecommunication network, and transportation network.

Bangalore Water Supply and Sewerage Board (BWSSB) is the parastatal agency responsible for drinking water supply, and wastewater collection and treatment in the city. Bangalore is on a ridge and does not have its own year-round sources of water. Drinking water is pumped from the river Cauvery, a distance of about 100 km over an elevation of 500 m with an energy expenditure of 75 MW for approximately 900 million litres per day (MLD). Apart from the river Cauvery supply, ground water and water from the river Arkavathy are also tapped. However, while water supply distribution is 100 percent in the

8 *The urban agglomeration refers to the area formally administered by Bangalore City Corporation and the 8 councils.*

Table 3: Organisations Concerned with Bangalore

Organisations	Functional Areas (Scope of Work)
Greater Bangalore City Corporation [Bruhat Bangalore Mahanagara Palike (BBMP)]	Urban local body responsible for overall delivery of services - Roads and road maintenance including asphalting, pavements and street lighting; solid waste management, education and health in all wards, storm water drains, construction of few Ring roads, flyovers and grade separators
Bangalore Development Authority (BDA)	Land use zoning, planning and regulation within Bangalore Metropolitan Area; Construction of few Ring roads, flyovers and grade separators
Bangalore Metropolitan Region Development Authority (BMRDA)	Planning, co-ordinating and supervising the proper and orderly development of the areas within the Bangalore Metropolitan Region, which comprises Bangalore urban district and parts of Bangalore rural district. BDA's boundary is a subset of BMRDA's boundary
Bangalore Water Supply and Sewerage Board (BWSSB)	Drinking water – pumping and distribution, sewerage collection, water and waste water treatment and disposal
Bangalore City Police	Enforcement of overall law and order; Traffic Police: Manning of traffic islands; Enforcement of traffic laws; Regulation on Right of Ways (One-ways)
Bangalore Metropolitan Transport Corporation (BMTC)	Public transport system – Bus-based
Bangalore Metro Rail Corporation Ltd (BMRC)	Public transport system – Rail-based (Proposed)
Regional Transport Office (RTO)	Motor vehicle tax; Issue of licenses to vehicles
Bangalore Electricity Supply Company (BESCOM)	Responsible for power distribution
Lake Development Authority (LDA)	Regeneration and conservation of lakes in Bangalore urban district

former Bangalore City Corporation limits, only about 20 % of the Municipal Council households are serviced. In view of the rapid growth of the city, and recent notification of Greater Bangalore, it remains a challenge to service the remaining areas.

Regarding collection and treatment of wastewater, the sewerage system is based on the city's four natural river valleys already noted and BWSSB is the nodal agency. There are three major treatment plants with a total capacity of about 450 MLD (the outlets of Koramangala and Challaghatta valleys are combined to form the K&C Valley Treatment Plant at Bellandur). Wastewater stress on natural water bodies is evident from the fact that the present wastewater treatment capacity in the city is around 450 MLD as against an estimated generation of domestic wastewater of 700 MLD. Although more secondary wastewater treatment plants are in progress, they are yet to be completed. Another problem is the frequent clogging of storm water drains, resulting in pollution of natural water bodies. Hence it is now proposed to rehabilitate and remodel all the major trunk sewers to prevent any discharge into the storm water drains.

Addressing mobility in Bangalore city, an overview of transportation and traffic reveals the following facts. Bangalore city is estimated to have vehicle population of about 2.6 million while the current city population is about 7 million. The vehicle to person ratio is far higher than any other city in India. This has led to increased congestion in road networks across the city and frequent traffic jams. Manning signalling at traffic islands have also become unmanageable with the amount of traffic plying across junctions. Again, in this sector different components related to mobility are vested with different parastatal bodies.

Public transportation forms one of the key functionalities for mobility in any urban area. In Bangalore where the working population is around 2 million, the Bangalore Metropolitan Transport Corporation (BMTC) operates on any given day with 4,144 schedules, 4,262 buses, 60,475 trips, and carries 3.5 million passengers. It earns Rs. 20.5 million per day and pay Rs. 0.955 million to the government as taxes (Bangalore Metropolitan Transport Corporation, 2006). Further, according to recent estimates, there are about 1.6 million two-wheelers, 0.32 million motor-cars, 80,000 auto-rickshaws, and 0.17 million other vehicles totalling to around 2.2 million vehicles on road (Regional Transport Office, 2006).

The onus of maintaining and improving road networks lies with the Corporation. Although a study for the City by consultants iDeCK and Rites (2005) identified 52 high and medium traffic intensity corridors requiring various interventions by different organisations, the former City Corporation proposed only to widen some of these roads. A key aspect ignored while addressing mobility is the role of land use in generating traffic demand. Failure by the city to acknowledge this, and in particular the implications of changes in land use from residential to commercial or industrial, has led to stereotypical approaches in addressing mobility such as road widening, creation of new flyovers and underpasses, or conversion into 'one-ways'. In general Bangalore has over a period promoted mixed land use which at some level has led to inefficient usage of land. With the City's compartmentalised approaches to widening of roads or construction of flyovers and grade separators, the problem of mobility is far from being solved.

Issues in Planning and Development

To understand the development characteristics of the Bangalore metropolitan area, it may help to distinguish three concentric zones – zones which correspond closely with previous current local authority areas. The first zone would comprise the erstwhile city corporation area of 226 sq. km. The second zone would include the areas of the former 8 neighbouring municipal councils and 111 villages, which together form the peri-urban areas and are now incorporated into the Greater Bangalore City Corporation. The third zone would include other villages extending up to the Bangalore Metropolitan Area limits as proposed by Bangalore Development Authority. The development characteristics and agencies across these zones are summarised in Table 4 and depicted in Figure 1.1.

Traditionally, planning has been restricted to land use planning, being vested with BDA for the region under Bangalore urban agglomeration, and with Bangalore Metropolitan Region Development Authority (BMRDA) for the larger peripheral area comprising the rest of Bangalore Urban DistrictP8P. BDA obtains the land, develops it as residential layouts which eventually are handed over to the city corporation, often involving the extension of city limits. Land use plans are formalised through the Comprehensive Development Plans (CDP) prepared every 10 years. Accordingly, the last CDP, prepared in 1995 for the period up to 2011, was revised in 2005-06 for the period up to 2015 (BDA, 2006) and is currently awaiting approval. A key aspect of these CDPs are that they indicate the amount and location of land use allocated for various uses (like residential, commercial, industrial, etc.) as well as restricting development in specific areas demarcated as Green Belt and Valley Zones. However, another organisation similar to BDA, the Karnataka Industrial Area Development Board (KIADB), is responsible for development of industrial areas. These industrial estates are situated for the most part in the outskirts of the city and KIADB has powers under the law to take over agricultural lands for the purpose.

Generally, however, the regulation and enforcement of land use zoning regulations are dismal, leading to a large number of illegal developments and encroachments on public land – problems which have led Karnataka State to constitute a legislative committee to look into irregularities in and around the city. In the particular case of growth occurring around outer industrial areas, the urban local bodies are generally unable to provide basic infrastructure and services, thus further aggravating inefficient utilisation of land and other natural resources. With such instances prevailing especially in the areas of the former Municipal Councils, the new Corporation faces a great challenge to deliver basic infrastructure and services.

On 3rd December 2005, the Ministry of Urban Development, Government of India, launched the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). This countrywide programme addresses renewal of urban areas for 63 cities encompassing nearly 70% of total urban population, its primary aim being to link the revitalisation of urban infrastructure with a specific agenda of institutional reforms. Bangalore is one of the beneficiaries under this programme with an estimated outlay of US $ 1.7 billion over the next six years. The key mission of this programme is to support reforms-driven, fast track, planned development with focus on improving efficiency in urban infrastructure and service delivery mechanisms, through community participation and ensuring accountability of urban local bodies and parastatals towards citizens. JNNURM is made operational with two sub-missions:

- Urban Infrastructure and Governance (UIG)
- Basic Services to Urban Poor (BSUP)

The sub-mission on UIG focuses on major infrastructure projects for water supply, sanitation, sewerage, solid waste management, road network, urban transport and redevelopment of inner (old) city areas with a view to upgrading infrastructure therein, shifting industrial and commercial establishments to conforming areas, etc. The sub-mission on BSUP focuses on integrated redevelopment of slums combining housing, water supply, drainage, storm water drains, solid waste management, street lighting, and community halls.

In accordance with the JNNURM guidelines, the erstwhile Bangalore City Corporation prepared the City Development Strategy Plan (CDSP) for both UIG and BSUP (Bangalore Mahanagara Palike, 2006). The CDSP outlines only an investment plan and financial strategy for taking up various initiatives envisaged in the mission. Under BSUP, 218 declared slums in the former City Corporation limits would be taken up by KSCB for redevelopment. Further, there are 169 slums under the erstwhile City

Table 4: Development Characteristics across Bangalore

Characteristics	Development Zones		
	Zone 1	**Zone 2**	**Zone 3**
Authority	Greater Bangalore City Corporation (formerly Bangalore City Corporation)	Greater Bangalore City Corporation (formerly 8 municipal councils) and 111 Villages)	Development Authorities and other Town and Village Municipal Councils
Urban Status	Core city	Outgrowth	Potential areas for future outgrowth
Infrastructure Services	Present, but nearly choked, needs augmenting of existing infrastructure	Not fully present, with new growth, requires planning and augmentation of infrastructure	Farmlands and scattered settlements with minimal no infrastructure
Impact of growth	No scope for new growth but calls for urban renewal to ease congestion, etc	High potential for growth since already peri-urban area and emergence of new residential layouts and other developments	Mostly rural, with minimal growth currently, but potential for future growth
Planning, Development and Regulation Controls	Corporation operates building controls. Planning vested with BDA.	Corporation operates minimal building controls. Planning vested with BDA.	Planning vested with parastatal agencies: BDA and BMRDA and not other local bodies. No regulation on building/ construction

Corporation jurisdiction that remain undeclared, which would be redeveloped by the new Corporation. There are, in addition, 155 slums in the neighbouring former municipal council areas that would be redeveloped by the new Corporation and KSCB. However a draft community participation law has not been enacted and in Karnataka State most of the infrastructure projects and redevelopment plans have been administered by ULBs and parastatal agencies and not through community participation as envisioned by the mission. The result is a continuation of top-down rather than bottom-up modes of planning and delivering infrastructure and services. This calls for introspection on the implementation and achievement of the mission objectives. However, with various initiatives under JNNURM underway, it does offer hope, and perhaps promise, and in improving the essential urban infrastructure and services in city.

Conclusion

Bangalore, with all due respect to its status as 'Silicon Valley' and 'Garden City', faces real challenges in terms of addressing and delivery of basic infrastructure and services to all its stakeholders. In spite of numerous initiatives and activities envisaged by the urban local bodies, past and present, and by parastatal bodies, the rationalisation of geographical units for these activities could mark the beginning of a coordinated effort in addressing the needs of the city. In the wake of recent notification of Greater Bangalore City Corporation and initiatives under JNNURM, Bangalore is currently experiencing a strange transformation. Bangalore also stands out as a beacon of globalising world and to sustain this, it needs to systematically address the key challenges facing the city in terms of governance and infrastructure.

City Infrastructure with special reference to Drainage

Bangalore Roads

Bangalore population has been growing at a rate of 2.8 to 3.20% per year during the last two decades. There has been a phenomenal growth in the population of vehicles as well especially the two and four wheelers in this period due to rising household incomes consequent to IT sector boom in the region. The number of motor vehicles registered has already crossed three millions. The issues relating to traffic and transportation in a large and growing city like Bangalore need to be viewed in the larger perspective of urban planning and development. Issues relating to land use planning and development control, public-private transportation policy, industrial locations and IT corridors would need to be integrated at the perspective planning level.

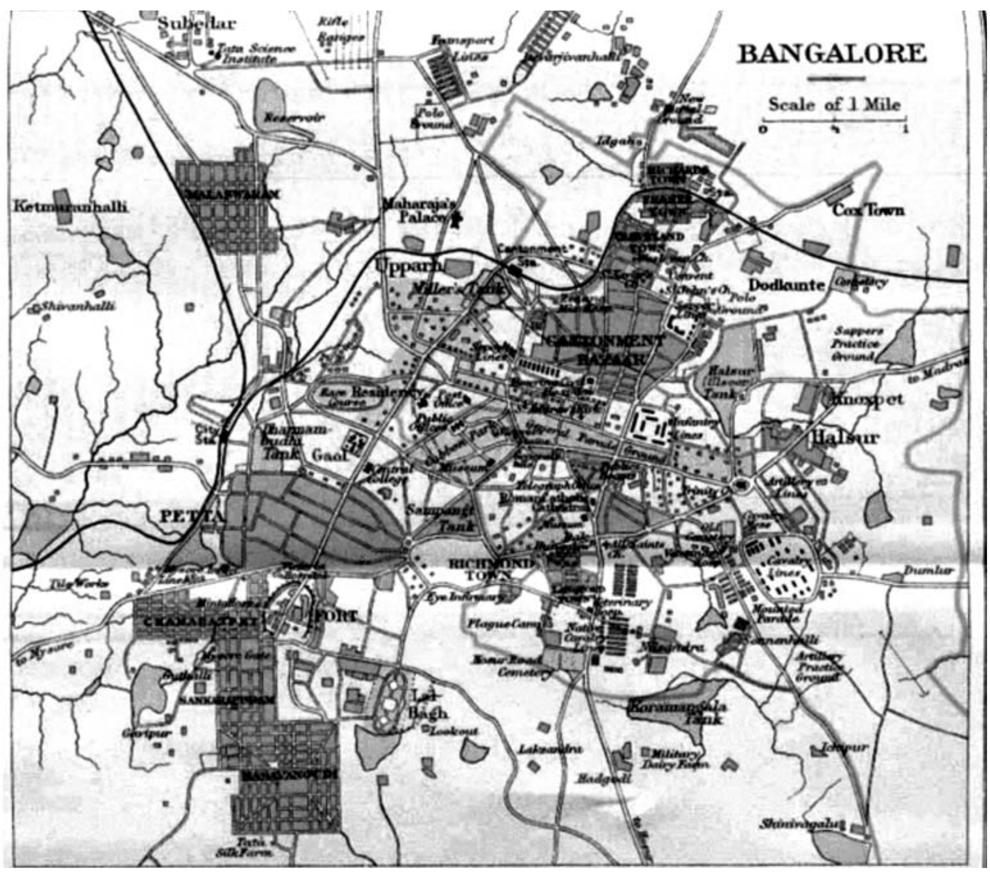

Figure 7.1: Road network in erstwhile Bangalore (Source: Murray's 1924 Handbook)

Bangalore's road network exceeds 3,000 km and consists of ring roads, arterial roads, sub-arterial roads and residential streets. The city road network is mainly radial, converging in the centre. The main roads of Bangalore coming into the city include Bellary Road in the north, Tumkur Road and Mysore Road in the west, Kanakpura Road and Hosur Road in the south and Airport Road and Old Madras Road in the east (Figure 7.2, and 7.1) . Many of Bangalore's erstwhile colonial and town streets were developed into commercial and entertainment areas after independence. The B.V.K Iyengar Road became the retail hub of Bangalore, while MG Road, Commercial Street and Brigade Road became important shopping, recreation and corporate areas . Consequently, traffic increased exponentially, especially on MG Road, which forms the main artery for the city's east-west traffic. But for MG Road, other roads in and around the erstwhile Parade Ground remain narrow, winding roads. Road network capacity is inadequate. Most of the major roads are with four lane or less with limited scope of their widening. This indicates the need for judicious use of available road space.

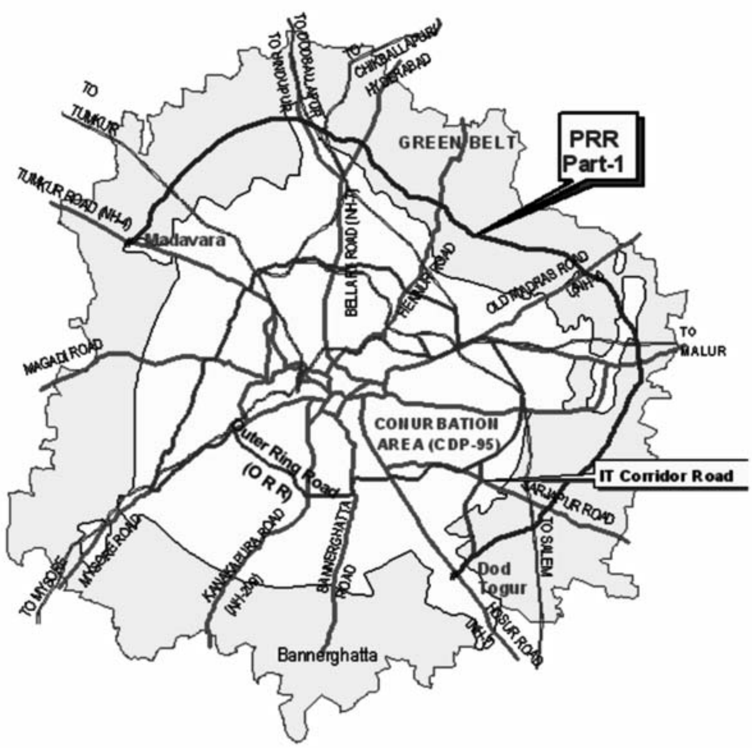

Figure 7.2: Road network as on 2007 (source: www.bdabangalore.org)

The maintenance and construction of roads to address the growing traffic in the city has been a challenge to the BDA and the BBMP. Development of the city road infrastructure has revolved around imposing one-way traffic in certain areas, improving traffic flow in junctions, constructing ring roads, bridges, flyovers and other grade separators. Six high volume junctions were identified for improvements, through a private public partnership involving corporate sponsors and various state government agencies, such as the Siddapur Road and Hosur Road junction, sponsored by Infosys and the Airport Road and Intermediate Ring Road junction. Flyovers were constructed in the city to ease traffic congestion. Newer flyovers were planned for the city for 2006 and beyond (HTUhttp://en.wikipedia.org/wiki/Infrastructure_in_BangaloreUTH). Area of the BMP has been increased as per Revised Master Plan-2015. This plan has provided for densification of existing areas, Mutation corridors, hitech areas etc in various parts of the city. This is likely to have a major impact on traffic demand. The transport network including mass transport system needs to be planned taking the proposed development in to consideration.

Solid Waste Management

The city is facing acute problems related to solid wastes. This is despite the fact that the largest part of the municipal expenditure is allotted to management of municipal solid wastes. The current waste generation in Bangalore is 3613 tonnes per day and the number is likely to grow in the next few years due to the increasing population and will present a formidable challenge to authorities unless an integrated approach is taken. The objective of this paper is to present an overview of the current waste management practices in Bangalore and to discuss suitable methods to overcome the constraints. This paper was built up on various interviews conducted with the authorities and of experiences and observations (Ramachandra, 2006; Ramachandra and Saira Varghese, 2003).

An overview of the current waste management practices in Bangalore

Bangalore City is divided into 100 administrative wards, which have been further divided into 273 health wards for functional convenience (Ramachandra and Saira Varghese, 2003). Of these, 147 health wards are under private contract system and the remaining 126 health wards are managed through Pourakarmikas (municipal sweepers) of the Corporation. Except for few wards in Bangalore there is no door-to-door collection service in Bangalore. The areas not served are mostly unincorporated or illegal settlements and slum areas with small and inaccessible streets. By contrast more prosperous areas are better served, kept clean and swept on a regular basis.

Waste generation: The waste generation in Bangalore is given in Table 4.1:

Table 4.1: Waste generation in Bangalore

Stakeholders	Quantity of Waste (tonnes/day)	%
Households	650	18
Commercial Establishments	1436	39
- Markets	369	1067
- Hotels		
Institutes	128	4
- Hospitals	20	
- Offices	16	
- Educational institutions	92	
Industries	1399	39
Total	3613	100

Source: Beukering, et al., 1999

As evident from the table, wastes from commercial establishment make up for the bulk of the total wastes. Although industries also generate a significant amount, it was analysed that most of this is recovered for recycling and reuse and only a small percentage find it's way into the city waste stream.

A typical waste composition for major Indian cities is given in Table 4.2

Table 4.2. Composition of urban solid waste in Indian cities (percentage by weight)

City	Paper	Metals	Glass	Textiles	Plastic[1]	Ash, dust	Organics	Others[2]
Chennai	5.90	0.70	-	7.07	-	16.35	56.24	13.74
Delhi	5.88	0.59	0.31	3.56	1.46	22.95	57.71	7.52
Kolkota	0.14	0.66	0.24	0.28	1.54	33.58	46.58	16.98
Bangalore	1.50	0.10	0.20	3.10	0.90	12.00	75.00	7.20
Ahmedabad	5.15	0.80	0.93	4.08	0.69	29.01	48.95	10.39
Mumbai	3.20	0.13	0.52	3.26	-	15.45	59.37	18.07

Source: Planning Commission on "Urban Solid Waste Management in India', GOI (1995), The expert Committee,2000

1 Includes rubber and leather

2 Includes bones, stones and wooden matter

As evident from the Table above, the composition of organic waste is high in all the cities and Bangalore ranks the highest. Waste densities and moisture contents are high, which require different technology and management system. High organic content and low biodegradable waste are typical of Indian cities and hence incineration is a less appropriate option.

Waste storage: Waste is stored in 14,000 bottomless and lidless cement bins having 0.9 meters diameter and 0.6 cubic meter storage capacity and large masonry bins for depositing waste placed at a distance of 100-200 meters. Recently 55 metal containers have been placed at different parts of the city. However not all parts of the city are provided with storage systems. In some places, the wastes are just deposited on roadsides.

Waste collection and transport: Collection of waste is either done by Bangalore Mahanagara Palike (BMP) or by private contract system. In December, 2001 BMP and Bangalore Agenda Task Force (government appointed body) through a joint initiative established a public private partnership, by launching a sustainable cleanliness program called 'Swachha Bangalore'. Twenty five percent of the city is served under this scheme. Swachha Bangalore is mainly door to door collection of wastes using pushcarts (Plate 2.1). There are totally 2105 pushcarts in operation in Bangalore, which consists of 4 buckets that are used to store dry wastes and wet wastes separately. Swachha Bangalore scheme also covers selected slum areas and auto tippers have been deployed for collection of wastes (Plate 2.3). There are 6500 pourakarmikas in charge of door to door collection, sweeping, emptying dustbins and clearing black spots. They arrive at a designated spot to transfer the waste to the truck. Trucks have a capacity of 4-5 tonnes capacity and are either openbodied or covered with a mesh (Plate 2.2). The ratio of truck to ward is 4:20. Other collection systems consist of bullock carts, tricycles etc. Collection is sometimes difficult due to narrow roads and due to this waste is not picked on time causing unsanitary conditions. There are no transfer stations in Bangalore.



Plate 2.1. Pushcart Plate 2.2. Waste transfer Plate 2.3. Auto tipper

Transportation of wastes to disposal site is done in two ways through the same trucks.

- by engaging 82 trucks of the corporation;
- through contractors by engaging 129 vehicles for layouts and markets and 72 vehicles on contract for transportation of waste.

The corporation also has 13 dumper placers for transporting metallic containers of 2.5 to 3 tonnes capacity and 6 minicompactors for transportation of wastes.

Waste processing and recovery: The method adopted to process waste is composting. Karnataka Compost Development Corporation handles 120 metric tonnes of raw garbage/day in the yard. Out of 100 tonnes of raw garbage, 55 tonnes of compost is obtained. Due to constraints of land, finance and demand, the facility can handle only 120 tonnes of wastes. As such out of the 369 markets in and around the city, only 2 have been accepted for composting. Vermicomposting is also practised to handle a portion of the waste. Dry wastes such as plastic, rubber, glass and other contraries are later disposed off.

Waste disposal: Disposal is the final stage of waste management system. About 90% of the municipal wastes collected by the civic authorities in Indian cities are dumped in low-lying areas outside the city/town limits. The waste disposal trends in major Indian cities are as given in Table 4.3.

Table 4.3 Waste disposal trends in India

Waste disposal methods	**1971 – (40 cities)**	**1991 and 1999 (23cities)**
Land dumping	Almost all	89.8%
Composting	-	8.6 %
Others (pelletisation, vermi-composting)	-	1.6 %

In Bangalore, the waste collected from roads and bins is directly transported to the final disposal site, usually an open dump. There is the likelihood of soil and groundwater contamination due to this practice. Birds (scavengers), vermin, insects and animals are attracted to the open dump for feeding and breeding. Since many of these may act as disease vectors, their presence may constitute a potential health problem. Sometimes plastic and other contraries are burnt, which may be hazardous to human health. Landfilling of wastes is not practiced in Bangalore. Figure 7.3 provides information on the various SWM options in Bangalore. Recycling takes up 43% and is an area to be further exploited. Thirty one percent of the waste is disposed, which is mainly burnt or simply dumped in open spaces.

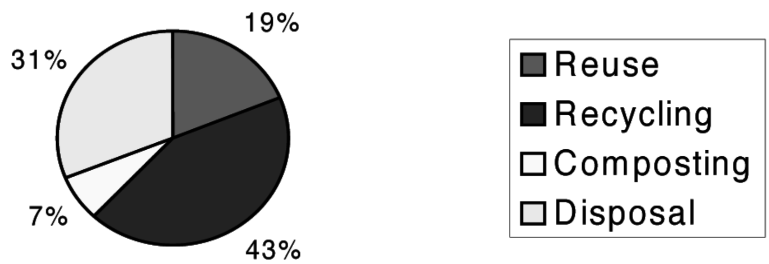

Figure 7.3: SWM Options in Bangalore

Under the Central Government Municipal Solid Wastes (Management and Handling) Rules, 2000, gazetted in India on 25th September 2000, all municipal authorities must:

1. Provide a waste collection service to all domestic dwellings, including slums and squatter areas, and commercial premises (note that no distinction is drawn between urban and rural areas).
2 Provide waste storage facilities which do not create unhygienic and unsanitary conditions;
3. Remove waste stored in the above facilities on a daily basis and in a manner such that manual handling by sanitary workers is avoided; and
4. By no later than the end of 2003, establish waste processing facilities and landfills at which:
    - the biodegradable fraction of municipal solid waste is only processed by biological conversion technologies; and
    - landfilling is restricted to non-biodegradable, inert waste and other waste that is not suitable either for recycling or for biological processing.

It is apparent that none of these, are presently being met in a satisfactory way in Bangalore. In this regard, recommended waste storage, segregation and collection, treatment and disposal (Ramachandra and Shruthi, 2007) are:

1. Adoption of door-to-door collection service daily, in all urban areas, including slums, where practical and affordable to do so. The household waste storage bins are collected, emptied and returned by the sanitary worker from the front of the residential premises at a predetermined period of the day (i.e. morning or afternoon) and day of the week. Community waste storage system in all markets, commercial and industrial premises, and domestic premises where it is either not practical or affordable to provide a door-to-door collection service. This will probably include multi-storey dwellings and rural areas where population densities are low. These containers are positioned to ensure convenience to users, particularly women who are the primary users, and hence minimise illegal littering and dumping practices. Segregation of waste at source in domestic, markets, restaurants and hotels and other commercial and industrial premises where biodegradables constitute a major component of the waste stream into wet and dry fractions.
2. A network of local and regional waste modular transfer stations is established throughout the region and municipal solid waste is hauled in bulk from these transfer facilities to the closest regional waste processing facility.
3. Decentralised biological treatment facilities are established and operated by the community based organizations at local levels (with the technical and financial support) where it complements the formal systems. Further expansion of the Karnataka Composting Development Corporation (KCDC) biological processing facilities are undertaken and similar units be initiated in other parts (Figure 7.4). Landfills are established close to biological processing facilities for disposal of waste processing rejects and other wastes not suitable for recycling.

Sewage System

Bangalore is located over ridges and the city's topography is characterized by a series of well defined valleys which radiate from a ridge (Figure 3) of high ground to the north of the city and fall gradually towards a wide belt of flat cultivated land extending beyond the limits of the BMP boundary to the south. Four major watersheds are Hebbal, Koramangala, Challaghatta and Vrishabhavathi. Three of the valleys, Vrishabhavathi (V-Valley), Koramangala (K) and Challaghatta (C), run generally in a north to south direction and divide the greater part of the metropolitan area which lies to the south of the ridge into three separate and distinct drainage zones. A fourth major valley, referred to as the Hebbal series, forms the drainage zone to the north of the ridge and runs in a north-easterly direction. Five minor valleys, the Kathriguppe and the Tavarakere to the south, the

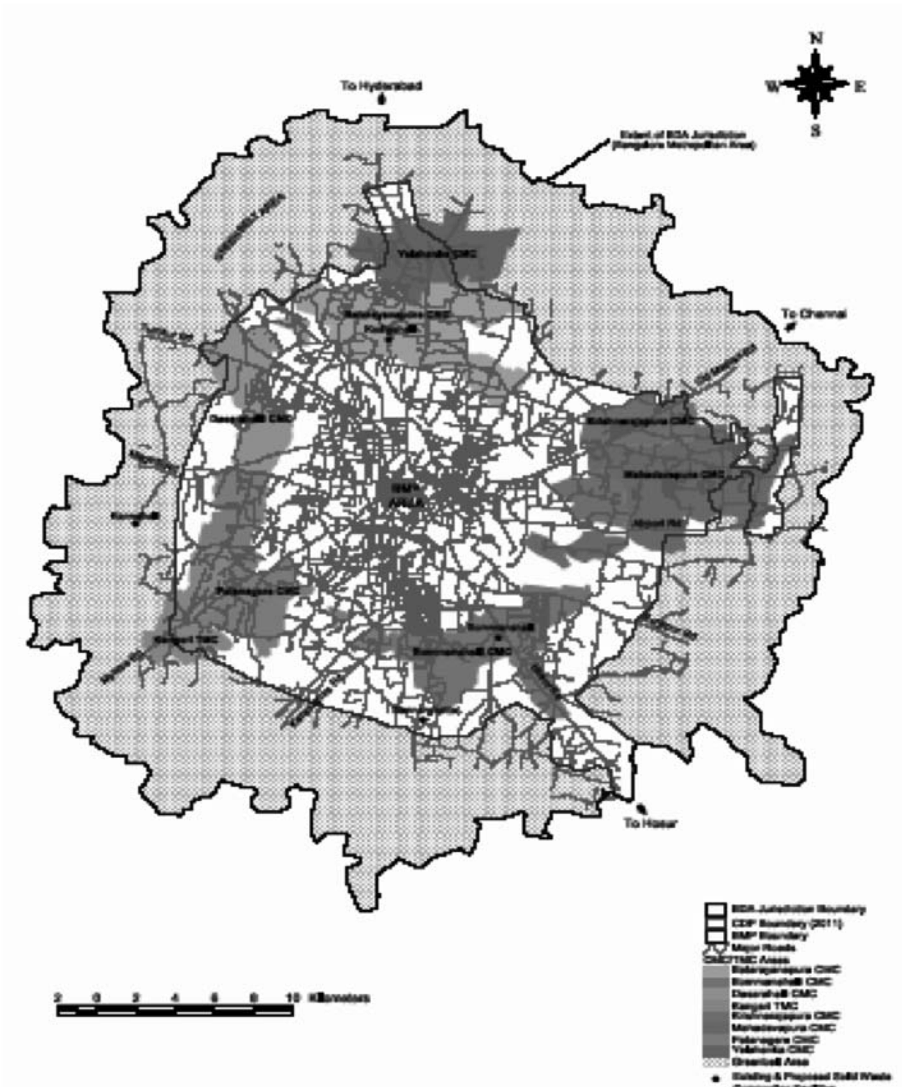

Figure 7.4: Road network in core area and CMC's with SW treatment facilities

Arkavathi and Kethamaranahalli to the north-west, and the Marthahalli to the east, lie outside the tributary areas of the major valleys and these drain independently the fringe areas which form the remainder of the metropolitan area. Table 5 lists the major and minor valley with the respective catchment area (BWSSB, 2003).

Table 5: Major and Minor Valleys in the core area of the city

Sewerage Zone	Major Valley(s)	Area (km²)	Minor Valley(s)	Area (km²)
Vrishbavathi (V – Valley)	Vrishbavathi	38	Katrhiguppe	16
			Kethmaranehalli & Arkavathi	35
Koramangala and Challagatta (K&C Valley)	Koramangala Challagatta	71	Tavarekere	19
Hebbal	Hebbal	32	Hebbal I	11

History of sewage systems in Bangalore: Plague outbreak in 1889 forced the town administration authorities to provide wider roads, open drains and sewage carrier lines. Localities such as Basavanagudi and Malleswaram were provided with conservancy roads and a good network of drains. The system for the conveyance of domestic and industrial waste was established in Bangalore in early thirties, which was initially confined to the densely populated old parts of the city. Following completion of the Thippagondanahalli reservoir in 1940's, the extension accelerated. The old city and 60% of the former Civil and Military area had been sewered by 1960's, and about 60,000 connections had been made to the sewers. Then followed the major sewerage development under the first three phases of the Cauvery project (CWSS), extending from the mid-1970's to late 1990's.

Coverage of Sewerage in Bangalore: The sewerage system in Bangalore has been guided by the nature of the topography formed by natural ridges and valleys and sewers were laid along natural channels to save on pumping costs. The sewerage system covers about 229 kmP2P and is made up of four principal drainage areas (major valleys) which drain to three wastewater treatment plants. Sewage flows from three of five minor valleys are intended to be treated at two of these treatment plants. The existing sewage system is given in Figure 8.1 and Figure 8.2 shows the drainage zones together with the major sewer system (sewers of 450mm diameter and above).

Sewerage and sewage treatment provided under CWSS Stages I, II & III since the 1970's in four major valleys (Vrishabhavathi, Challaghatta, Koramangala and Hebbal) and five minor valleys (BWSSB, 2003). Wastewater from the two major valley zones of Koramangala and Challaghatta is collected and treated at K&C Valley STP at the southern extremity of the same zone on the northern edge of Bellandur Tank. The Taverekere Minor Valley is also a part of the contributory area of this treatment plant.

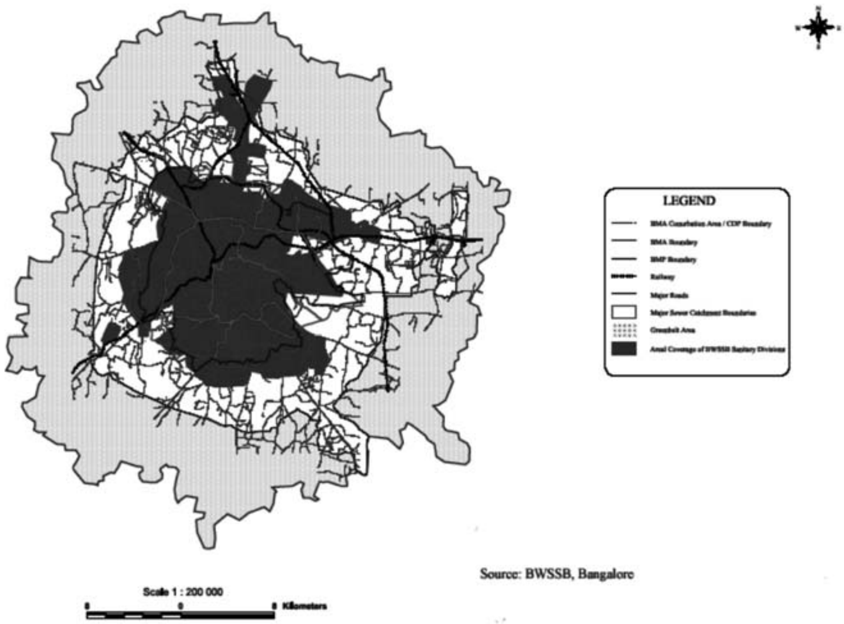

Figure 8.1: Major sewer system in Bangalore core area

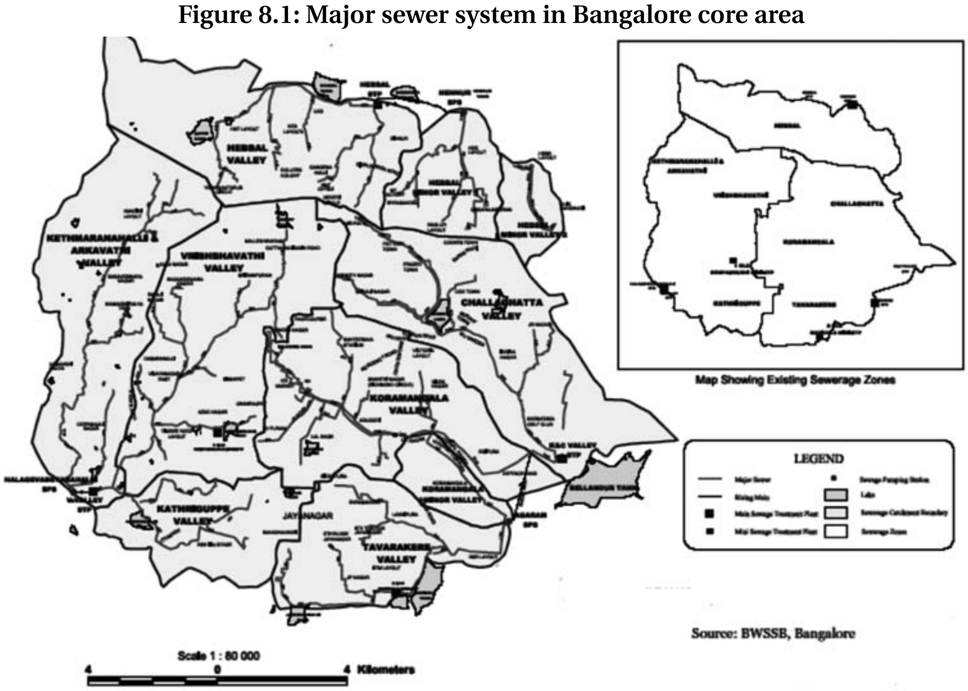

Figure 8.2: Drainage zones with major sewers

The Vrishabhavati Valley zone is part of a contributory area to the V-Valley STP in the south-west of the city which includes the minor valleys of Arkavathy and Ketmaranahalli (A&K) and Kathriguppe. The Hebbal zone to the north is served by a sewage treatment plant near the Nagavara tank; it has an associated minor valley to its east.

- Main and sub-main sewers were laid along the major valleys (V-Valley, K-Valley and C-Valley); and sewage treatment plants providing primary treatment only were constructed for the V-Valley (123 MLD) and K&C valley (163 MLD) catchments under CWSS Stage I.
- Main and sub-main sewers were constructed in the minor valleys from 1981 to 1984 (K&A, Kathriguppe and Tavarakere); main and sub-main sewers were laid in Hebbal (1982 – 1984); a 60 MLD sewage treatment plant was constructed at Hebbal (1989 - 1999); the V-Valley STP was expanded from 123 MLD to 180 MLD (1990 to 1999) and secondary treatment added; and secondary treatment was added at the K&C STP (1989 – 1999) (without increasing overall capacity but with screens and detritors sized for 218 MLD) under CWSS Stages II & III,.
- Under Cauvery IV Phase I, trunk sewers, pumping stations and seven sewage treatment plants in eight zones, will serve the peripheral area of the city, the zone between the outer boundary of the existing sewerage catchments and the BMA conurbation boundary.

Most part of the sewerage system operates under gravity in the drainage zones, while three pumping stations have been deployed to pump flows from the minor valleys to the main valleys: Halagevadeyarahalli SPS in the south-west of the city serving the A&K Minor Valley; Hennur SPS in the north-east (Hebbal); and Agaram SPS in the south which serves Tavarekere Minor Valley and part of the Koramangala Valley.

Bangalore is currently served by three major sewage treatment plants, all providing secondary treatment, with a combined capacity of 403 MLD. Two recently constructed much smaller plants (total capacity 9 MLD) also exist, these having been provided by BWSSB to rejuvenate lakes (BWSSB, 2003). The STP's are:

- V-Valley STP, a plant first commissioned with primary treatment in 1974 (123 MLD), then upgraded in the 1990's (commissioning in 1999) to 180 MLD with secondary treatment by trickling filters. This plant serves V-Valley and the Kathriguppe and K&A minor valleys;
- K&C STP, a plant also constructed with primary treatment only in the 1970's (163 MLD), then upgraded to secondary treatment by activated sludge in the late 1980's (commissioning 1990). This plant serves the Koramangala and Chalaghatta

valleys and Tavarakere minor valley;

- Hebbal STP, a 60 MLD plant with secondary treatment provided by activated sludge, commissioned in early 1999. This plant serves the Hebbal Valley catchment as well as a minor catchment served by Hennur SPS;
- Madivala STP, an 8 MLD ultimate capacity plant in the Tavarakere Minor Valley which provides treatment by UASB and oxidation ponds, the treated effluent providing rejuvenation to Madivala Tank. The plant has been operating for nine months; and
- Kempambudhi STP, a 1 MLD plant in V-Valley which treats sewage to secondary standard using the extended aeration process ; the treated effluent will rejuvenate Kampambudhi Tank.

Major problems in these sewer systems are:

- encroachment of sewers by buildings preventing access for maintenance;
- siltation of sewers, unrepaired broken pipe bridges – with sewage discharging to the drains;
- sewer crown corrosion leading to sewer collapses;
- poor design and construction standards- lack of conformance to Indian Standards (CPHEEO) on the current sewer laying contracts in the primary drain of V-Valley
- sewage diversions by farmers for irrigation purposes in the V-Valley and Kathriguppe valleys.

Stormwater System

Four major storm water catchment systems (Vrishabhavathi Valley; Challaghatta Valley; Hebbal Valley; and Koramangala Valley) pass from the city's ridge in the north to an enclosed lake system at the perimeter of Bangalore (Figure 3). Waterbodies are part of these four major waterways "valley" systems, which drain the majority of the city's storm water to large tanks or lakes, which were traditionally used for recreation and water supply for irrigation. These waterways with interconnected lakes in addition to their primary function as flood carriers, have provided the city with reasonable ecological and recreational values. The urban growth in recent times, not guided by strong strategic planning or development control measures to minimise the impacts on existing infrastructure, on the surrounding environment, and in particular on the storm water system, had severe impacts on waterways. This has lead to the depletion of waterways in addition to pollution and wastewater discharge to the storm water system.

One of the main problems that characterises the storm water system in Bangalore is that the larger sewer pipes are frequently located in the drainage channels (Plate 2.4). This has lead to the significant reduction in the storm water system with obstruction from sewers and also from the sewer manholes. These sewer manholes and other structures cause significant turbulence and redirection of the storm water flows, during high storm water flows, resulting in erosion of the bed and bank instability (Plate 2.5). This also restrict drainage rehabilitation and maintenance works, including stabilisation, widening and de-silting activities. Manholes in drainage channels trap significant amounts of solid waste as well as localised sediment deposit due to the reduction in velocity of flows. In addition to this, sewer maintenance and construction in the drainage channel contributes major quantity of sediment. During periods of high storm water flows, floodwater sometimes back-up into houses through the sewer connections.

Road drains typically consist of a box shaped trench on either side of the road, covered by slabs in the core areas of the city. The inlet pits consist of an open pipe or hole in the side of the road, with no grating covers. These inlets are generally not located in the lowest point in the road and are slightly above the road gutters, which results in ponding in low lying areas before storm water flows into the drains. These roadside drains connect to secondary drains and finally to the main open channel drains. Main drains consist mainly of open channels lined with concrete retaining walls, especially in the built up area. The levels of service provided by drains has diminished in most areas due to increasing degrees of imperviousness and encroachment on drainage waterways by building, roads, culverts and other infrastructure, such as sewers (BWSSB, 2003).

Flooding is a wide-spread problem through-out the drainage system due to lack of drainage upgradation consequent to the increase in impervious area due to land use changes in the catchment from open space to high-density urban developments. This is compounded by the encroachment of drains and filling in the floodplain on the waterways, obstruction by the sewer pipes and manholes and relevant structures, deposits of building materials and solid wastes with subsequent blockage of the system and flow restrictions from under capacity road crossings (bridge and culverts).

Plate 2.4: Manhole and a sewer connection – obstruction as well as pollution (Source: BWSSB)

Plate 2.5: Sewer manhole and dumping of solid waste – reducing channel section (Source: BWSSB)

Drainage System

Lakes and wetlands are an essential part of human civilization meeting many crucial needs for life on earth such as drinking water, protein production, energy, fodder, biodiversity, flood storage, transport, recreation, climate stabilisers and also they aid in improving water quality by filtering sediments and nutrients from surface water. Wetlands play a major role in removing dissolved nutrients such as nitrogen and to some extent heavy metals (Ramachandra, 2002). They are getting extinct due to manifold reasons, including anthropogenic and natural processes. Burgeoning population, intensified human activity, unplanned development, absence of management structure, lack of proper legislation and lack of awareness about the vital role played by these ecosystems are the important causes that have contributed to their decline and loss. Identifying, delineating and mapping of wetlands on temporal scale provide an opportunity to monitor the changes, which is important for natural resource management and planning activities (Ramachandra *et al.*, 2002). Bangalore is situated on the divide between the Cauvery Basin and the Ponnaiyar, with approximately 50% of the existing population concentrated within the Cauvery Basin. There are three major drainage outfalls and five small outfalls from the Conurbation Area as shown in Figure 9 and listed in Table 6. The unsanitary conditions created by large volumes of raw, or partially treated, sewage and dumping of large volumes of solid wastes including building debris have seriously impacted the drainage system.

Table 6: Drainage Catchments with valley gradients

Catchment names	Municipalities in Catchment	Typical Valley Gradients		
		Upper	Middle	Lower
Arkavathi & Vrushabhavathi (V) Valley	BMP, Kengeri TMC, Patnagere CMC	1 in 60	1 in 200	1 in 120
Koramangala, (K) Tavarakere (K& C) Valley	BMP, Bommanahalli CMC, Mahadevpura CMC,	1 in 270	1 in 980	1 in 710
Challagatta (C) Valley	Krishnarajpura CMC	1 in 210	1 in 640	1 in 430
Hebbal	BMP, Krishnarajpura CMC, Batarayanpura CMC, Yelahanka CMC	1 in 230	1 in 700	1 in 450
Minor (to TG Halli Reservoir)	BMP, Dasarahalli CMC, Batarayanpura CMC			

Note: Drainage catchments do not coincide with sewerage valleys of the same name

Lakes constructed for agricultural and water supply have suffered in the transition to an urban environment. These lakes provided flood prevention by storing excess flows, slowing down the passage of flood waters and protecting the downstream waterways from erosion and flooding caused by the urbanisation of the catchments. They allowed

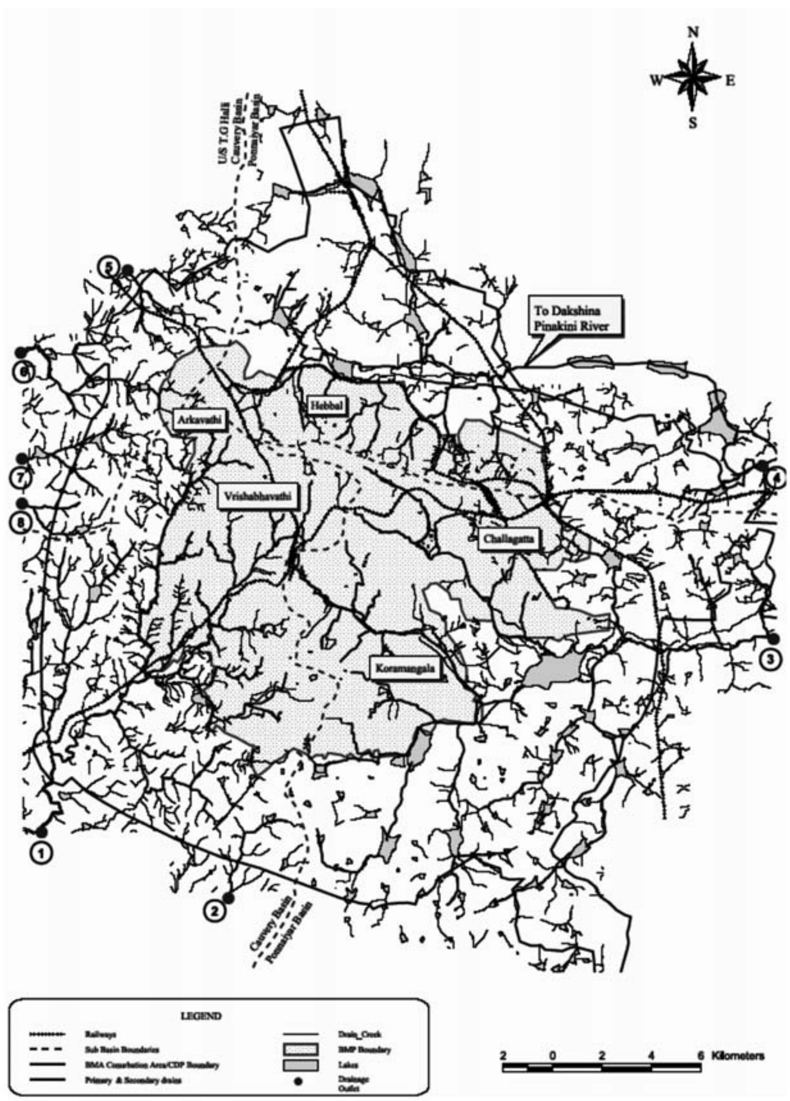

Figure 9: Drainage system in Bangalore (Source: BWSSB)

an opportunity for storm water to percolate to aquifers to supplement groundwater resources (Ramachandra and Uttam Kumar 2008). Now, lakes original function of water supply have been impaired due to dwindling number and size, depleting functions of remaining waterways due to reduced widths, conversion to hard lined drains and to pollution from wastewater discharges, solid wastes and a generally high silt load. Increasing development pressures within the core area have been accompanied by a general neglect by private and public institutions of even the basic flood protection function of drainage system (Ramachandra, 2006 and 2007).

An important function of drainage is to minimise flood damage and as per the estimates by BWSSB for Koramangala Valley the extent of flooding as 8.8 sq. km/year on average (Ashwathnarayana, 1999), would amount to 20 sq. km/year for the core area. Principal factors contributing to the flooding problem in Bangalore are unplanned urbanisation with mushrooming layouts (land development) and buildings with respect to easement provisions and floor level controls (Plate 2.6 and 2.7). Other related contributing factors are inadequate culverting at major and minor roads (Plate 2.8), obstructions by sewerage works in channels, restrictions caused by cross services (including water supply, power and telecom utilities), encroachment of buildings into waterways, dumping of solid wastes and accumulation of sediments in the drains and low design standards (Plate 2.9), combined with use of inappropriate data and analysis techniques. Low-lying and flood-prone lands are listed in Table 6.

Plate 2.6: Flood plain encroachment (Source: BWSSB)

Plate 2.7: Bank erosion and instability due to modification in the floodplain

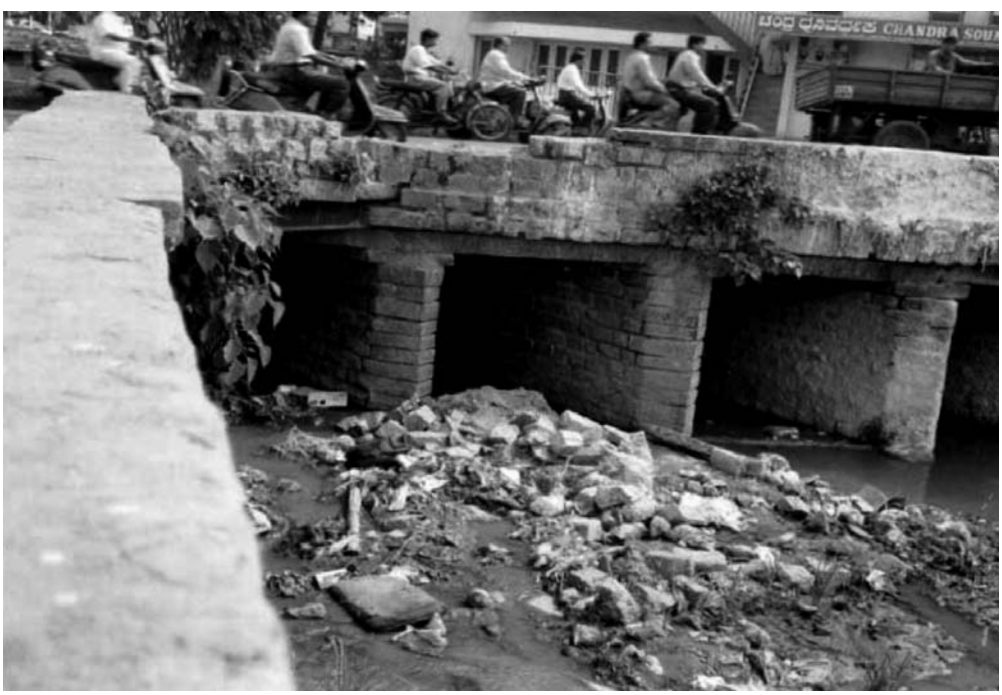

Plate 2.8: Reduced culvert capacity - dumping of solid waste and supports (Source: BWSSB)

Plate 2.8: Reduced culvert capacity - dumping of solid waste and supports (Source: BWSSB)

Plate 2.8: Stormwater flow hindrance from water pipes, solid waste, reduced culvert capacity

Plate 2.9: Sewer manhole, solid waste and under capacity road crossing

Table 6: Low-lying and flood-prone regions	
Flood prone regions	**Ward No.**
Koramangala Valley	
City Market Area	30
Sulthan Palya Main Road	28
Jayanagar 3rd Block LIC Colony	
Krishnappa Garden behind Byrasandra Tank D/s	
Wilson Garden Area up to Bannerghatta Road	63
Arekempannahalli Area	61
Jurist Colony	47
Marehahalli Tank	58
Bismillanagar - Agencies	67
Pillappa Gard en - Agencies	63
Ejipura	69
Koramangala Slum	
Sampangiram Nagar	77
Wipro Junction	

Table 6: Low-lying and flood-prone regions	
Hebbal Valley	
Brindavananagar below Matthikere Tank Market	2
KEB Compound Maththikere	4
Tannerana Halli	2
Anandanagara	96
Ring Road	96
New - Bangalore Layout	94 & 95
Challaghatta Valley	
Miller Tank, Chinnappa Garden	
Shivajinagar, Munireddy Palya	
Saraswath ipuram - Jogu Palya	
K R Garden	
Vrushabhavathi	
Gubbanna Layout	22
Shankarappa Garden Gopalapura	25
Cholurpalya	32 & 33
Bapujinagar	42
Minerva Mill	33
Dhovi Colony, near Sane Guruvanahalli Tank	19
Kamakshipalya Tank Slum Area	18
Binny Mill Tank Area	30
Markandayyanagar (n ear Binny Mill)	31
Sanjaya Gandhi Slum Area	41
Rudrappa Garden	45

Land-Use Changes

Land use is the use of land by humans, usually with emphasis on the functional role of land such as land under buildings, plantation, pastures, etc. Flows in the catchment were indirectly estimated by the land use area, runoff coefficient and precipitation. Land use pattern in the catchment has direct implications on hydrological yield. The yield of a catchment area is the net quantity of water available for storage, after all losses, for the purpose of water resource utilization and planning. Runoff is the balance of rainwater, which flows or runs over the natural ground surface after losses by evaporation, interception and infiltration [Ramachan dra and Uttam Kumar 2008]. The runoff from rainfall was estimated by rational method that is used to obtain the yield of a catchment area by assuming a suitable runoff coefficient.

Land use analysis was done using temporal remote sensing data - Landsat data of 1973 (of 79 m spatial resolution), 1992 and 2000 (30 m), IRS LISS-3 data of 1999 and 2006 (23.5 m) and MOD IS data of 2002 and 2007 (with 250 m to 500 m spatial resolution).

The analysis was done with supervised pattern classifiers based on maximum likelihood (ML) estimation followed by a Bayesian statistical approach. This technique quantifies the tradeoffs between various classification decisions using probability and costs that accompany such decisions. It makes assumptions that the decision problem is posed in probabilistic terms, and that all of the relevant probability values are known with a number of design samples or training data collected from field that are particular representatives of the patterns to be classified. The mean and covariance are computed using maximum likelihood estimation with the best estimates that maximizes the probability of the pixels falling into one of the classes.

Data: Survey of India (SOI) toposheets of 1:50000 and 1:250000 scales were used to generate base layers of taluk boundaries, city boundary, drainage networks, and water bodies. Field data were collected with a handheld GPS. Remote sensing data (spatial and spectral resolutions are listed in table 1) used for the study are:

- Landsat MSS of 1973 [downloaded from http://glcf.umiacs.umd.edu/data/]
- Landsat TM of 1992 [downloaded from http://glcf.umiacs.umd.edu/data/]
- Landsat ETM+ of 2000 [downloaded from http://glcf.umiacs.umd.edu/data/]
- IRS (Indian Remote Sensing) LISS (Linear Imaging Self Scanner)-III of 1999 and 2006
- MODIS (Moderate Resolution Imaging Spectroradiometer) Surface Reflectance 7 bands product [downloaded from http://edcdaac.usgs.gov/main.asp] of 2002 and 2007
- MODIS Land Surface Temperature/Emissivity 8-Day L3 Global and Daily L3 Global (V004 and V005 products)
  [downloaded from http://lpdaac.usgs.gov/modis/dataproducts.asp#mod11]
- SRTM (Shuttle Radar Topography Mission) elevation data of 90 m resolution [downloaded from http://glcf.umiacs.umd.edu/data/] and
- Google Earth image (http://earth.google.com) served in pre and post classification process and validation of the results.

Supervised classification was performed using Bayesian classifier and was verified with field knowledge, visual interpretation and Google Earth image. The supervised classified images of 1973, 1992, 1999, 2000, 2002, 2006 and 2007 with an overall accuracy of 72%, 75%, 71%, 77%, 60%, 73% and 55% were obtained by using the open source programs (i.gensig, i.class and i.maxlik) of Geographic Resources Analysis Support System (http://wgbis.ces.iisc.ernet.in/ grass) as displayed in Figure 11.1. The class statistics is given in table 6.1. The implementation of the classifier on Landsat, IRS and MODIS image helped in the digital data exploratory analysis as were also verified from field visits in July, 2007 and Google Earth image.

Table 6.1: Land use in Greater Bangalore

Class → / Year ↓		Built up	Vegetation	Water Bodies	Others
1973	**Ha**	5448	46639	2324	13903
	%	**7.97**	**68.27**	**3.40**	**20.35**
1992	**Ha**	18650	31579	1790	16303
	%	**27.30**	**46.22**	**2.60**	**23.86**
1999	**Ha**	23532	31421	1574	11794
	%	**34.44**	**45.99**	**2.30**	**17.26**
2000	**Ha**	24163	31272	1542	11346
	%	**35.37**	**45.77**	**2.26**	**16.61**
2002	**Ha**	26992	28959	1218	11153
	%	**39.51**	**42.39**	**1.80**	**16.32**
2006	**Ha**	29535	19696	1073	18017
	%	**43.23**	**28.83**	**1.57**	**26.37**
2007	**Ha**	30876	17298	1005	19143
	%	**45.19**	**25.32**	**1.47**	**28.01**

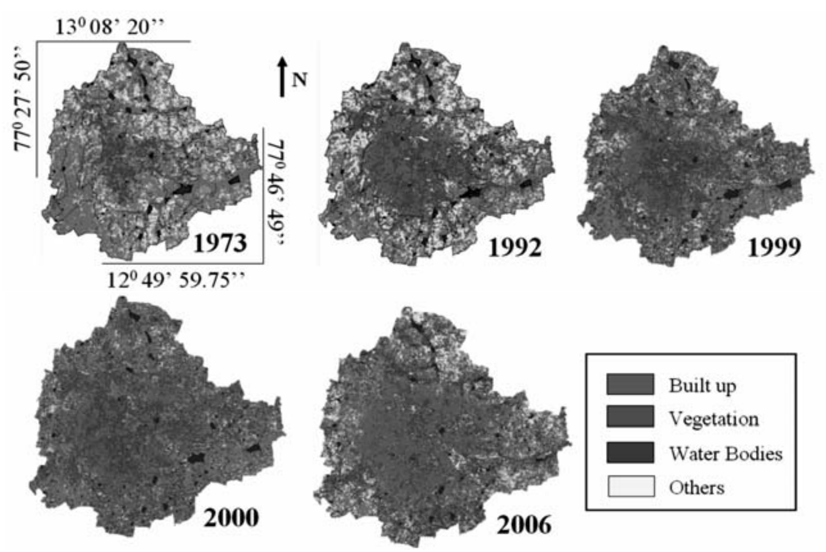

Figure 11.1: Temporal land use changes in Greater Bangalore

From the classified raster data, urban class was extracted and converted to vector representation for computation of precise area in hectares. There has been a 466% increase in built up area from 1973 to 2007 as evident from temporal analysis leading to a sharp decline of 61% area in water bodies in Greater Bangalore mostly attributing to intense urbanisation process. Figure 11.2 shows Greater Bangalore with 265 water bodies (in 1972). The rapid development of urban sprawl has many potentially detrimental effects including the loss of valuable agricultural and eco-sensitive (e.g. wetlands, forests) lands, enhanced energy consumption and greenhouse gas emissions from increasing private vehicle use. Vegetation has decreased by 32% from 1973 to 1992, by 38% from 1992 to 2002 and by 63% from 2002 to 2007. Disappearance of water bodies or sharp decline in the number of waterbodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Many lakes were unauthorised encroached for illegal buildings (54%). Field survey (during July-August 2007) shows that nearly 66% of lakes are sewage fed, 14% surrounded by slums and 72% showed loss of catchment area. Also, lake catchments were used as dumping yards for either municipal solid waste or building debris. The surrounding of these lakes have illegal constructions of buildings and most of the times, slum dwellers occupy the adjoining areas. At many sites, water is used for washing and household activities and even fishing was observed at one of these sites. Multi-storied buildings have come up on some lake beds that have totally intervene the natural catchment flow leading to sharp decline and deteriorating quality of waterbodies.

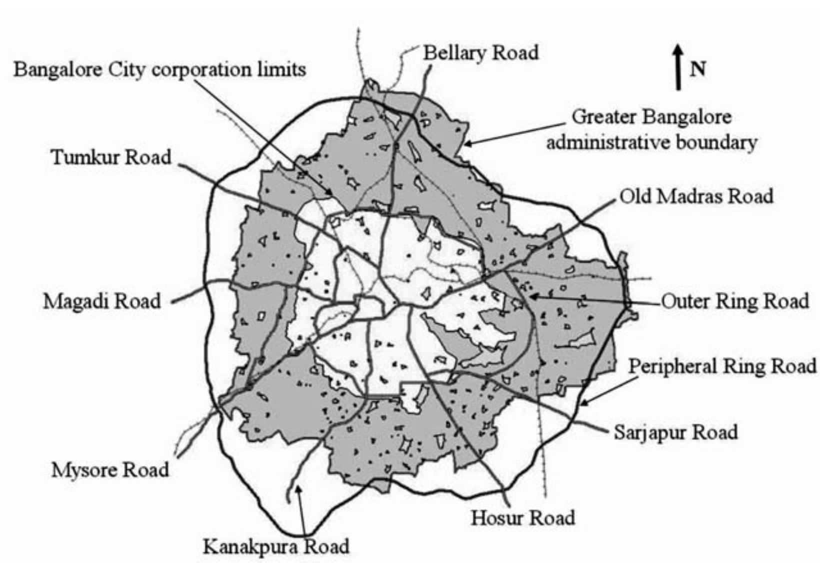

Figure 11.2: Greater Bangalore with 265 water bodies.

Figure 11.3 provides the distribution of wetlands in 1973, 1992, 2002 and 2007 based on the respective years' remote sensing data. The analysis revealed that there were 51 wetlands (321 ha) in 1973, 38 (207 ha) in 1992, 25 (135 ha) in 2002 and dropped down to 17 with an extent of 87 ha in 2007 in the Bangalore city limits.

There were 159 waterbodies spread in an area of 2003 ha in 1973, that reduced to 147 (1582 ha) in 1992, which further declined to 107 (1083 ha) in 2002 and finally there are only 93 waterbodies (both small and medium size) with an area of 918 ha in the Greater Bangalore region. Waterbodies in northern part of greater Bangalore are in a considerably poor state compared to the wetlands in southern greater Bangalore. Validation of the classified data was done through field visits during July 2007, which indicate the accuracy of 91%. The error of omission was mainly due to cover of water hyacinth (aquatic macrophytes) in the waterbodies due to which the energy was reflected in IR bands than getting absorbed. 54 waterbodies were sampled through field visits while the remaining waterbodies were verified using online Google Earth (http://earth.google.com).

Temporal analyses indicate the decline of 34.48% during 1973 to 1992, 56.90% during 1973-2002 and 70.69% of waterbodies during 1973-2007 in the erstwhile Bangalore city limits. Similar analyses done for Greater Bangalore (i.e Bangalore city with surrounding 8 municipalities) indicate the decline of 32.47% during 1973 to 1992, 53.76% during 1973-2002 and 60.83% during 1973-2007 (Table 4). This is correlated with the increase in built up area from the concentrated growth model focusing on Bangalore, adopted by the state machinery, affecting severely open spaces and in particular waterbodies. Some of the lakes have been rested by the city corporation and the concerned authorities in recent times [13].

Urbanisation and the consequent loss of lakes has led to decrease in catchment yield, water storage capacity, wetland area, number of migratory birds, flora and fauna diversity and ground water table. Studies in selected lake catchments in Bangalore reveal the decrease in depth of the ground water table from 10-12 m to 100-200 m in 20 years due to the disappearance of wetlands.

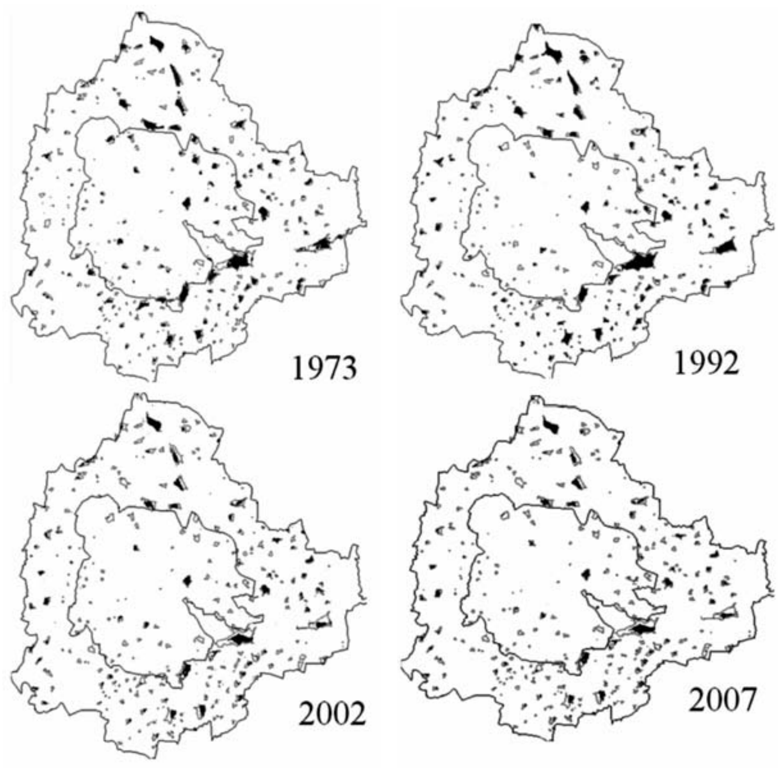

Figure 11.3: Unsupervised learning to extract waterbodies from NIR bands. Waterbodies are represented in blue and the vector layer of waterbodies generated from SOI Toposheet is overlaid (in red colour) that exactly fits on the exiting waterbodies. The inner boundary (in black) is the Bangalore city limit and the outer boundary represents the spatial extent of Greater Bangalore.

The dramatic increase in builtup area could be attributed to the urban sprawl in the peri urban areas of the city. The Shannon's entropy was computed to detect the urban sprawl phenomenon. Shannon's entropy computed for Bangalore city, Peri-urban and outskirts (hence n = 3), together comprising Greater Bangalore for 1973, 1992, 2000 and 2006 are listed in Table 6.2. The entropy values obtained for 2000 and 2006, (1.0325 and 1.0782) are closer to the upper limit of log n, i.e. 1.0986, showing the higher degree of dispersion of built-up in the city. The urbanisation process increased in 2000 and 2006, indicating higher entropy value as the distribution of built-up during 2006 was more dispersed than in 1973 or 1992.

Table 6.2: Shannon's entropy for Greater Bangalore				
Year	**1973**	**1992**	**2000**	**2006**
Entropy	0.9007	0.9023	1.0325	1.0782
ln(n)	1.0986			

Consequences of urbanisation and urban sprawl: Urbanisation and urban sprawl have posed serious challenges to the decision makers in the city planning and management process involving plethora of issues like infrastructure development, traffic congestion, and basic amenities (electricity, water, and sanitation), etc. [Ramachandra and Uttam Kumar 2004, 2007]. Apart from this, major implications of urbanisation are:

- **Floods:** Common consequences of urban development are increased peak discharge and frequency of floods as land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Conversion of water bodies to residential layouts has compounded the problem by removing the interconnectivities in an undulating terrain.
- **Heat island:** Surface and atmospheric temperatures are increased by anthropogenic heat discharge due to energy consumption, increased land surface coverage by artificial materials having high heat capacities and conductivities, and the associated decreases in vegetation and water pervious surfaces, which reduce surface temperature through evapotranspiration.

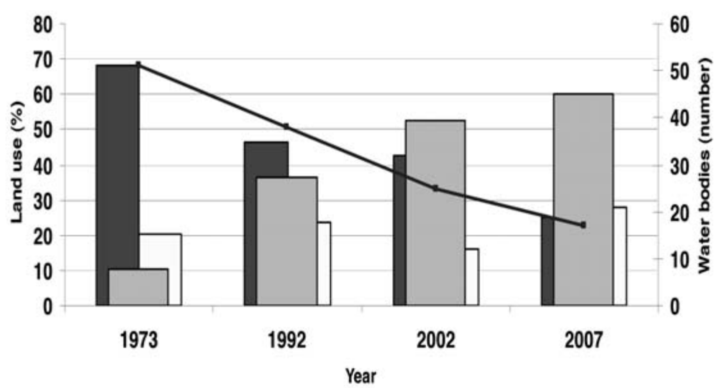

Figure 11.4: Temporal changes in built up and its impact on vegetation and water bodies

- **Loss of aquatic ecosystems:** Urbanisation has telling influences on the natural resources evident from the sharp decline in number of water bodies and also from depleting groundwater table. Figure 11.4 illustrates the loss of aquatic ecosystems (70% decline during 1973-2007 in the Bangalore city limits) and vegetation with the increase in built up area (466% during 1973-2007).

Floods in the City

Purpose of Assessment

Burgeoning human population coupled with the increased urban concentration has escalated both the frequency and severity of disasters like floods, etc. With the tropical climate and unstable land forms, coupled with land use changes, unplanned growth proliferation non-engineered constructions make the disaster-prone areas mere vulnerable. In this regard basic policy statements as part of comprehensive development plan of a region need to address:

- Protect life and health
- Minimising property losses
- Enhance floodplain use
- Ensure a functional drainage systems
- Encourage aesthetics
- Curb large scale land use changes in the immediate vicinity of waterbody catchment
- Guide development

This entails appropriate strategies for natural resources planning, development and management by adopting an integrated approach for a hydrological unit such as lake catchment, incorporating quantity, quality and environmental considerations (Ramachandra, 2007). Development projects and investment proposal has to be formulated and considered within the framework of lake catchment, river or sub-basin plan so that the best possible combination of options can be obtained for poverty alleviation, increasing incomes and productivity, equity, reduced vulnerability to natural and economic risks and costs (Ramachandra, *et al.*, 2007). Solutions to water allocation and planning issues will be found adopting a demand management approach.

Techniques adopted for assessment include data collection (primary and secondary data), analysis (remote sensing and collateral data) and interpretation.

Incidence Description

Unplanned urbanisation has drastically altered the drainage characteristics of natural catchments, or drainage areas, by increasing the volume and rate of surface runoff. Drainage systems are unable to cope with the increased volume of water and are often encountered with the blockage due to indiscriminate disposal of solid wastes. Encroachment of wetlands, floodplains, etc. Obstructs floodways causing loss of natural flood storage. Damages from urban flooding can be grouped into two categories:

- Direct damage—typically material damage caused by water or flowing water.
- Indirect damage—social consequences that are negative long term effects of a more psychological character, like decrease of property values in frequently flooded areas and delayed economical development, for e.g. traffic disruptions, administrative and labour costs, production losses, spreading of diseases, etc.

Table 7: Rainfall during 1995-2005, Bangalore

Wettest day		Rainfall in May	
Year	Day	mm	mm
2005	28-May	61.2	150.1
2004	4-May	42.9	207.9
2003	14-May	0.8	1.3
2002	26-May	95	183.5
2001	4-May	31.6	60.2
2000	6-May	19.2	56.6
1999	15-May	46.9	200.6
1998	12-May	52.2	110.3
1997	3-May	28.1	77
1996	30-May	33.6	117.6
1995	21-May	39.4	147.7

Source: IMD

Rainfall pattern in Bangalore: Monthly and Yearly rainfall record

Month	Days	Mm
Jan	0.2	2.70
Feb	0.5	7.20
Mar	0.4	4.40
Apr	3.0	46.30
May	7.0	119.60
Jun	6.4	80.80
Jul	8.3	110.20
Aug	10.0	137.00
Sep	9.3	194.80
Oct	9.0	180.40
Nov	4.0	64.50
Dec	1.7	22.10
Total	59.8	970.00

Year	Rainy days	Rainfall (mm)	liters/ 100sq.m
1990	42	509.40	40,752
1991	65	1338.50	1,07,080
1992	56	844.60	67,568
1993	65	1059.70	84,776
1994	45	587.10	46,968
1995	61	1072.20	85,776
1996	64	1173.30	93,864
1997	52	717.40	57,392
1998	68	1431.80	1,14,544
1999	52	1009.40	80,720
Average	57	974.34 mm	77,947

Urban flooding creates considerable infrastructure problems and huge economic losses in terms of production, as well as significant damage to property and goods. Flooding in urban areas causes large damage at buildings and other public and private infrastructure. Besides, street flooding can limit or completely hinder the functioning of traffic systems and has indirect consequences such as loss of business and opportunity. The expected total damage; direct and indirect monetary damage costs as well as possible social consequences is related to the physical properties of the flood, i.e. the water level above ground level, the extend of flooding in terms of water volume escaping from or not being entering the drainage system, and the duration of flooding. With sloped surfaces even the flow velocity on the surface might have an impact on potential flood damage. Precipitation, intensity and the duration of time are the key elements that decide flooding. Sometimes even 8 cm to 10 cm of rainfall in a short span of time have resulted in flooding, and if it occurred in a matter of one or two days, the water seeps into the soil, in the case of mixed land use (urban, vegetation). Even a 30 mm rainfall in a matter of 30 minutes could cause flooding, especially in the low-lying areas, due to

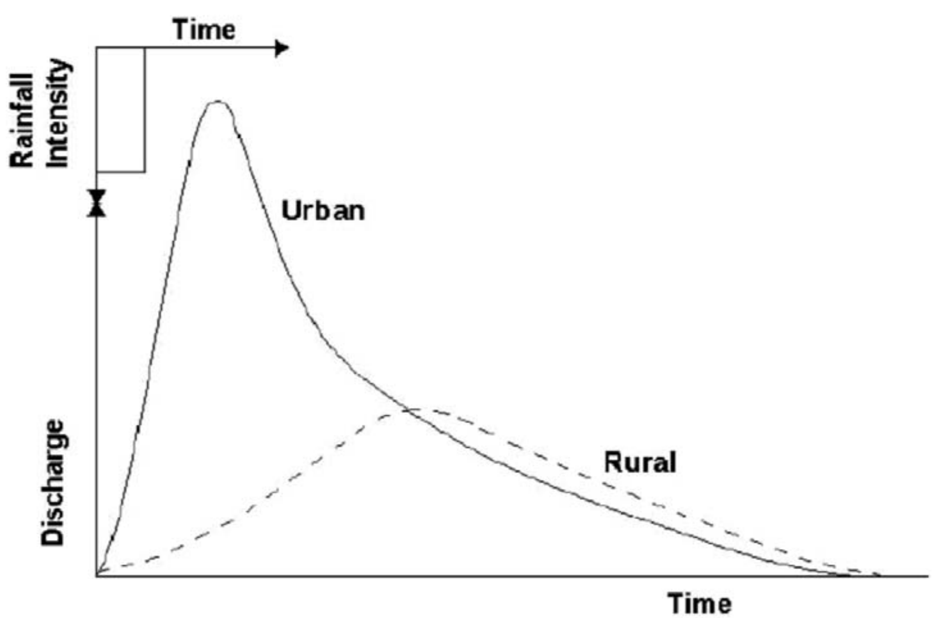

Figure 12.1: Flood Hydrographs for Urbanized and Natural Drainage Basins

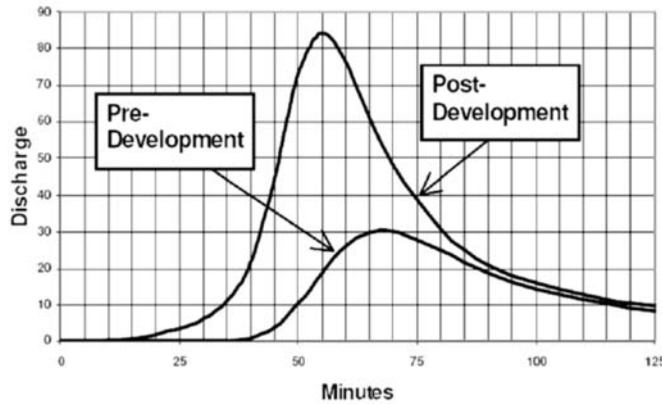

Figure 12.2: Runoff Hydrograph under Pre-and Post-Development conditions

intense urbanisation. Frequent thunder showers accompanied by squall and hail being the characteristic of the month of May, resulting in the uprooting of trees.

The highest rainfall recorded on a single day has been 10 cm during the month of May in 2002 (Table 7.1). The closest in record to this was 9 cm recorded in 1991 on a single day. Earlier, 1999 witnessed 200.6 mm rainfall and the lowest rainfall recorded has been 1.3 mm in 2003. The heaviest rainfall in 24 hours has been 153.9 on May 6 1909. As the development of land use in urban areas, less water can be absorbed by the soil and the volume of urban stormwater is increasing. This escalating volume of urban runoff not only increases pollution, it elevates the risk of flooding. The amount of urban runoff is largely a factor of rainfall and the amount of paved area. As paved area increases – for

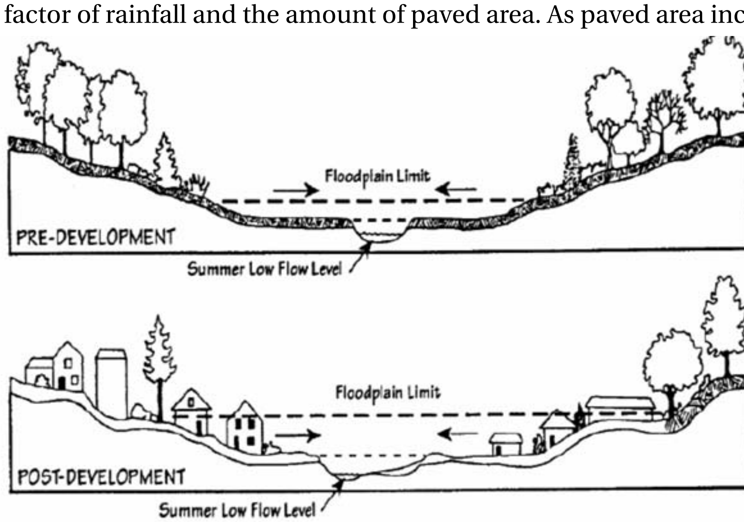

Figure 12.3: Change in Floodplain Elevations

example, due to vegetation clearing, new housing or industrial developments, urban infill, paving driveways, patios, new roads etc., so does the amount of runoff.

Increasing urbanization has led to significant changes in the natural systems. These changes include alterations in the hydrologic flow regime as well as shifts in the chemical and biological makeup of stormwater runoff from these developing areas. As an area is developed, the natural ability of the catchment to withstand natural hydrologic variability is removed. Infiltration capacity is decreased due to the increase in impervious surface and disrupted native soils and vegetation. Natural retention and detention capabilities of a catchment are removed through channelization of natural waterways and the installation of formal drainage systems such as pipes and gutters (Vijay Kulkarni and Ramachandra, 2006). Anthropogenic activity also introduces chemical and biological constituents to the catchment.

Increased peak discharges for a developed watershed can be two to five times higher than those for a watershed prior to development (Figure 12.1). The changes in the rates and amounts of runoff from developed watersheds directly affect the morphology, or physical shape and character, of creeks and streams (Figure 12.2). Some of the impacts due to urban development include: Stream widening and bank erosion, stream down cutting, changes in the channel bed due to sedimentation, increase in the floodplain elevation. Urban floods differ from those in natural basins in the shape of flood hydrographs (Figure 12.1), peak magnitudes relative to the contributing area, and times of occurrence during the year. The imperviousness of urban areas along with the greater hydraulic efficiency of urban conveyance elements cause increased peak stream flows but also more rapid stream response. Summer floods resulting from high intensity thunderstorms are more common in urban areas. Infiltration and evapotranspiration are much reduced at this time of the year under developed conditions (Prasad, et al., 2002, Ramachandra, 2002, WHGM, 2003).

Some of the impacts due to urban development include: reclamation of lakes (Plate 4.1), stream widening and bank erosion, stream down cutting, changes in the channel bed due to sedimentation, increase in the floodplain elevation (Figure 12.3). Urban floods differ from those in natural basins in the shape of flood hydrographs (Figure 12.1), peak magnitudes relative to the contributing area, and times of occurrence during the year. The imperviousness of urban areas along with the greater hydraulic efficiency of urban conveyance elements cause increased peak stream flows but also more rapid stream response (WHGM, 2003). Summer floods resulting from high intensity thunderstorms are more common in urban areas. Infiltration and evapotranspiration are much reduced at this time of the year under developed conditions.

Thus, flooding is a consequence of the increase in impervious area due to land use changes in the catchment from open space to impervious surfaces with the high-density urban developments. This is coupled with lack of drainage upgrade works with the changes in enhanced run-offs, the encroachment and filling in the floodplain on the waterways, obstruction by the sewer pipes and manholes and relevant structures, deposits of building materials and solid wastes with subsequent blockage of the system and also flow restrictions from under capacity road crossings (bridge and culverts).

The lack of planning and enforcement has resulted in significant narrowing of the waterways and filling in of the floodplain by illegal developments. This has subsequently caused flooding to other properties that have not previously been flooded, new properties in the flood plain built below the high flood marks (designated flood levels), these being frequently flooded and restrictions of options for future flood mitigation including widening of waterways.

Pre-Incidence Scenario

Table 7.2: Rainfall during May-November for forested and urban area (40% impervious)

Distribution of May to November Rainfall for Forested and Urbanized Areas Item	**Forested Areas**		**Urban Areas with 40% Impervious Cover**	
	Depth (mm)	% of Total Depth	Depth (mm)	% of Total Depth
May to November Rainfall	515	100.0	515	100
Interception Storage and Depression Storage on Impervious Areas	342	66.5	235	45
Infiltration	155	30.0	100	20
Runoff	18	3.5	180	35

Urban floods are linked to the total lack of attention to the nature of region's hydrological system. Despite the knowledge of occurrence of heavy downpours and its frequency, the natural drainage channels are not maintained, catchment area of lakes and lakes have been allowed to be encroached by land mafia in connivance with the government machinery. This is something our ancestors knew but our current urban planners and politicians don't worry about such mundane things (http://www.rainwaterharvesting.org/

catchwater/oct2000/newslet9_1.htm,http://www.downtoearth.org.in/editor.asp?foldername=20000930&filename=Editor&sec_id=2&sid=1).

Urban flooding is not a new phenomenon. Increasingly, more and more cities and towns face waterlogged streets. Post 2000 have witnessed, even relatively small downpours are enough to clog up drains, fill up streets and disrupt life and the study proved that unchecked construction of big buildings, loss of open spaces, and clogged drains were the cause.. Meanwhile, cities continue to face water scarcity and the water tanker business continues to grow. Bangalore is just one example of bad water management practices. Years of siltation of tanks have reduced their water storage capacity. Encroachments of nalas, lakes and other waterbodies, choking of streams and stormwater drains have taken their toll. There is a need for urban areas to improve water management. Urban water harvesting offers a solution to deal with meeting water demand as well as reducing the intensity of urban flooding. Thus, the urbanization process and the hydraulic insufficiency of drainage systems are two of the most common causes of urban flooding.

Development and redevelopment of the district, by nature increases the amount of imperviousness in the surrounding environment. This increased imperviousness translates into loss of natural areas, more sources for pollution in runoff, and heightened flooding risks. In recent decades, stormwater runoff has emerged as an issue of major concern. Stormwater affects local waterways both in terms of the volume of runoff that is generated, and the nature of the pollutants that may be conveyed. Allowing stormwater to infiltrate in urban residential areas is one of the major ways for urban floods.

A major consequence of the increase in impervious area which accompanies urbanization is an increase in direct runoff and a corresponding decrease in infiltration. Table 7.2 illustrates the changes in hydrological components that result from developing a forested area. Urbanization also results in decreased evapotranspiration. The net effect of conventional development practices on an urban stream is a dramatic change in the hydrologic regime of the stream.

The downstream urban flooding problem has become acute during the past thirty years as communities have grown and as curbed roadways (paved channels) have been installed in both new suburban areas and throughout older areas that formerly provided runoff-retarding storage in roadside swales or ditches. Amelioration of the unfortunate results of past urbanization requires very large investments to construct additional flood control works. Where flood control is infeasible, the flooding hazard reduces property values and may lead to abandonment, which is unacceptable.

Response & Loss Summary

The survey carried out by BWSSB in Bangalore reveals that few households from the peri-urban and the Green Belt areas reported that their houses had been flooded in the recent past, suggesting that high density of houses and unplanned urbanisation have contributed to the problem of improper drainage in the Corporation Area. Major highlights of the survey are:

- 7% of households reported that they faced instances of flooding;
- 10% of households of lower socio-economic status reported that they had faced flooding in the past decade – instances of flooding had been more common in the central part of the city;
- Of the households that had experienced flooding, 72% reported such occurrences in the last one year, 15% had experienced flooding in the year 1999, 7% during the period 1995 to 1998, while 2% reported that they had experienced flooding prior to 1995;
- Of the households that had experienced flooding, a majority said that the effects had lasted for one to three days, while 3% said they had extended beyond a week;

BANGALORE CITY BUS STAND, ONCE DHARMAMBUDHI TANK

THE KGA GOLF COURSE STANDS ON WHAT WAS ONCE THE CHALLAGHATTA TANK

THE KARAMANGALA TANK IS TODAY A SPORTS COMPLEX

A SPORTS STADIUM TODAY..., THIS WAS THE SAMPANGI TANK EARLIER

Plates 4.1: Conversion of lakes in Bangalore Similar past incidences

[Source: http://www.thisismyindia.com/pictures_of_india/bangalore-pictures.html]

GARVIBAVI PALYA NEAR HOSUR RADO

HOSUR ROAD FLOODED IN BANGALORE

HOUSE IN JP NAGAR BANGALORE

TRAFFIC JAM TO HEAVY RAINS

SUBWAY BETWEEN MAGESTIC AND RAILWAY STATION

RISING WATER LEVEL AND VEHICLES

Plate 4.2: Rain havoc in Bangalore during 2005 and 2007

- Two thirds of the households ascribed the reasons for flooding to blockages in the sewerage system, 12% to ingress of rainwater into the house, while 11% said that it had been caused by a blocked drain or gutter;
- Lower income households and those living in the slums were more vulnerable to flooding caused by blocked drains; and

All households reported damage to assets and loss of workdays on account of such flooding. Majority of these affected communities are engaged in daily wage labour or small-scale retail activities. Flooding and the resultant disruption of mobility have a direct impact on the incomes of the households. Their ability to cope with such disturbances is much lower than that of other socio-economic groups who have larger social and economic security nets to fall back upon. Women, children and the elderly are most vulnerable to hazards of poor environmental sanitation, as they spend more time in the house and its vicinity than adult men who have greater mobility and often spend little time within the house or the neighbourhood.

In addition to this, newspaper reports in response to rain havoc (one such example on May 28, 2005, Plate 4.2)

- A woman and a man were killed (HTUhttp://www.thisismyindia.com/UTH pictures_of_india/bangalore-pictures.html)
- Heavy water logging was reported from 35 areas in southern and eastern parts of the city
- The Fire and Emergency Services had to press in 20 vehicles to clear uprooted trees and pump out water in flooded areas
- 434 electric poles were uprooted. BESCOM suffered a loss of Rs. 4.8 crore
- A number of trees were uprooted, damaging a BMTC bus, a car and three other vehicles

Litter, building debris, sediments and solid waste are the main causes of blockages of the drainage system and subsequent floodinge. Therefore, minimising flooding and the establishment of clean healthy waterways are some of the many benefits which can be achieved through appropriate solid waste and catchment management practices by reducing pollution from the sources. BWSSB's Sewer Division has, over the last two years, carried out de-silting of the 2000 mm diameter outfall sewer including sewer section through Ejipura – where much of the silting up was caused by local residents breaking into the sewer to release flood water.

Various Factors Responsible for the Floods

Reclamation of lakes for various developmental activities (Plate 4.1) has resulted in the loss of interconnectivity in Bangalore district leading to higher instances of floods even during the normal rainfall. Analyses of Bellandur and Ulsoor drainage network (Figure 13.1)

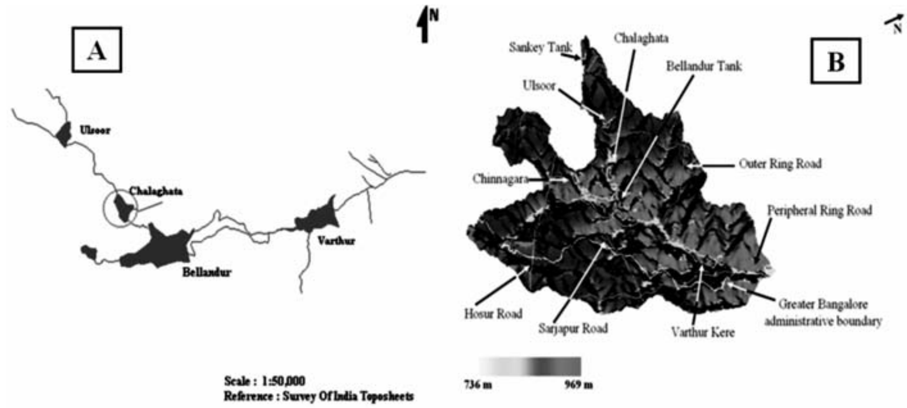

Figure 13.1: Ulsoor-Bellandur-Varthur (a) drainage network (b) lakes overlaid on 10 m DEM showing their missing interconnectivity

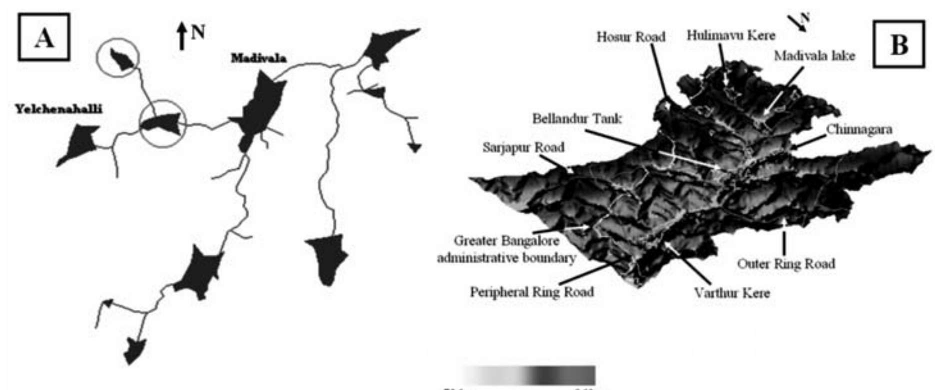

Figure 13.2: Madivala-Bellandur-Varthur (a) drainage network (b) lakes overlaid on 10 m DEM showing their missing interconnectivity

showed that the network is lost due to conversion of Chelgatta tank into a golf course. Similarly the drainage network between Madivala and Bellandur revealed of encroachment and conversion that has resulted in the loss of connectivity between Yelchenhalli kere and Madivala (Figure 13.2). Figure 14.1, 14.2 and 14.3 provides the line diagrams of drainage systems of three valleys namely Challaghatta , Ulsoor Valley and Hebbal Valley

Increased peak discharge and higher frequency of floods are the consequences of urbanisation. As land is converted from fields to built up, it loses its ability to absorb rainfall. Urbanisation has increased runoff 2 to 6 times over what would occur on natural terrain in some pockets of Bangalore. During periods of urban flooding, streets become swift moving rivers, while low lying residential areas and basements become death traps as they fill with water. Conversion of water bodies to residential layouts has further exaggerated the problem.

Flooding in urban areas causes large damage at buildings and other public and private infrastructure (evident during 1997, 2002 and 2007). Besides, street flooding can limit or completely hinder the functioning of traffic systems and has indirect consequences such as loss of business and opportunity. The expected total damage; direct and indirect monetary damage costs as well as possible social consequences is related to the physical properties of the flood, i.e. the water level above ground level, the extent of flooding in terms of water volume escaping from or not being entering the drainage system, and the duration of flooding.

Ulsoor–Belandur catchment: This catchment has 6 lakes – Sankey, Ulsoor, Chalghata, Chinnagara and Varthur and was classified into three major land use types – built up, vegetation and others (comprising open land, waste land etc). The total rainfall yield in this catchment is 240 MmP3P, percolated water is 90 MmP3P and water overflow is 150 MmP3P. The SRTM DEM data were resampled to 10 m resolution and the volume of each lake was computed assuming the depth to be 1 m and the mean annual rainfall to be 850 mm. The total volume of all the 6 lakes in this catchment is 73 MmP3P. Hence there is surplus overland flow of 77 MmP3P, which cannot flow to downstream due to disruption of natural drainage (removal of lakes and blockage of storm water drains) resulting in flooding (even during normal rainfall).

Madivala–Varthur catchment: Similar analysis was done for Madivala catchment which has 14 lakes – Venkatapura, Yellakunte, Bandepalya, Begur Doddakere, Madivala, Hulimavu, Marenahalli, Govindanaikana kere, Tank north of Doresanipalya, Gittigere and Vaddarpalya. The total rainfall yield is 247 MmP3P, percolated water is 97 MmP3P and the remaining 150 MmP3P water flows as overland flow and storage in lakes. The total volumes of all the lakes considering 1 m depth is 110 MmP3 Presulting in the excess of 40 MmP3P from the catchment leading to artificial floods. In addition to rainfall, Belandur-Varthur watershed receives untreated municipal sewage to the order of 500MLD.

Disappearance of waterbodies or sharp decline in the number of waterbodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Many lakes were encroached for illegal buildings (54%). Field survey (during July-August 2007) shows that nearly 66 % of lakes are sewage fed, 14 % surrounded by slums and 72% showed loss of catchment area. Also, lake catchments were used as dumping yards for either municipal solid waste or building debris. The surrounding of these lakes have illegal constructions of

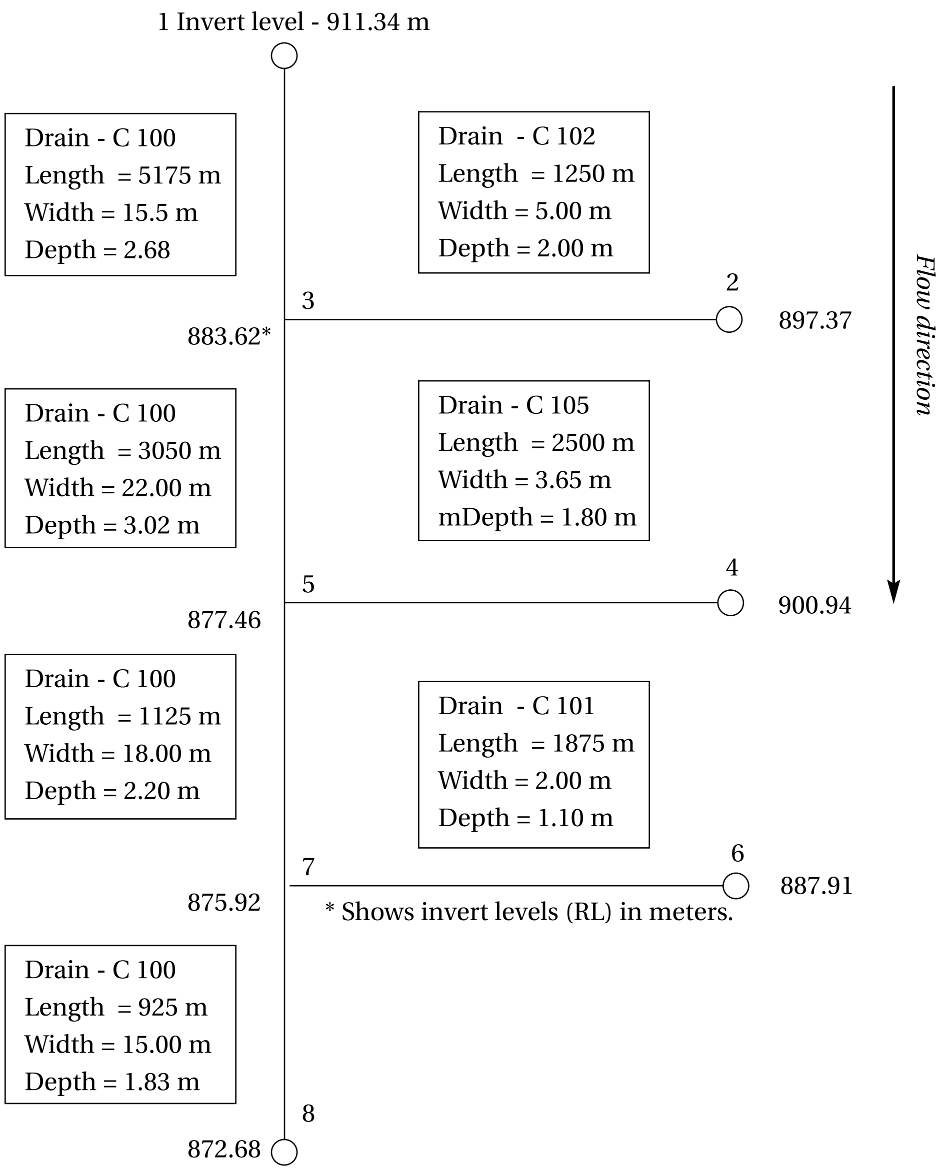

Figure 14.1.Line-diagram showing the Drainage System of Challaghatta Valley

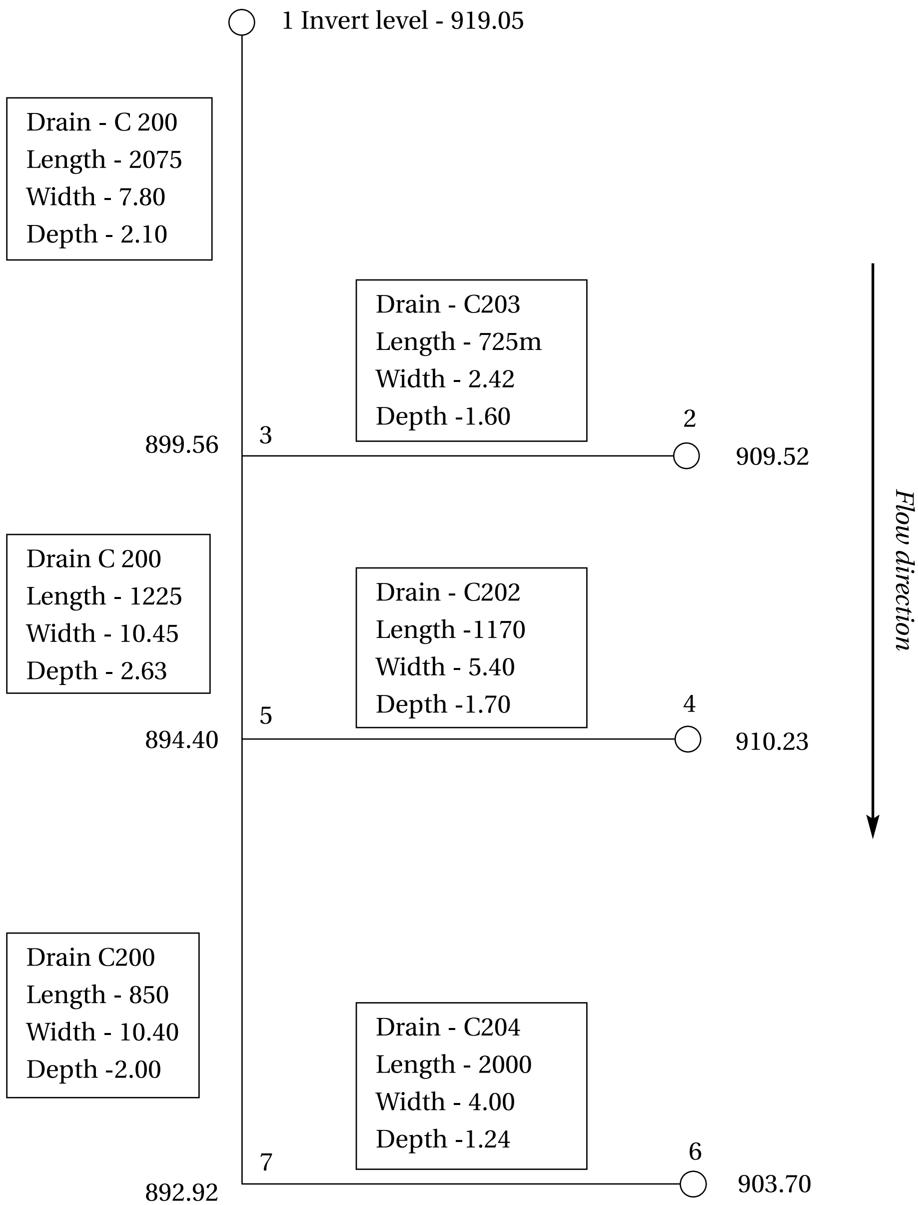

Figure 14.2: Line diagram showing the drainage system of Ulsoor Valley

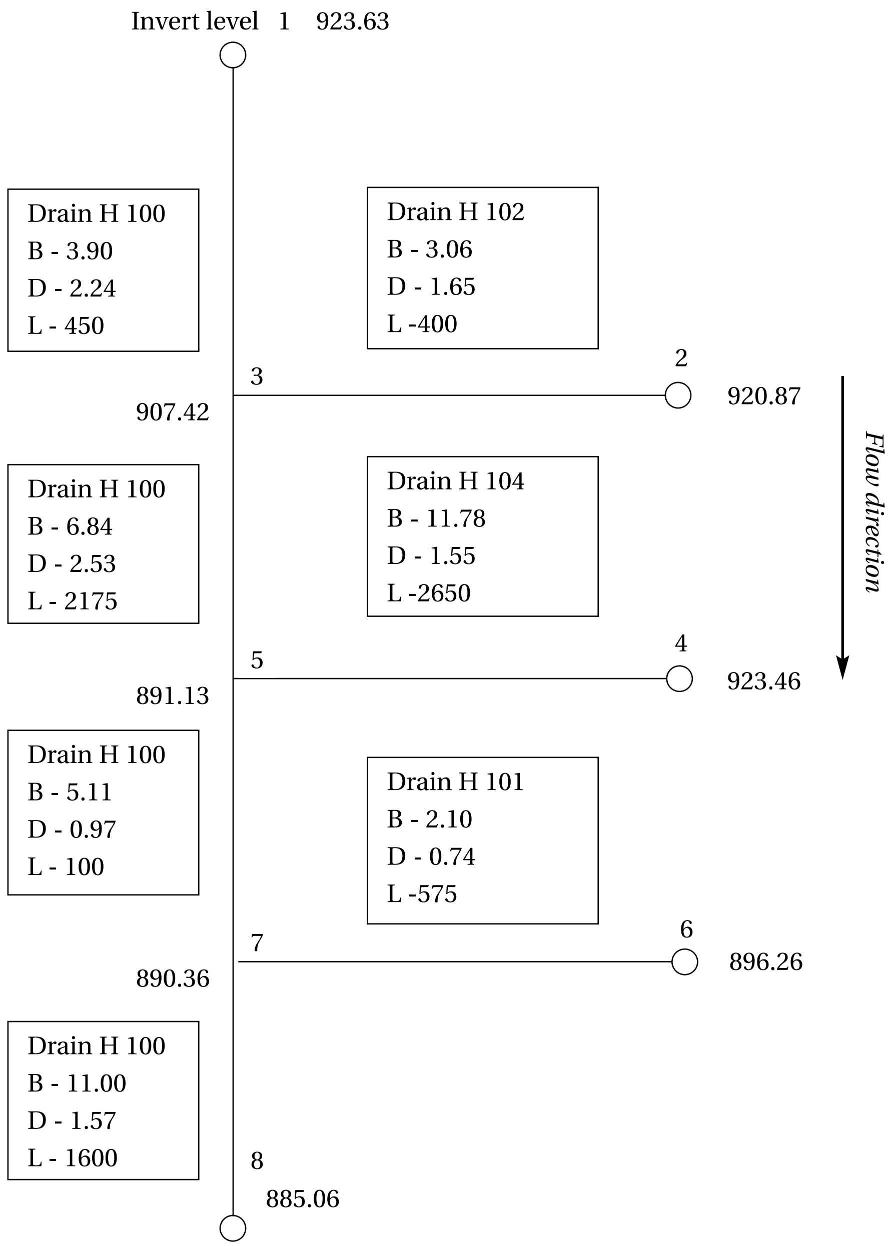

Figure 14.3: Line diagram showing the drainage system of Hebbal Valley

Table 8.1: Causal factors and key impacts

Causal factors	Key Impacts and remedial actions
Unplanned urbanisation	
Increase of impervious surfaces and non-upgradation of drains to handle enhanced runoff Encroachment of drain	Causes increased volume and rate of surface run-off from developed lands, which leads to more flash flooding and increased extent, height and frequency of flooding. ✓ Prevention of alteration of topography in the catchment. Upgradation of drains from top of catchment to catchment outlet for handling increases in run-off
Sediment and erosion from median strips and verges, spills from construction vehicles (e.g. concreting, earthmoving)	Reduced capacity, ✓ Improved catchment management practices
Development in flood-prone areas	
Encroachment and alteration of floodplain	Restricts flow and increases flooding on unfilled lands ✓ Control filling to overall valley Reduces flood storage capacity, increasing downstream flooding
	✓ Undertake whole of catchment planning for drainage
Inadequate provision for main drains in development plans	Causes gradual reduction in waterway capacity due to encroachments ✓ enforce compliance ✓ Incorporate drainage reserves
Development below flood level	Creates high flood damage, lowers standard of housing and reduces property values ✓ Prepare flood level plans to a datum and use them to control building floors and other development
Cross drainage (and services in drains)	
Lack of capacity of cross drainage works	Causes localised and widespread flooding ✓ Reconstruct to a standard equal to the future drain requirements
Construction of services (water, telecommunication, power etc.) above invert and below flood level	Obstructs flow and aggravates flooding ✓ Relocate services, coordinate works and agree on service locations
Sewerage system in drains	
Reduction in stormwater system capacity	Increases flooding significantly ✓ Lower manholes and reconstruct sewers below drain invert
Obstruction and redistribution of stormwater flow, generally poorly constructed sections	Causes bank and bed erosion; flooding in the waterways ✓ Reconstruct and improve future designs
Solid waste disposal	
Dumping of solid waste and building site waste in the drainage channel	Causes blockage and pollution in the drainage system ✓ Implement solid waste strategy plan
Unstable and degraded waterways	
Weed infestation, encroachment, vegetation loss, and eroded and unstable riparian zones	Causes siltation of downstream waterways ✓ Treat erosion sites and develop guidelines for silt control during construction

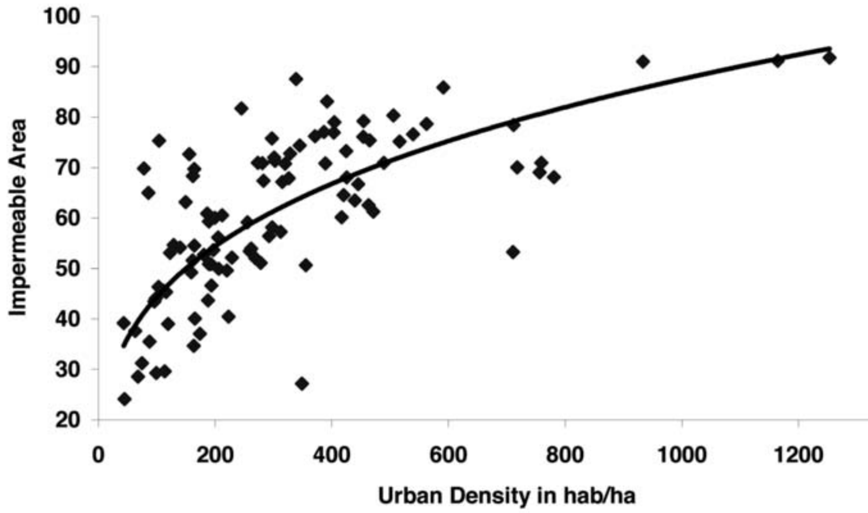

Figure 15: Impermeable area and urban density for Bangalore

buildings and most of the times, slum dwellers occupy the adjoining areas. At many sites, water is used for washing and household activities and even fishing was observed at one of these sites. Multi-storied buildings have come up on some lake beds that have totally intervened the natural catchment flow leading to sharp decline in the catchment yield and also deteriorating quality of waterbodies. Table 8.1 summarises the causal factors for poor drainage system and remedial measures to be undertaken to improve the condition.

Plate 4.3: Flooding In Banashanakari (Photo: Ranjini)

Landsat ETM+ data of 15 m spatial resolution (on fusing with Landsat ETM+ PAN) have been used to estimate impermeable areas that does not distinguish between types of urban land use (industrial, commercial and residential) but consist of a sample from a mixture of residential and commercial areas. Figure 15 shows the relation found between impermeable area to urban population density. Consequence of increase in built up pixels (evident from the increase in paved surface or impermeable area) is the increase of population density in a region.

There is a general lack of appreciation of the potential values and importance of waterways in the urban environment and also fragmented management approaches have contributed to decline in waterways in the catchment. Although sewerage system is provided in many drainage basins in the core area by BWSSB, there are still large quantities of raw and partially treated sewage flowing in the urban drains and ultimately polluting the lakes. This is due to combination of wastes discharged from un-sewered premises, branch sewers not connected to the trunk sewers, and effluent from trunk sewers that are under capacity due to siltation or higher than planned development densities. Another significant factor contributing to frequent flooding of low-lying areas and to unsanitary conditions in drains and lakes is the large and rapid accumulation of sediments in the drains, dumping of solid wastes, building debris and casual litter disposal on drains. Similarly, erosion control practices in construction sites, public parklands, private gardens and on the medians and verges of roads are not sufficient to prevent large silt loads

Plate 4.4: Encroachment of a drain by slums and disposal of solid and liquid waste

reaching the main drains. These factors, combined with infrequent clearance of drains, have lead to the unsanitary conditions in drains and to drains with much reduced capacity.

Also, due to increased paved surface and concentrated human activities the magnitude of the difference in observed ambient air temperature between urban pockets (artificial land surface) and the regions covered with vegetation (natural area), which is ascribed as urban heat island effect. The urban heat-island effect results in increased local atmospheric and surface temperatures in urban pockets compared to the surrounding open spaces, etc. Specifically, surface and atmospheric temperatures are increased by anthropogenic heat discharge due to energy consumption, increased land surface coverage by artificial materials having high heat capacities and conductivities, increased vehicular and industrial emissions and the associated decreases in vegetation and water pervious surfaces, which reduce surface temperature through evapotranspiration. An attempt is made here to understand the implications of land cover changes on local climate.

Inadequate drainage causes inconvenience and loss to the property and human life depending on the intensity (Plate 4.3). It leads to flooding of houses and establishments in the floodplains. In its least severe form, poor drainage causes water stagnation that provides a breeding ground for disease vectors.

Vulnerability of Communities with Poor Drainage

Socio-economic condition, age and gender decide the vulnerability. This is aggravated by type of dwelling as well as inadequate drainage in and around living areas. Many of the slums and informal settlements of poor communities are either located along the drainage lines or in low-lying areas (Plate 4.4). They build their houses using semi-permanent materials (such as earth, thatch and plastic sheets) that afford little protection from floods. These communities suffer extensive damage to their property in the event of even minor localised flooding and are also are vulnerable water logging from slow drainage of rainwater. Many of these settlements are illegal encroachments, the losses suffered by residents are never formally recognised or compensated. Vulnerability arising from the specific location of poor households is one of the key factors contributing to the inadequate living conditions of the poor in urban areas. Often plinths of houses in slums and informal settlements are lower than the road heights, which are raised over the years due to road development activities. Such areas require very good drainage, as even small quantities of stagnant water can flood the houses. Out of the 360 officially recognised slums in Bangalore only 30 percent have underground sewerage services. Hence, in the majority of slums wastewater must be discharged via the stormwater system, where one exists.

Efforts made to mitigate and manage the floods

Sustainable urban development is possible only with the effective good governance at local levels. These are more effective than statutory authorities in mobilising community resources and undertaking local action to improve or protect the local environment. There is a need to integrate the functioning of all parastatal agencies. Transferring lakes to local government ownership provide an incentive for collective community action against polluters. In 1988 the Government transferred responsibility for 114 tanks within the conurbation area from the Minor Irrigation Department to the Karnataka Forest Department (KFD). The total area of the tanks is 1584 ha, of which 220 ha are under unauthorised occupation. Between 1988 and 2000, the KFD fenced 37 tanks and posted watchmen, and undertook minor improvement works at 10 tanks. In Calcutta, for example, the major drainage is the responsibility of the Irrigation Department and the minor drainage is the responsibility of local governments. In Bangalore, local governments have to coordinate with the KFD, the Minor Irrigation Department, and the BDA.

Name of the village	Survey nos.	Proposed CDP Land use	Existing development
Bommanahalli CMC			
Puttenahalli	31 - 41, 55 - 60	Park	Residential
	29,30 (part)	Residential	Forest nursery
	51,61 (part)	Public & Semi Public	Mango garden
Sarakki kere	24,25	Park	Residential
Billekally DoresanypaIya)	151 (part), 154	Residential	Industry
Jaraganahalli	24,25 (Part)	Traffic & Transportation	Residential
Arekere	26, 30	Industry	Residential
Hongasandra	33, (part)	Residential	Industry
Bommanahalli	61	Park	Residential, industrial
Kodichikkanahalli	3, 4, 5, 6 (parts)	Commercial	Residential
	34, 35 (part)	Public & Semi Public	Residential
Devarachikkanahalli	20, 21 (part), 19 (part)	Public & Semi Public	Residential
Hulimavu	77 (part)	Park	Industry
	86	Park	Residential
	76, 78 (part), 79 (part) 80	Industrial	Predominantly residential

Krishnarajapura CMC.			
Kowdenahalli	82-84, 86, 87, 88P P(part)	Industrial	Residential
	89	Public & Semi Public	Residential
	90, 91, 92	Traffic & Transportation	Residential
Virjnapura	121 (part), 118-119P P(part)	Park	Residential
	23P P(part), 24P Ppart), 103P P(part) 104 (part)	Traffic & Transportation	Residential
	34 (part), 35 (part), 42 (part)	Park	Residential
Krishnarajapuram	115 (part), 123 (part), 112 (part)	Public & Semi Public	Residential
G M Palya	123, 124	Industry	Residential
Devasandra	4 (part), 5, 6 (part), 7 (part)	Residential	Industry
Vibhuthipura	104 (part), 105 (part), 106 (part) 170 (part), 205 (part)	Railway	Residential
	108P P(part), 110P P(part), 184P P(part)	Park	Residential
Bhattarahalli	50, 51, 53, 54 (all part)	Green Belt	Industrial and residential
Medahalli	All survey nos.	Green Belt	Industry

Three statutes define the responsibilities and powers of local governments in Karnataka:

- *The Karnataka Municipalities Act 1964*, which applies to the CMCs and the TMC;
- *The Karnataka Municipal Corporations Act 1976*, which applies to the BMP;
- *The Karnataka Panchayat Raj Act 1993,*which applies to the panchayats.

Each statute sets out obligatory and discretionary functions and specific powers. The functions are in partial alignment with the functions that the Twelfth Schedule to *The Consitution) Seventy-fourth Amendment Act 1992*.

The 73rd and the 74rd amendments to the Indian Constitution in 1994 have been regarded as landmarks in the evolution of local governments in India. The Constitution (73PrdP Amendment) Act, 1992 (commonly referred to as Panchayat Raj Act) came into effect on April 24th, 1993 and the Constitution (74th Amendment) Act, 1992 (the Nagarpalika Act) came into effect on June 1st, 1993. While the 73rd amendment provides for constitution of Panchayats in rural areas, the 74th amendment provides for constitution of Municipalities in urban areas. Since local government is a State subject in Schedule VII to the Constitution, legislation with respect to local government can only be done at the State level. Therefore, upon the coming into force of the 73PrdP and the 74PthP amendments, it was the task of the respective States to pass laws in conformity with the amendments.

The Comprehensive Development Plan (CDP)

In 1984, the Government of Karnataka approved the first CDP for BMA. The Government approved a revised plan in 1995 (GO Bi. HUD 139 MNJ, 5 Jan 1995). The CDP covers the entire 1279 kmP2P of the BMA, comprising a 565 km^2 "Conurbation Area" and a 714 km^2 Green Belt. The CDP permits only a few types of development in the zone. BDA can demolish any construction in the Green Belt without its approval. However, extensive construction has taken place within the Green Belt. .

Under *The Karnataka Town and Country Planning Act 1961*, any new layout in the region requires the approval of the BDA. The widespread practice of forming sites for sale out of agricultural land contravenes the Karnataka Land Reforms Act, the Karnataka *Land Revenue Act, and the Bangalore Development Authority Act*. Verification of development in the region, reveals numerous discrepancies from the CDP (Table 9.1 and Table 9.2).

Table 9.1 Deviations from CDP

City Development Plan (CDP, 2006. City Development Plan for Bangalore, BMP, Bangalore), prepared for the city of Bangalore by BMP, is a 6- year policy and investment

Table 9.2: Land use Pattern in BDA Area

Category	Area (Hectares)	Area (%)
Residential	16,042	14.95
Commercial	1,708	1.59
Industrial	5,746	5.36
Park and open spaces	1,635	1.52
Public, semi-public	4,641	4.33
Transportation	9,014	8.40
Public utility	192	0.18
Water sheet	4,066	3.79
Agricultural	64,243	59.88

Souce: CDP, 2006

plan (2007-12) designed to articulate a vision of how Bangalore will grow in ways that sustain its citizens' values. Bangalore city has developed spatially in a concentric manner. However, the economic development has occurred in a different manner in different sectors of the City. The current urban structure results from the interlocking of these two developments. Five major zones can be distinguished in the existing land occupation:

- **1st Zone - The core area** consists of the traditional business areas, the administrative centre, and the Central Business District. Basic infrastructure (acceptable road system and water conveyance), in the core areas is reasonably good - particularly in the south and west part of the city, from the industrial zone of Peenya to Koramangala. This space also has a large distribution of mixed housing/commercial activities.
- **2nd Zone - The Peri-central area** has older, planned residential areas, surrounding the core area. This area also has reasonably good infrastructure, though its development is more uneven than the core area.
- **3rd Zone - The Recent extensions** of the City (past 3-5 years) flanking both sides of the Outer Ring Road, portions of which are lacking infrastructure facilities, and is termed as a shadow area.
- **4th Zone -** The New layouts that have developed in the peripheries of the City, with some vacant lots and agricultural lands. During the past few years of rapid growth, legal and illegal layouts have come up in the periphery of the city, particularly developed in the south and west. These areas are not systematically developed, though there are some opulent and up-market enclaves that have come up along Hosur Road, Whitefield, and Yelahanka. The rural world that surrounds these agglomerations is in a state of transition and speculation. This is also revealed by the "extensive building of houses/layouts" in the green belt. Both BDA and BMRDA are planning to release large lots of systematically developed land, with appropriate infrastructure, to address the need for developed urban spaces.
- **5th Zone - The Green belt and agricultural area** in the City's outskirts including small villages. This area is also seeing creeping urbanization. While the core area has been the seat of traditional business and economy (markets and trading), the peri-central area has been the area of the PSU. The new technology industry is concentrated in the east & southeast. These patterns are obviously not rigid - especially with reference to the new technology industry and services that are light and mobile, and interspersed through the City, including the residential areas. Table 9.2 provides the current land use pattern in BDA area

While infrastructure in the City is reasonably good in some aspects (water and sewerage, for instance), it is under stress in other aspects, particularly urban transport. Qualitatively, the urban infrastructure situation is profiled in the following:

- **Water supply:** The availability of raw water at about 140 lpcd is adequate, though the draw distances are increasing progressively. UFW is high, and distribution is uneven - being better in the BMP areas and poor in the peripheral areas.
- **Storm water Drainage:** Drainage is an area of concern, with the natural drainage system (Valleys) being built upon. With the growth of the City, the number of lakes has dwindled, and small lakes and tank beds have vanished because of encroachment and construction activities. This has resulted in storm-water drains reducing to gutters of insufficient capacity, leading to flooding during monsoon. Dumping of MSW in the drains compounds the problems, leading to blockages. To control floods, it is important to remove silt and widen these storm water drains to maintain the chain flow and avoid water from stagnating at one point.
- **Transport:** Rising traffic congestion is one of the key issues in the City. Though the length of roads available is good, the problem lies with the restricted widths. BMTC is one of the best bus transport corporations in the country, but the absence of a rail-based commuter system compounds the problem.
- **SWM:** Collection and transportation coverage is very good, but proper and adequate treatment/ disposal facilities are lacking.
- **Green Areas & Water bodies:** The City has a tradition of being a "Garden City" with plenty of green spaces and water bodies. However, the very high growth rate in the past two decades is having an adverse impact on these.

Key Issues of Urban Drainage Systems

Urban drainage has a direct impact on the City's image, citizens' life, and health. If the system does not work properly, it leads to environmental hazards (CDP, 2006). Improving the urban drainage system requires not only capital infusion, but also recurring expenditures for operation and maintenance. A single point obstruction in a storm-water drain would have a cascading overall impact. Citizen awareness is therefore a critical issue, and citizens and non-governmental organizations can play a key part in monitoring development in the region to ensure that drainage is not obstructed, and dumping of debris and MSW in drains does not occur.

Adherence to best practice guidelines as pre conditions to issuing a permit for development will help to ensure that all development within the city contributes positively to the maintenance of water quality, structural stability, hydraulic capacity and environmental and ecological values of the City's waterbodies. This includes:

- the protection and enhancement of the good water quality of the waterbodies and the improvement of areas of degraded water quality;
- the maintenance of the structural stability and hydraulic and flood carrying capability of the cities waterbodies;
- the protection of the water supply function (i.e. for irrigation) of the City's existing catchments, waterways and lakes;
- the inclusion of appropriate storm water quality and quantity management in the planning and design of developments; and
- the provision of adequate space for stormwater quantity and quality management infrastructure and the utilisation of existing features of the site such as drainage lines and waterbodies, in the design of the development and stormwater layout.

Suitable measures to assist in maintaining the pre-development storm water discharges include; retention/detention basins as part of a storm water treatment, increase in pervious areas on the site, the use of porous materials in those areas normally surfaced (such as footpaths); and the inclusion of on-site detention storage tanks with the design of multi-unit/building developments. The objectives of an urban drainage system should include:

- No encroachment of the designated waterway area or reduce the waterway area or obstruct the flows by filling in the floodplain
- nsuring habitable buildings are not flooded in major storms (i.e. 5, 10 or 25 year Average Recurrence Interval (ARI) or as appropriate).
- Flood waters do not present an unacceptable risk to personal safety in major storms (i.e. 5, 10 or 25 year ARI or as appropriate).
- Underground drains with sufficient capacity to ensure that flooding is not a regular nuisance in minor storms.
- The risk of pollution of drains and waterways minimised by preventing sewage discharge to storm water, by managing the storage and discharge of hazardous materials, by controlling land use and by reducing the major sources of pollutants.
- Drainage and waterways must be considered in the development of a strategic plan for future development including:
  - ✓ protection of waterways by incorporating open space as a designated waterway corridor in the City Plan. This will reduce future building encroachment and subsequent flooding; and

✓ any developments in the stormwater catchment will increase flooding and potential pollution of downstream. These issues should be considered in the planning stage, especially in cases where flood mitigation options are limited in the downstream system.

Drainage lines can contribute substantially to the landscape and open space amenity of development. A decision needs to be made as to the appropriate land take for drainage areas and the style of waterways to be adopted. Key actions required are:

Core Area Drain Rehabilitation: A broad approach towards correcting the more severe problems would involve work on cross drainage, cross services and sewers in manholes, together with new drains and wall replacement. Such works would be followed by the correction of severe - but more problematic - drain deficiencies. That may involve land resumption and major construction of walls. Approximately 81 km of main sewers are laid in drains. At least 20 km of these sewers are in need of replacement for capacity reasons. Additional lengths may have to be replaced for condition or other reasons. Similarly, drain improvements will require modification of these sewers. Total relocation of sewers out of drains is not essential and it is proposed that wherever a sewer needs to be replaced, consideration be given to relocation into adjacent roads or reserves. Of those sewers that will remain in drains, the vast majority should have their manholes modified to avoid flow obstructions. Sewer leakage and direct discharge to drains is to be addressed under the sewerage rehabilitation program.

Scheduled Drain Clearance: Until such time as drain inverts are redesigned for self-cleansing velocities and solid waste programs are implemented, ongoing regular clearance of drains is necessary to minimise flooding risks.

Even when drain upgrading as well as improvements in solid waste collection are completed, there will remain a need to remove silt and litter from the drains and inlets to tanks. In the longer term, catchment management practices which control silt loads from erosion sources will also need to be implemented.

Water Quality Improvements: At present, the principal causes of poor water quality are the sewage flows and large solid waste content in the drains. The sewer rehabilitation program would involve sewerage of unsewered premises (including those directly connected to drains); repair of sewer leaks; and upgrade of sewer capacity.

Capacity building: Training of drainage practitioners, operating within private and government organisations, is needed in a range of main drainage activities, including rainfall trends analysis, run-off estimation for small catchments, run-off estimation for larger catchments, using hydrograph techniques, hydraulic analysis of channels, culvert and pipes, using basic and backwater techniques, planning and design for major and minor drainage systems; and powers and duties relating to drainage and planning legislation.

Land Use and Development Controls: Review of regional planning, including the Bangalore Metropolitan Region Development Authority (BMRDA) structure plans and the Comprehensive Development Plan (CDP) to include drainage policy, provision for identification of flood-prone lands and control of its subsequent development, creation of wide reserves and easements for primary and secondary drains and control of development in the floor of primary and secondary valleys with respect, at least, to building floor levels and set-backs from reserves. In implementing land use and development controls and in enforcing legislation, consideration needs to be given to the special needs of the urban poor who are likely to bear the disproportionate burden of such measures.

Legislation and Institutional Reforms: A comprehensive review of the institutional arrangements for management of primary and secondary drainage within the BMA is desirable, with a view to creating one single drainage authority with the responsibility for identification of flood-prone lands and flood levels, approval of development plans for layouts with respect to flooding and drainage, planning of all waterways and drainage, integration of waterways and drainage with urban land use planning, including identification of easements, setting of levels of service for all secondary and primary drains and lands adjacent to tanks, in conjunction with all stakeholders, preparation of integrated drainage plans for each main catchment; and Monitoring of development and advising planning authorities on non-complying urban development.

The roles of implementation and operation could be undertaken within existing and strengthened municipalities and/or an expanded BMP.

Education and Consultation: Environment education programs through schools, colleges, NGO's and mass media to raise community awareness and understanding of the risk of flooding, the importance of clean waterways and their role in supporting community well being, health and the overall life style in the city of Bangalore.

Best management practices (sediment fences, re-vegetation, sediment barriers, graved channels, dimension channels, etc.) for erosion and sediment control to manage development activities in a catchment, and involves:

- Erosion Control - the process of minimising the potential of soils to be eroded and transported in the first instance through the effects from wind, water or physical action through surface stabilisation, revegetation, erosion control mats, mulching, surface roughening, etc. These techniques represent a source control in preventing erosion of the soil material in the first instance.
- Sediment Control - the process of minimising the transport of eroded material

Plate 5.1: Removal of storm water drain encroachments in Nayandahalli, Bangalore *(Source: BMP)*

Plate 5.2: Removal of solid waste from the drain in KH Road, R.R. Nagar *(Source: BMP)*

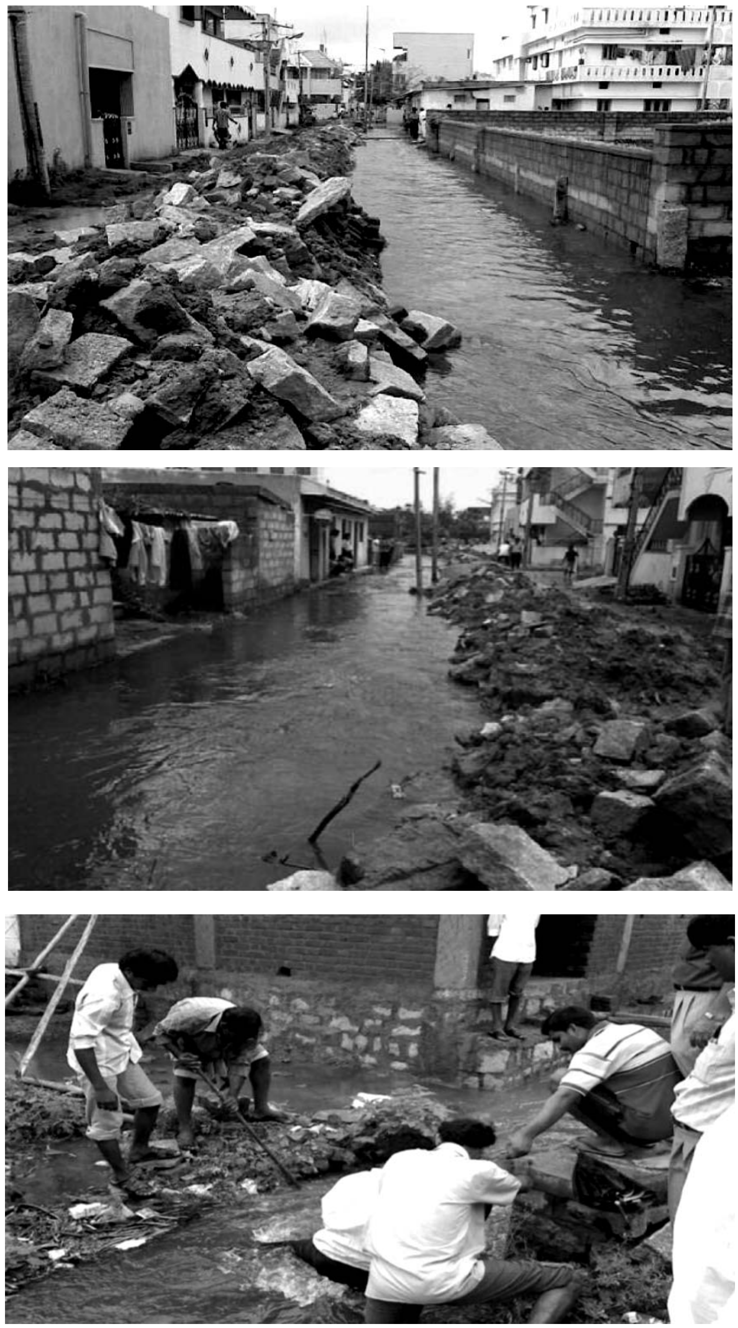

Plate 5.3: Removal of blockage in Kalappa layout *(Source: BMP)*

Plate 5.4: Desilting in Koramangala main valley, KH Road and Chalgatta valley

(source: BMP)

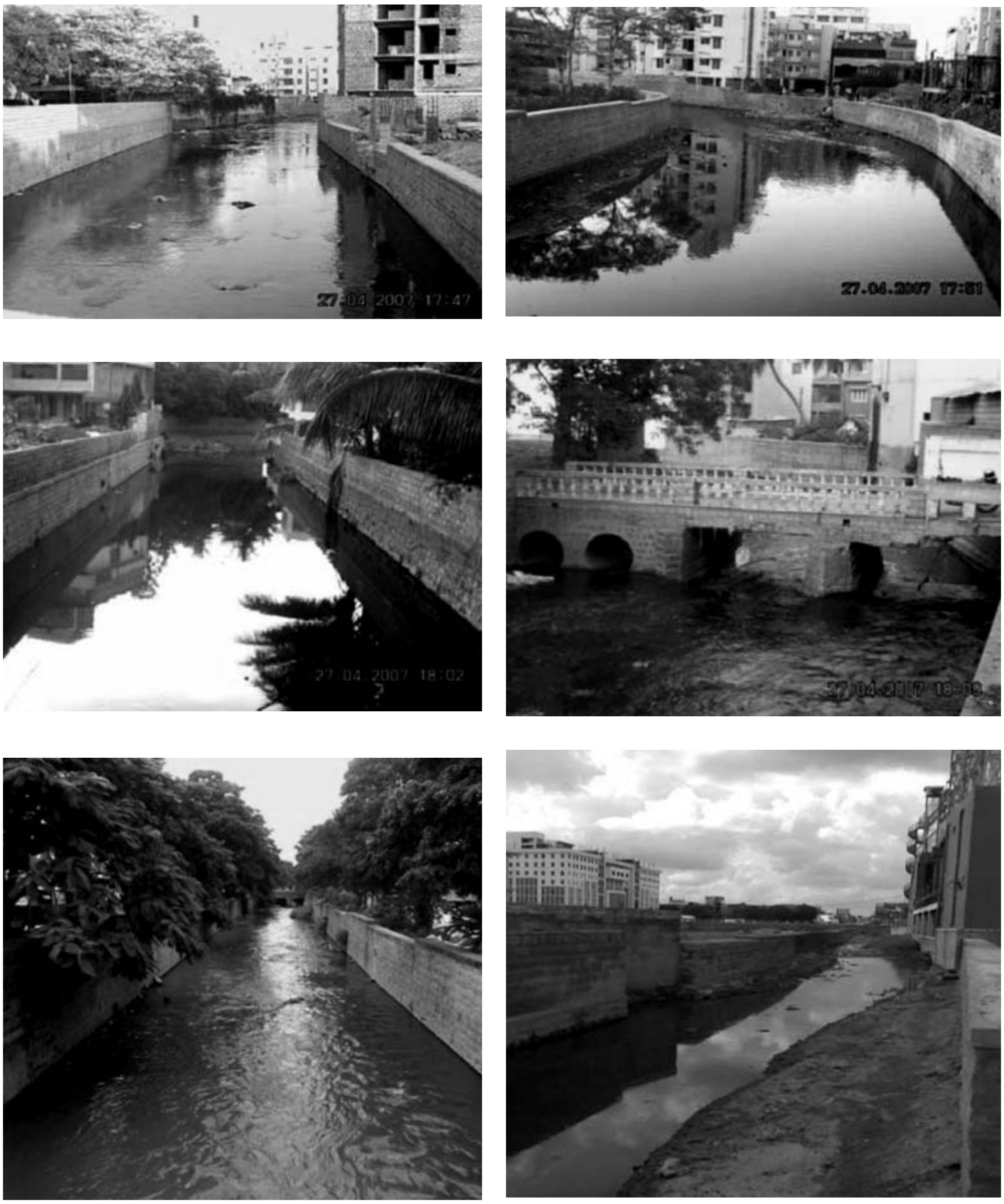

Plate 5.5: After desilting - Koramangala Valley, Vajapayee nagar

Plate 5.6: Construction of RCC box drain in Puttenahalli *(Source: BMP)*

Plate 5.7: Remodelled storm water drain

Plate 5.8: Storm water drain retaining wall construction *(Source: BMP)*

Plate 5.9: Chain link fencing to prevent solid waste dumping *(Source: BMP)*

Plate 5.10: Providing screen in storm water drain

Plate 5.11: Restoration of Ulsoor lake with STP *(Source: BMP)*

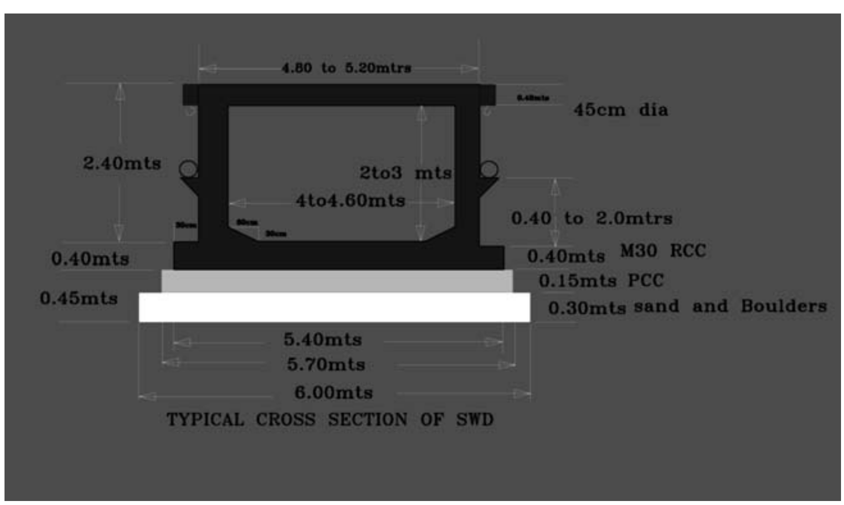

Plate 5.12: Redesign of storm water drain *(Source: BMP)*

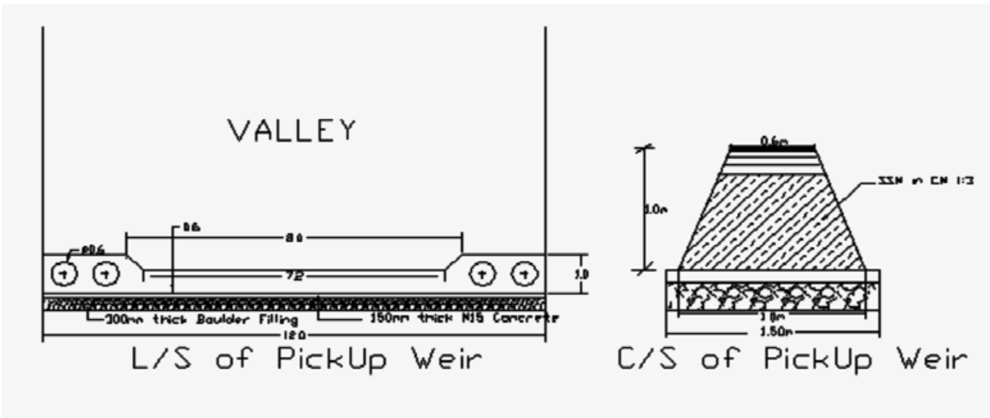

Plate 5.13: Design of pickup weir *(Source: BMP)*

(sediment) suspended in water or wind through catch drains, check dams, lined channels, grassed channels, and diversion channels, drop pipes, chutes and flumes.

In Bangalore, the sources of sediment supply to the drains include wash-off and erosion of unvegetated median strips, walkways and parklands, litter from trees and other vegetation, wash-off from roadways and impervious areas, wash-off and erosion from unmade roads and partially developed layouts, erosion of steeper unlined drains, construction site erosion or drainage water, drainage channel erosion and solid wastes dumped directly into drains or washed from pavements.

Key activities implemented for improvement of SWD

The key activities for improving storm water drains in the city included construction and rehabilitation of roadside drains, remodeling and strengthening, clearing silt, constructing of walls, laying of beds, provision of enabling and awareness information architecture and green area development. The action plan included:

- Clearing all encroachments that come in the way of the storm water drain network in the city (Plate 5.1);
- Aligning the drain network and checking blockage and overflowing of drains; Removing silt (Plate 5.2, 5.3, 5.4 and 5.5);
- Construction/remodeling/rehabilitation of road side drains (Plate 5.6 and 5.7) - Constructing 1,500 km of roadside drains (cost of construction assumed at Rs. 30 lakh per km for a 5-metre drain);

- Decreasing the load on Koramangala storm water drain (originating from Majestic and flowing into the Bellandur Lake) by building a bypass box canal from this drain via Agaram to the Bellandur Lake;
- Constructing a similar bypass canal via the Karnataka Golf Association; Reviewing existing storm water drains, ensuring connectivity of primary, secondary and tertiary drains;
- Constructing retaining walls (Plate 5.8);
- Redesigning for current load conditions along with building barriers between roads and open drains at crossings (Plate 5.9 and 5.10).
- Restoration and conservation of waterbodies (Plate 5.11)
- Laying of beds (plate 5.7);
- Remodelling of storm water drains (Plate 5.12 and 5.13);
- Provision of enabling and awareness information architecture; and
- Green area development.

The City is proposing to have a coordinated action plan to address the issue of urban drainage. At present BMP is coordinating the "valley projects," and is carrying out the works in coordination with other agencies, facilitated by the GoK.

Compounding the flooding problems are the unsanitary conditions created by large volumes of raw, or partially treated, sewage and large volumes of solid wastes entering the drainage system (Plate 5.2 and 5.3). Strategic options for rehabilitating and extending the Bangalore Water Supply and Sewerage Board (BWSSB) sewerage system and for expanding the BMP (Bangalore Mahanagara Palike) solid waste management system have been prepared. Following filing of writ petitions in 1999, and subsequent issuance of High Court Orders against the Government of Karnataka (GOK) and several authorities in Bangalore responsible for provision of environmental sanitation services, an Environmental Action Plan was devised to address the worst of the existing problems and remedial actions, including desilting of drains, have been completed in some localities (Plate 5.3 and 5.4).

The potential values and importance of waterways in the urban environment have been undermined consequent to fragmented management arrangements. Similar fate might befall the waterways in the rapidly developing lands within the Bangalore Metropolitan Area (BMA), but outside of, and downstream of, the BMP catchments. The critical issues that is to be addressed relates to the fact that inadequate drainage in a particular ULB jurisdiction may not have the impact in that ULB but elsewhere. Coordination and continuity of action between the ULBs is of critical importance.

Objective	Action Areas	Summary of Measures
Manage the Flood Risk		
Minimisation of the impacts of flood events and potential damage costs	Existing development (core area and outer area)	Introduce flood mitigation structural measures, (restriction removal, widening/deepening) Remove illegal encroachments Develop and implement awareness programs
	Proposed development (core area and outer area)	Control land use, development Develop and implement awareness programs
To collect and provide best available data for managing the flood risk	Develop spatila information system with an up to date Topographic, land use, hydrologic, flood impact data, etc.	Identify flood-prone areas, flood levels Collect flood impact information Conduct topographic surveys
Control Land Use Planning and Development		
Integrating urban storm water drainage functions in CDP	Land use planning	Amend planning legislation and regulations if necessary Incorporate drainage policy into structure and consolidated development plans (CDP) Provide drainage reservations in planning schemes
	Development controls	Impose development controls (filling levels, floor levels, reserves, set backs) for each drainage authority/municipality
	Monitoring and enforcement	Monitor encroachments and floor levels Enforce policy and regulations
Implement Effective Asset Operation and Maintenance		
To manage the urban storm water drainage assets economically and to protect public health and safety	Drain siltation and litter	Schedule and perform regular drain clearance Support solid waste strategy (at source collection) Trap gross sediment on tank inlets
	Asset condition monitoring and maintenance	Schedule inspections and audits of drain assets Conduct safety audits of tank embankments and spillways Prioritise maintenance activities Coordinate other infrastructure assets
	Construction standards	Develop design, construction and maintenance standards to reflect economic life cycle asset costing Apply construction standards through appropriate supervision and QA systems
	Drain safety	Erect warning signs, fencing, etc., where appropriate Minimise safety risks in design

Objective	Action Areas	Summary of Measures
Enhance the Environment and Social Conditions		
To expand and protect the social and environmental amenity of open urban waterways, where possible	Social equity	Promote community based representative decision making Set basin wide drainage levels of service Target improvement works according to agreed priorities
	Cultural and heritage	Restore water quality in tanks (drainage system) Desilt tanks Develop and implement education programs within an overall communications strategy Restore tanks
	Recreation/landscape	Landscape riparian lands Provide access and linkages along drainage corridors
	Aquatic environment	Provide in-stream features (water falls, swales, wetlands) Introduce water quality improvement actions Use alternative waterway design
Improve Water Quality		
To improve the quality of water in the drains and tanks	Sewage entering stormwater system	Extend sewerage system Repair sewer leaks Upgrade sewer capacities
	Litter & solid wastes	Collect solid wastes Develop and implement education and awareness programs
	Stormwater quality improvement	Enforce appropriate stormwater and catchment management practices (erosion control, litter and silt traps, street sweeping)
Provide Supporting Drainage Legislation and Regulations		
To provide effective drainage regulations and management arrangements	Drainage authority	Review roles and responsibilities of authorities involved in drainage and provide effective mechanisms for drainage planning, implementation, monitoring, enforcement and funding
	Land use planning	Amend structure plan, CDP to reflect drainage policy
	Building and development controls	Amend municipal and planning legislation to provide adequate controls over land filling, floor levels etc.
Prioritise Resources & Actions		
To provide adequate funding and resources for capital and recurrent activities according to agreed priorities	Priorities and funding	Collect supporting flood damage data Prepare integrated drainage management plans Consult with stakeholders on priorities Introduce general drainage tariffs Introduce development contributions to main drainage Allocate appropriately government grants and loans Use lending agency loans
	Training	Train practitioners in drainage management methodologies and techniques

Strategies for improved service delivery include:

- The importance of inter-ULB and Agency coordination:
- Inadequate drainage in a peripheral ULB may impact drainage in BMP areas;
- Improper drainage of BWSSB's system may pollute the valley system and impact quality of life across the City; and
- Improper roadside drainage and cross-connectivity may similarly impair system performance;
- Citizens to be involved to monitor contractor's activity on clearing of drain systems in their area:
- Citizens who dump debris into storm water drains could be penalized; and
- Removing silt to be a regular activity before the monsoons starting with the main (primary) drain.

Drainage management plans (DMPs) for each catchment are required to enable all deficiencies identified, an affordable level of service developed, all upgrades designed to a consistent standard and priorities set for implementation. Action plan suggested in this regard are listed in Table 9.3

Progress during 2008-09

The torrential rain of May 2006 crippled almost the entire city. Posh residential layouts, poor low-lying slums and even the busy streets such as Mahatma Gandhi Road and Vidhana Veedhi were affected. While parts of Jayanagar went without power for three days as the junction boxes were damaged following the rain, Church Street, Shantinagar, Rest House Road were inundated in knee-deep water. The impact of the rain in areas such as Ejipura, Jogupalya, Jeevanabimanagar, Murgeshpalya, parts of Sampangiramnagar and surrounding areas was devastating. During 2006 monsoon, people used boats to cross the road in this locality because of flooding of water. The water logging happens when the intensity of rain is high and whenever the flow of water into the drains is more than the discharge capacity. Several areas in the surrounding suburbs such as Puttenahalli, Pai Layout, HSR Layout and Bommanahalli were the worst-affected last year. That was because these areas did not have a stormwater drain network and, moreover, they had encroached upon lake-beds.

TTraditional storm water management techniques simply collect the rain water and funnel it across the city downstream. Newer methods combine traditional approaches with new ones such as Sustainable Drainage Systems (SUDS). It employs a range of natural processes to purify urban runoff. Removal of sediment, bio-filtration, biodegradation and water uptake by plants all help to remove pollutants. The city needs many such recharge wells in the catchment area of critical flood zones to detain flood waters and top up the aquifers instead of surface flow floodingT. TAt the broader scale, tanks and lakes need to be networked and managed as retention and detention structures. With rainfall prediction accuracy being developed, tanks have to be linked to catchments and kept ready to hold the maximum water to dampen peak storm eventsT. A deslited tank in Bengaluru can recharge up to 11 mm of water every day while an undesilted one can recharge hardly 1 mm. Desilted tanks can recharge aquifers quickly, lower the surface water levels and be in a position to function as flood mitigators. Full tanks are not good at dampening floods.

The Bruhat Bangalore Mahanagara Palike (BBMP) during 2008-09, focused on providing permanent solution to overflowing of storm water drains, water logging, and other related problems during rains. BBMP built a new storm water drain to prevent flooding in Bandeppa Colony. Similarly, a storm water drain was widened besides raising the height of retaining walls. BBMP was successful partially in evicting the encroachers of storm water drains as owners of buildings, built on the raja kaluve, had obtained stay orders from courts. The BBMP demolished 10 structures covering 600 sq.m. of drain area in Bhadrappa Layout in Hebbal. These structures had come up on the storm water drain leading to the Hebbal Lake. Work on increasing the height of retaining walls of storm water drain and providing gradient to shoulder drains at Bhadrappa Layout were in progress and the situation was likely to improve once the works were completed. BBMP established control rooms, including the zonal control rooms. The control rooms were fully equipped with men and material. Of the 280 identified vulnerable areas, 48 had been marked under "A" category and four of these are under "A+" category (the region highly vulnerable). The Central Silk Board area, Puttenahalli, Arakere, Nayandanahalli, Katriguppe, Illyas Nagar, Bhadrappa Layout, S.T. Bed Layout, Kamakhya Layout, Hennur, Ejipura and Bandappa Colony are these vulnerable spots.

Strategies for the future

Strategy to incorporate Integrated Storm Water Management (ISWM) approach to flood management integrating land and water resources development in a lake catchment or river basin, within the context of integrated water resources management, and aims to maximize the net benefit from floodplains and to minimize loss to life from flooding.

This is based on

- A participatory approach involving users, planners and policy-makers at all levels and should be open, transparent, inclusive and communicative.

Table 10 - Strategic Actions

Proposed Actions	How	Possible Implementation Mechanisms
Integrated catchment based management and planning to improve catchment landuse and drainage conditions	Developing Catchment and Stormwater Management Plans (CSMP) to integrate all stormwater issues on catchment levels including: Water quality, flooding, waterways, assets management and funding, planning and development control, and other environmental and social issues. More details on typical CSMP's contents, objectives, and outcomes are presented in section 8.2 of this report.	Catchment and Stormwater Management Plans should be developed for each major catchment. Significant coordination between all stakeholders is required. This study would require multi-disciplinary team, with expertise in hydrology, environmental, planning and socials issue.
Enforce best practice guidelines as conditions to issuing permits for new or reconfiguration of developments	This should include guidelines for: This should include guidelines for: • Erosion and sediment controls • Setting Floor levels above designated floods) • Restrictions on filling in the floodplain and obstruction to flow • Legal point of discharge and connection to storm water and sewerage systems. • Storm water quality objectives and treatments prior to discharge. • Preferred subdivision layout in relation to storm water assets.	Accountability of the agency to ensure implementation of best practice information
Stormwater management solutions to the overall urban water cycle and water conservation strategy	• Encourage and promote "water sensitive urban design" for maximising infiltration, treatment of stormwater runoff by grass strips, reduction in paved areas in new developments. • Rehabilitate and maximise the use the remaining waterbodies to reduce flooding through retardations and to maximise infiltration to groundwater by retaining floodwaters in these basins. • Maintain (where possible) the natural conditions (i.e.; unlined) of the channels and waterways to maximise infiltrations to groundwater and also to treat water quality.	The BMP should develop and promote best practice design manual for urban developments and implement these options in the development of the flood mitigation strategy.
Regular water quality monitoring in major waterbodies through a network of educational institutions	This helps to establish base line data, assess the impacts of land use changes and management practices on water quality, and provide instructions for water usage and human health purposes. • Review the conditions and the importance of waterbodies • Identify priority areas	The key objective is to monitor improvements rather than to confirm existing conditions are poor.

Proposed Actions	How	Possible Implementation Mechanisms
	• Determine the type and frequency of monitoring required (this should include average values and events monitoring) • Develop and undertake program for storm water quality monitoring	
Minimise flooding	Identify educational institutions to undertake at regular interval drainage and flood studies for the city to: Identify existing drainage system and flood prone areas. • Develop overall flood mitigation strategy for the city. • Prioritise and undertake the mitigation works based on flood risks. • Control new developments, which may impact on flooding.	Develop centralised infrastructure database with a network of instituions. BMP currently embarking on major flood study, Flood mitigation options and strategy will need to be coordinated and endorsed by a number of other authorities to cover issues such as land resumption, planning, changes in sewerage system.
Establish designated flood levels along the main waterway, to provide guidance for new developments or reconfiguration of existing developments.	• Determine flood profile for the high flood levels (say 10, 20 or 50 years ARI) from the t drainage study • Use new survey and contour maps to plot the extent of the flood levels along the waterways. • Use GIS based technology to develop a spatial database with web based information systems.	BMP to develop and maintain spatial information systems
Protect the remaining waterways corridor from encroachments of new developments	• Identify preferred waterway corridor width based on the above high flood levels and other planning and environmental factors. • Incorporate the corridor in the Comprehensive City Plan as designated areas for new or reconfiguration of developments.	As part of the review of the City Plan, the BMRDA, BDA in conjunction with the BMP should incorporate the designated corridor area into the plan.
Minimise sewage inflow to storm water	• Separation/ relocation of the sewerage system from stormwater system • Implement the Sewerage Master Plan including treatment plant upgrade. • Enforce/develop planning laws on illegal connections. • Develop and upgrade guidelines on sewer construction and maintenance	Establish coordinating committee/taskforce between BWSSB and BMP to coordinate these issues and to undertake an option study (risk, cost, constraints) to identify the preferred option to separate the two systems.

Proposed Actions	How	Possible Implementation Mechanisms
		It is may be cost effective to incorporate this option investigation study into the BMP current drainage study. The BWSSB may provide additional funding to this component of the study.
Integrated Municipal Solid Waste Management	Adoption of an appropriate strategy is essential for any improvement in the storm water quality and quantity in Bangalore.	Implementation to conform MSW Rule, 2000.
Community education programs to improve understanding of the important of clean drainage and waterways	Raising community awareness and understanding of the risk of flooding, the importance of clean waterways and its role of supporting the community well being, health and the overall life style in the City of Bangalore. with numerous successes around the world. This can be undertaken in various forms: • Environmental education at schools and colleges • Education through mass media • Encouraging the community to be involved in catchment care groups • CBD and NGO's to devlop and implement catchment management plan.	• Schools and colleges • NGO's and CBO's • BMP

- Decentralization of decision-making is necessary, with full public consultation and involvement of stakeholders in planning and implementation.
- Coordination at the highest level to promote coordination and cooperation across functional and administrative boundaries needs to be ensured.
- Land use planning and water management are combined in one synthesized plan, through coordination of land and water management authorities to achieve consistency in planning.
  - Clearing all encroachments that come in the way of the storm water drain network in the city.
  - Restoring all lakes. Removal of all encroachments in lake catchments
  - Declaring 500 m around the lake as no activity zone
  - Aligning the drain network and checking blockage and overflowing of drains.
  - Reviewing existing storm water drains, ensuring connectivity of primary, secondary and tertiary drains.

Redesigning for current load conditions along with building barriers between roads and open drains at crossings.

Thus, an integrated approach to stormwater management maintains the traditional function of minimising flooding, in addition to integration of water quantity and quality management policies and practices with the coordinated, total catchment approach to the issues of stormwater management. In addition to flood management, a primary goal is to protect downstream water bodies from contamination and erosion, while maintaining, or in some cases re-establishing, natural waterways and wetland features as part of the drainage network. The location and design of significant stormwater management infrastructure (e.g. drainage corridors, culverts, etc.) is to be based on a firm understanding of the local needs/values, legislative requirements and practical constraints considering the hydraulic, hydrologic, environmental, economic, social, legal and practical aspects. For example, maintaining or improving the natural conditions of a waterway in Bangalore (i.e., widening and grading the banks) instead of channelising and concreting, could bring multiple benefits including flood mitigation, water quality improvement by vegetation and recreational benefits. Suggested strategic actions are outlined in Table 10.

The storm water system consists of many natural water-bodies and a high-density waterway system. Sewage contamination leading to eutrophication of waterbodies would result in a major health and socio-economic disaster for the city. Some receiving waterbodies have no major outlets and pollutants are accumulated in the sediment deposits. Litter, discarded building materials, sediments and other solid waste items are the main causes of blockages of the drainage system resulting in flooding in some pockets of Bangalore.

The objective of Catchment and Storm water Management Plan is to integrate all water quality, quantity and waterways issues from a catchment perspective to enhance and stabilise degraded waterways, minimise flood risk, maximise amenity and property values and improve water quality in the stormwater system with the following objectives:

- Prevention of raw sewage from entering the stormwater system;
- Promotion of best management practices to improve stormwater quality;
- Management of storm water drainage ensuring the protection of waterways, water quality and minimising floods;
- Integration of water quality management with flooding and waterway corridor management issues;
- Design and implementation of flood mitigation schemes (where necessary) to

minimise the impacts of large flood events and potential damage costs;

- Mapping and monitoring of flood prone areas and flood levels along the waterways under appropriate Average Recurrent Interval storms through drainage and flood studies. Based on the designated flood levels along the main waterway system, waterway corridors are to be determined and to be incorporated as "no development" areas into the City Comprehensive Development Plan to prevent development within these corridors.
- Alteration in topography in the catchment area to be banned through an appropriate legislative measures;
- To provide and coordinate an information and education program for the community and schools to improve understanding of the risk of flooding, the importance of clean waterways and their role in supporting the community well being, health and the overall lifestyle in the City. The objective should be to achieve increased community involvement in waterway care.

List of Abbreviations

ARI	Average Recurrence Interval (years)
BDA	Bangalore Development Authority
BMA	Bangalore Metropolitan Area
BMP	Bangalore Mahanagara Palike (or Bangalore City Corporation)
BMRDA	Bangalore Metropolitan Region Development Authority
BWSSB	Bangalore Water Supply and Sewerage Board
CBO	Community Based Organisation
CDP	Comprehensive Development Plan
CMC	City Municipal Council
CPHEEO	Central Public Health and Environmental Engineering Organisation
DMP	Drainage Management Plan
GIS	Geographic Information System
GOK	Government of Karnataka
KSCST	Karnataka State Council for Science and Technology
KSPCB	Karnataka State Pollution Control Board
LDA	Lake Development Authority
NGO	Non-government Organisation
TMC	Town Municipal Council
UGD	Underground Drain for Sewerage

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