KEY WORDS:
Urban Development, Ecological Resources, Forests, Parks, Lakes, Groundwater, Water-sensitive, Bengaluru.a

Ecological Impact of Urban Development: Lakes of Bengaluru

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ABSTRACT

The United Nations projected by 2030, at least 60% of the world's population will live in cities, with nearly 2 billion new city residents, many migrating from rural areas. The urban population in India is growing at around 2.3% per annum with the global proportion of urban population increasing from 13% (220 million in 1900) to 49% (3.2 billion, in 2005). At the current pace of urbanization, natural resources and ecosystems could be severed by 2030.

With Bengaluru as a case study area, the research is based on the hypothesis that urban development can have a substantial amount of threat to ecological resources. The study maps the extinction of ecological resources namely lakes, forest, and parks at metropolitan area level over the period of time. By various analyses at macro, meso and micro level, the study projects the issues causing it.

The study concludes with an understanding that urban growth where environmental or ecological concerns have not been a priority will have several consequences on the ecological resources and brings solutions for the current practice of urban development which could have likely impact on ecological resources and directs the future developments for the Bengaluru city.

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Introduction

The United Nations, in 2014 revealed that at least 52% of the world's population is living in cities. By 2050, that number will jump to 66%, with nearly 2.5 billion new city residents, many migrating from rural areas (UN DESA, 2014). Most of the growth is occurring in developing countries like China, India, and Africa, ecologically rich areas such as coasts and islands are at risk.

Urbanization is taking place at a faster rate in India. Population residing in urban areas of India was 11.4 % as per 1901 Census. This count increased to 28.53% as per 2001 Census and crossing 30.0% as per 2011 Census, standing at 31.16%. An increased urban population mainly due to migration is in response to the growth in urban areas. There are 53 urban agglomerations in India with a population of 1 million or more as of 2011 against 35 in 2001(India, C.o., 2012).

Bengaluru Urban with 90.94% of its population living in urban areas is the most urbanized district and accounts for 35.7% of the urban population of the state (Census, 2011).
Such uneven urbanization will increase the pressures on natural resources and increase the likelihood of resource extraction and other threats to the protected places like forests, lakes, etc. Bengaluru is blessed with a network of lakes which moderate temperatures and affect the climate of the surrounding land. They store water, recharge groundwater aquifers. They provide habitat for aquatic and semi-aquatic plants and animals. The quality of water of any water body may be affected by the land use pattern of the catchment area and activities taking place in and around it. Lakes not only act as a source of water but also add recreational values in the urban areas.
This paper attempts to identify the issues related to lakes in Bengaluru with reference to its urbanisation and formulate strategies and proposals for eco-friendly urban development.

Impact of Urban Development on Ecological Resources

The city's long-term development is beyond spatial and infrastructure planning and is associated with sustainable development.
As the MoHUPA (2009) suggesting that 41% of India's population is expected to be concentrated in urban centers by the year 2030, it makes sense to rethink 'ecology' and understand its urban manifestation, wherein the role that trees, green cover and water bodies play in defining the city's climate, pollution, cultural values and socio-economic opportunities can be evaluated.

Urban development has been accompanied by disruption and sometimes destruction of fragile ecosystems, including surface water bodies, groundwater, forest cover and the green cover. With the depletion of Forests, parks, lakes, flora, and fauna, many secondary problems occur, they are,

- Groundwater contamination due to soak pits and improper drainage system.
- Decrease in groundwater recharge due to increasing surface runoff in paved areas.
- Polluting surface water bodies by the letting sewage into the lakes, ponds etc.
- Increase in temperatures due to heat islands, and inadequate tree cover to counter this rise in temperature.

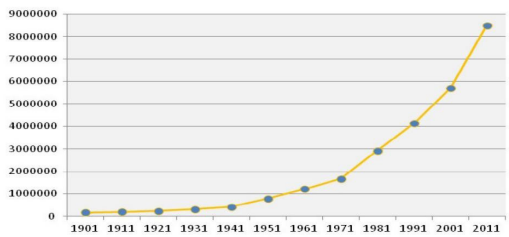

Figure 1: Population growth rate of Bengaluru 1901 – 2011
Source: *Census of India, 1901 - 2011*

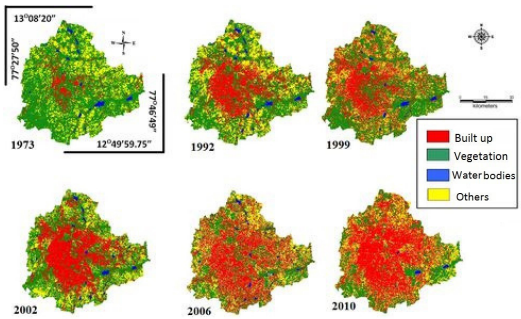

Figure 2: Population growth rate of Bengaluru 1901 – 2011
Source: *T.V. Ramachandra, Aithal, and Kumar, 2010*

- Air circulation is also reduced due to the dense residential development and loss of vegetation cover.

Objectives of the Study

1. To study the spatial growth and development pattern of Bengaluru city.
2. To assess the impacts of urban development on ecological resources at the macro level of Bengaluru Metropolitan Area (BMA), meso (Hebbal lake system) and micro level (Rachanahalli lake).
3. To review environmental issues by critically analyzing various existing policies and plans.
4. To formulate strategies for Eco-friendly urban development.

Factors Influencing Bengaluru's Growth

Key projects influencing the population growth and socio-economic development in the city and peri-urban area comprise of the following.

- Bangalore International Airport (North Bengaluru)
- Bangalore-Mysore Infrastructure Corridor (South-West Bengaluru)
- Information Technology (IT) Corridor (South-East Bengaluru)
- Bangalore Metro Rail (cross-cutting Bangalore City)
- Location of large-scale/manufacturing industries (East and North Bengaluru)
- Location of IT/ITES/Biotech Industries (East and South Bengaluru)
- Development of five Integrated Townships in the BMR
- Responsive energy and power supply projects
- Peripheral Ring Road (around Bengaluru)
- Urban basic service delivery projects proposed by the local self-government institutions (LSGIs) in the city.

Population Growth

Bengaluru is the fifth largest urban center in India with a population of 8.5 Million (census 2011). Around 14.64% of the state population resides in Bengaluru within 0.64% of land share. The city has witnessed 42% growth rate in population from 2001 – 2011 which has been the highest in urban India. **Figure 1** shows the decadal population of Bengaluru.

Spatial Growth

Bangalore is characterized by a radial system formed by the axes, which converge towards the center of the city. **Figure 2** shows the

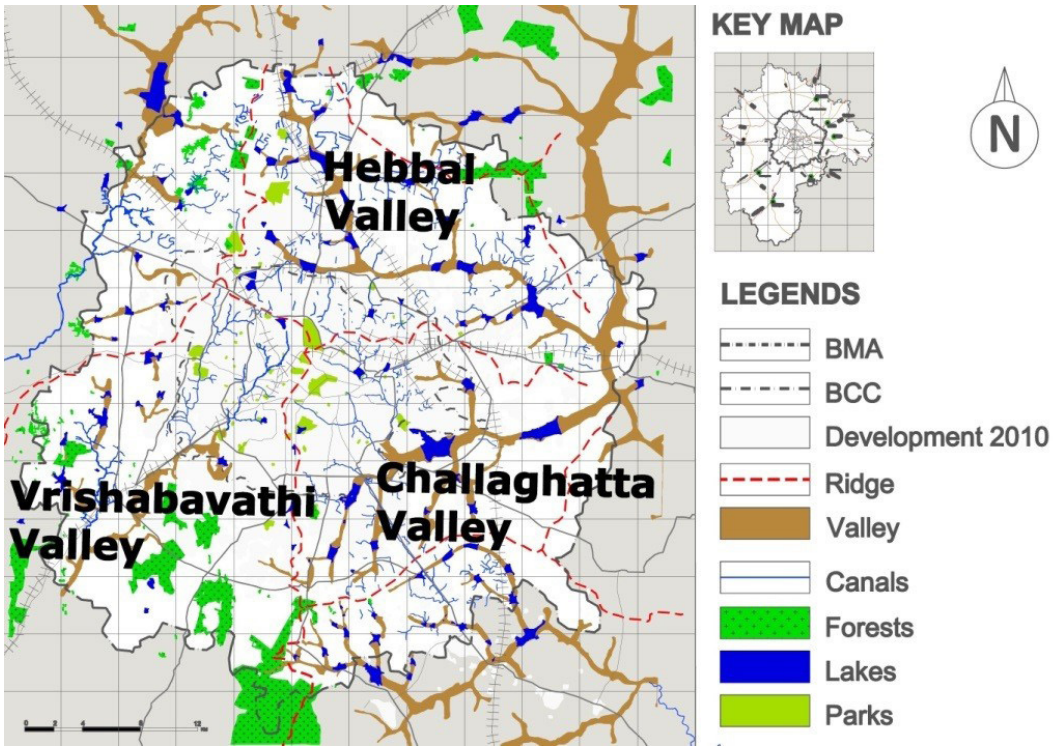

Figure 3: *Ecological resources of Bangalore Metropolitan Area.*
Source: *Revised Master Plan 2015, Bangalore Development Authority (BDA) Drawn by the Chandrakanth.K*

spatial growth of Bengaluru from 1973 to 2010. Urban development in the south is driven by services sector (Electronic City and Bommasandra) and the resultant boom in the Real Estate market. There has been a slowdown in the West (Dasarahalli, Magadi road, and Tumkur road) with the losing momentum of development in the Peenya Industrial Zone. Urbanization has increased in a substantial manner in the Northeast and East, again due to service sector (Whitefield and ITPL), and the current airport being within the city. North side of Bangalore is now beginning to see an exponential growth as the new airport is located in that direction (Devanahalli).

Ecological Resources in Bengaluru Metropolitan Area (BMA)

Bengaluru with its varied ecological resources like forest, parks and botanical gardens, agriculture plantation land, lakes, ponds, rivers, wetlands, flora and fauna and renowned botanical gardens is rightly called "The Garden City of India" and "The City of Lakes". As shown in **Figure 3**, forest Constitute 4% of land use (16.89 sq.km), lakes constitute 9.25% of land use (36.45 sq.km) and parks constitute 7.5% of land use (30. 24 sq.km). Lakes constitute the major portion and they are quantitatively and qualitatively quite important for a detailed study.

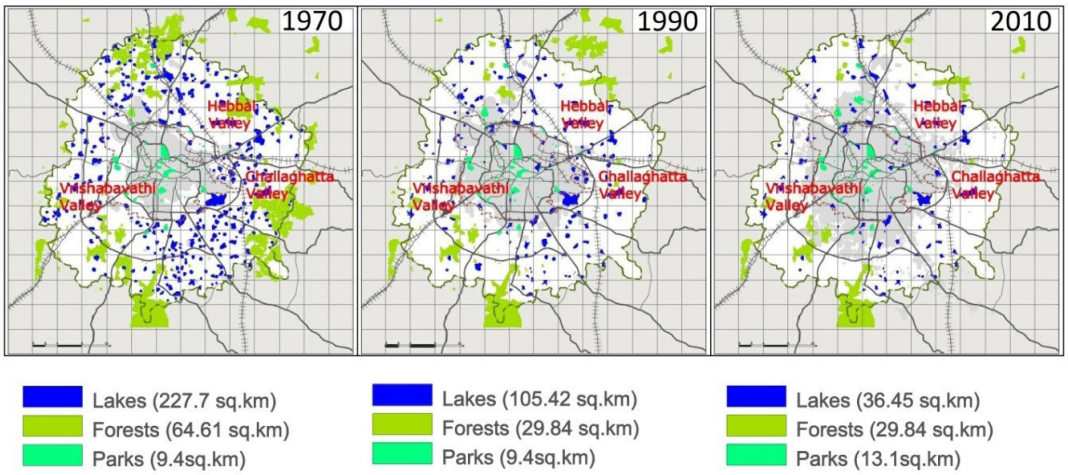

Figure 4: Loss of Ecological resources at various years. Drawn by Chandrakanth. K

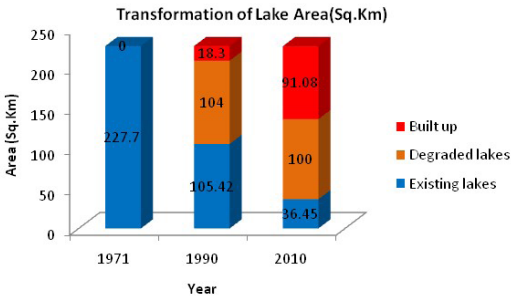

Figure 5: Transformation of lakes for various years

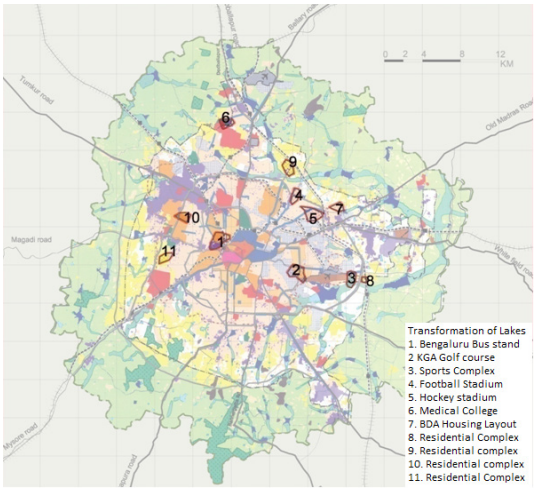

Figure 6: Map showing the transformed lakes into other uses.
Source: *CGWB, 2009-10, Drawn by Chandrakanth. K*

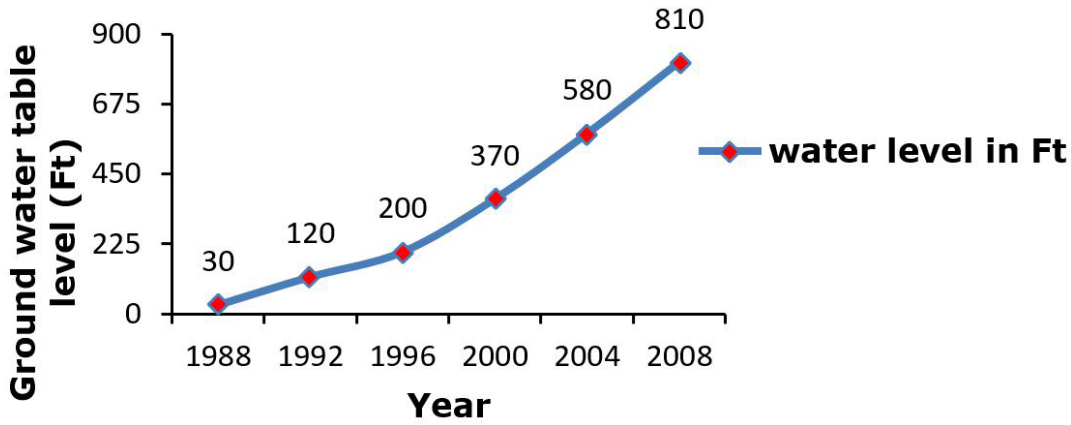

Figure 7: Graph showing the water table from 1988 to 2008
Source: CGWB, 2009-10, Drawn by Chandrakanth. K

Analysis at Macro Level of the BMA

The loss of ecological resources over the period of years are given in **Figure 4**, from which, it is clear that the development stomped out huge ecological resources. Further analysis is done mainly dealing with the lakes as it is the focus of this study.

Bengaluru's predominant water source is Cauvery river, which is about 140 km away from the city. The naturally undulating terrain develops lakes that can capture and store rainwater. The lakes form a chain of hydrological connection through them. Around 227.7 Sq.km. of lake area found in 1975. In 2001, out of 227.7 Sq.km. of the lake area, only 105.42 Sq.km. remained as lakes and 18.3 Sq.km are transformed into the built-up area and the rest were dried up. From 1990 to 2010 there was a transformation of 72.78 Sq.km. of lake area in the built-up area as shown in **Figure 5**. Major transformed lakes are shown in **Figure 6.**

Here, the challenge is on the degraded lakes, which is 100 sq.km. area and it can be easily modified into a built-up area. Urban ecology loss has serious consequences on the microclimate of the city and several other problems. Now managing the city's ecological resources is a great challenge in Bengaluru. The decrease of water bodies had its serious effect on the level of ground water level shift from 30ft in 1988 to 810 feet in 2008 (refer **Figure 7**) with around more than a lakh borewells in the city.

The quality of lake with respect to pH (Potential of Hydrogen), DO (Dissolved Oxygen), BOD (Biological Oxygen Demand) is analyzed and the status of the lake is quantified as shown in **table 1**. pH is the potential of hydrogen is a scale of acidity from 0 to 14. It tells how acidic or alkaline a substance is. More acidic solutions have lower pH. More alkaline solutions have higher pH. Substances that aren't acidic or alkaline (that is, neutral solutions) usually have a pH of 7. pH level of 6.5 to 8.5 represents a clean and safe water. As dissolved oxygen

(DO) levels in water drop below 5.0 mg/l, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills. Biochemical oxygen demand (BOD, also called biological oxygen demand) is the amount of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. Generally, for a clean lake, BOD should be in between 500 to 2000.

The major issues at macro level in BMA (refer **Figure 4**) are related to, transformation of lakes and forest and pollution of parks. Table 2 shows various issues that affect the BMA natural resources.

Analysis at Meso Level –Hebbal Lake System

The radial drainage system of Bengaluru flow of water from the top of the plateau to the base is punctuated by various undulations in the landform. Since there were no other perennial sources of water nearby, the people depended highly on the rainwater and groundwater. They dug out lakes and tanks in these depressions to serve a major part of their water needs. The main North-South ridge with the cross East-West ridge divides Bengaluru in the five main catchments and as we see that these lakes were dug out in the flow of water they were linked to each other. The five lake systems (**Figure 8**) are, Hebbal lake system, Bellandur lake system, Vrishabavathi system, Arkavathy system and the 5th system.

Of the five lake systems, Hebbal lake system is selected as meso study area. the reasons for the selection of Hebbal lake chain are as follows,

- No sewerage system covering the Hebbal catchment area (refer **Figure 9**).
- Receding groundwater table with more than 85% extraction and deteriorated quality.
- The existence of a diverse land use with Southern half developed and Northern half undeveloped area.
- Influence of newly developed Bangalore International airport

The Hebbal lake system is most affected by urban development, hence solutions given to herbal lake systems can solve the other lake systems as well. The total area of Hebbal lake system catchment is 204 sq.km. Out of which 101sq.km. is developed. There are 17 lakes in number in the whole system, which have a total capacity to hold 12,000 million liters of water. There are more than 8.5 lakh people residing in the catchment. The total water demand is 114 MLD whereas the present supply is 77 MLD. So a shortage of 37MLD exists. There is 92 MLD of sewerage generated every day but there is no sewage treatment plant. Although there is one STP proposed at the Hebbal Lake. There are slums on the periphery of some lakes accounting to a population of 1,10,000. The catchment of different lakes is defined by the minor ridges of the Hebbal catchment area as shown in **Figure 10.**

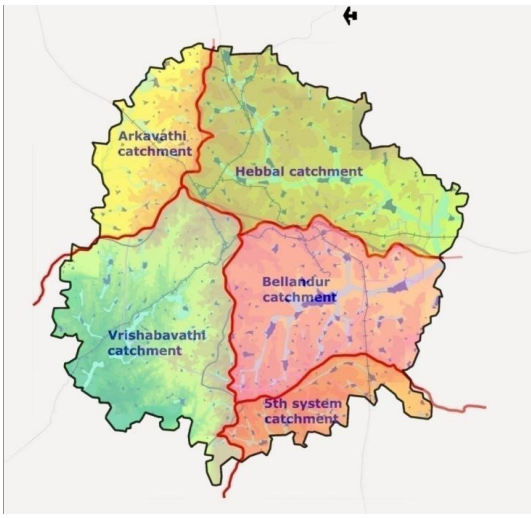

Figure 8: Map showing the five catchments of lake systems of BMA.
Source: ISRO, 2001

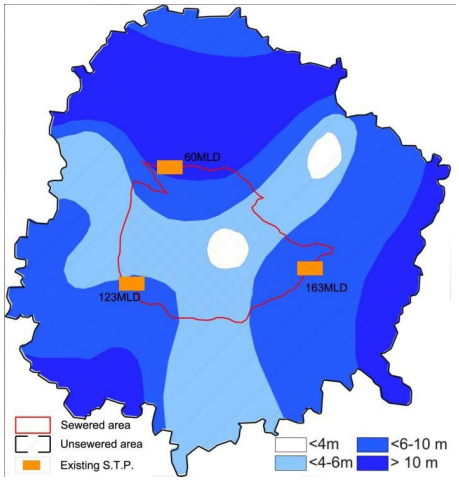

Figure 9: Status of groundwater and sewerage system in 2011.
Source: Karnataka State Irrigation department.

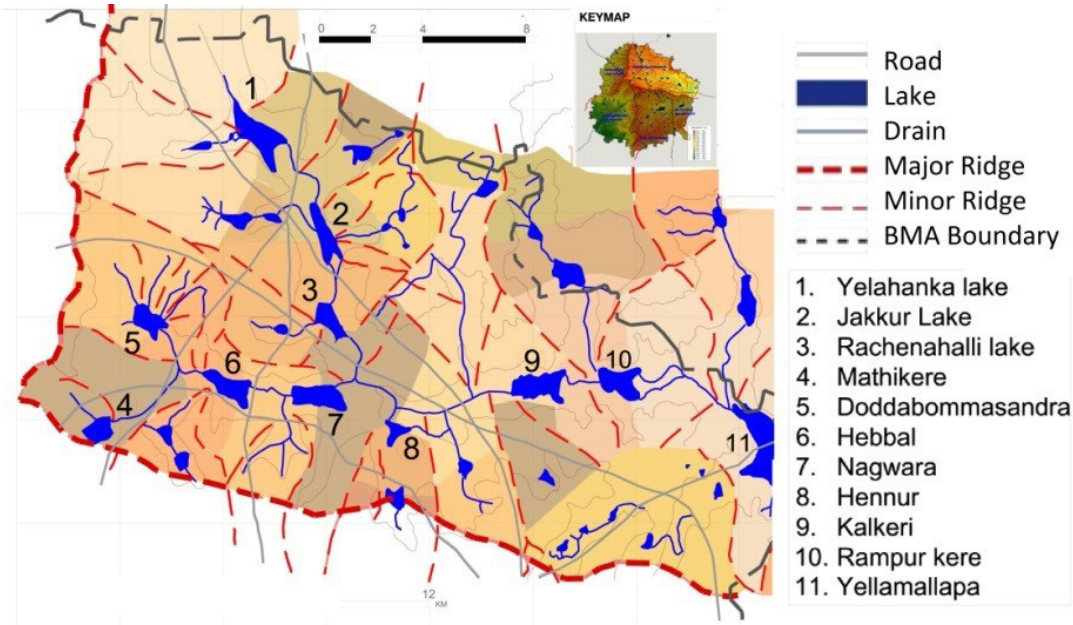

Figure 10: Map showing Hebbal catchment area.
Source: Lake Development Authority (LDA). Drawn by Chandrakanth. K

S.no	Name of the Lake	Area in Ha	pH	DO	BOD	Status of Lake
	Standard		6.5-8.5	>5	500-2000	
1	Hebbal Lake	52.81	6.8-8.4	1.0-9.0	03-54	Polluted
2	Madivala Lake	94.69	7.6-7.9	6.5-8.9	03-121	Desilting under progress
3	Vasanthapura Lake	6.07	7.7-7.9	7.7-8.2	02-05	Not polluted
4	Subramanyapura Lake	5.22	7.9-8.2	7.4-8.6	02-04	polluted
5	Sankey Tank	12.79	7.1-7.5	3.7-8.1	02-08	Desilting under progress
6	Vengaiah Lake	21.66	7.5-7.9	5.4-6.9	02-03	polluted
7	Doddabommasandra	4.67	7.4-7.9	1.7-8.0	01-07	Desilting under progress
8	Dasarahalli Tank	50.00	7.2-8.3	0.3-4.15	42-210	Not polluted
9	Yediyur Lake	4.54	7.2-7.8	3.2-9.0	13-225	Desilting under progress
10	Madavara Lake	24.00	7.3-8.0	1.3-8.5	03-07	Not polluted
11	Karihobanahalli Lake	0.31	7.3-8.1	7.5-8.3	03-09	polluted
12	Doddabidarakallu	18.40	7.2-7.6	1.0-8.7	10-14	Not polluted
13	Kempambudhi lake	13.23	7.2-7.8	1.0-3.3	55-250	polluted
14	Byramangala Lake	4.22	7.3-7.7	1.0-4.0	04-23	Marshy
15	Nayandahalli Lake	6.61	7.2-7.4	.05-1.0	56-285	Desilting under progress
16	Varthur Lake	166.87	7.4-7.7	0.5-1.8	03-46	polluted
17	Doddanakundi Lake	45.29	7.0-8.0	5.0-8.9	02-03	polluted
18	Gangadharaiah Lake		7.0-7.8	0.2-8.4	08-54	Not polluted
19	Chikkabanavara Lake	5.11	8.2-8.9	2.7-8.5	02-18	polluted

S.no	Name of the Lake	Area in Ha	pH	DO	BOD	Status of Lake
	Standard		6.5-8.5	>5	500-2000	
20	Jigani Lake	1.56	7.3-7.6	5.0-7.6	01-03	Not polluted
21	Gottegere Lake	12.93	7.4-7.7	6.8-8.3	01-03	polluted
22	Kodigehalli Lake	4.21	7.1-7.7	1.0-8.5	01-08	Desilting under progress
23	Rampura lake	75.12	7.3-7.9	0.3-5.4	12-20	Marshy
24	Kalkere Lake	63.37	7.3-7.6	0.2-0.4	21-41	polluted
25	Ulsoor Lake	43.81	7.0-7.8	2.8-8.5	17-32	polluted
26	Basavanapu-ra Lake	2.52	7.8-8.0	05-6.5	01-05	polluted
27	Seegehalli Lake	10.35	7.5-8.0	1.1-7.4	01-27	Marshy
28	Yelahanka Lake	115.8	7.4-7.8	5.1-7.9	02-05	polluted
29	Amruthahalli Lake	8.70	6.8-7.0	0.79-1.9	04-400	polluted
30	Jakkur Lake	58.96	7.0-7.7	1.9-8.4	2.0-32	polluted
31	Agaram Lake	4.33	6.8-6.9	0.2-1.1	90-470	Muddy Water
32	Puttenahalli Lake	5.26	7.0-8.2	4.0-7.6	04-400	polluted
33	Uttarahalli Doraikere	4.51	7.0-7.9	0.2-8.0	0.6-180	Desilting under progress
34	Rachenahalli Tank	45.98	7.4-9.6	6.1-9.2	1.0-8.0	Polluted
35	Allalasandra Lake	16.75	6.9-7.2	0.4-8.1	04-390	Desilting under progress
36	Kattigenehalli Lake	8.08	7.0-8.2	7.4-8.1	1.0-3.0	polluted
37	Bellandur Tank	307.35	7.0-7.9	0.3-8.8	12-275	polluted

Table 1: *Composition and status of lakes in Bengaluru.*
Source: *Lake Development Authority (LDA, 2010).*

Status of the Hebbal Lake System

The status of the lake can be assessed in two different ways- firstly, the physical conditions and the existing activities in the lakes and secondly, the quality of the lake water in terms of different parameters for the following 16 lakes that form Hebbal lake chain.

1. Yelahanka kere is a moderately polluted lake, with aquatic weeds around the periphery. It is partially filled and has industries around it.
2. Allasandra is near Yelahanka satellite town and has colonies and L.I.G. settlements. It gets sewage by a 600mm diameter sewage pipe end.
3. Jakkur kere gets sewage overflow from Yelahanka and Kacharakana Lake. There are weeds and even trees in the lake. It has aesthetic value as a wetland.
4. Rachenahalli kere is moderately polluted.
5. Kamanahalli is a breached lake having the residential area around.
6. Kacharakanahalli is dried up and lost its character as a lake.
7. Hennur gets industrial wastes and overflows from the Nagavara Lake.
8. Doddabomasandra gets sewage, is polluted, eutrophic, silted up and has weeds. Residential colonies of BEL and HMT surround it.
9. Hebbal is a revived lake, which was initially extremely polluted. A foreshore afforestation program with an island inside for bird nesting has changed the quality of water. It also has boating, and parks for tourism. The sewage that was coming to this lake prior to the revival has been diverted to the Nagawara Lake, making it even more polluted.
10. Nagawara had sewage, weeds, silt, and sludge. It has a bad odor, mosquitoes, and health problems and even the water contaminated the groundwater around.
11. Kalkeri Lake does not have well-defined channels carrying water to it due to obstruction caused by urbanization. It is deeper than most of the other lakes and its water spreads laterally when flooded. Also,the road and rail culverts flood it extensively. It receives highly polluted sewage from all channels. It has eutrophication and 70% of the surface of water sheet is covered with hyacinth.
12. Doddagubbi has less water than its capacity.
13. Rampur Kere has significant water storage capacity. It has natural water treatment system thus ensuring better water quality.
14. Yellamallappa chettykere is the large lake, which is divided by national highway 4. It has vast water sheet, is aesthetic, has peripheral weed growth.
15. Byapanahalli is all silted up and has broken into small lakes.
16. Bideranahalli receives overflow from agriculture area.

Groundwater Status of Hebbal Lake System

Groundwater also occurs in the confined conditions in the fractured rock below the weathered rock. The dug-wells are generally confined to weathered zone and borewells mainly to top fractured zone in the hard rocks. The yield of dug wells varies from 50-100 cu.m/day whereas the yield of borewells ranges from 142-518 cu.m/day for four to ten hours of pumping per day. The depth of water varies between 5-20m. The boreholes drilled near the

Hebbal area have encountered innumerable fractures and the yield is high. Overall the area has good groundwater potential.

The status of the lakes can be assessed in two ways- The physical condition and existing activities in the lakes (Degraded chain, sewage disposal, solid waste disposal, vegetation growth, industrial effluent inflow, silt deposit, mud lifting etc); and the quality of the lake water in terms of different parameters (COD, BOD, DO, TDS, TSS, pH etc). The major lakes of Hebbal lake system are compared in the **Table 3**.

The drains are the important component as it enables the proper flow of water from one lake to another. So the study of the drain with respect to the condition is equally important that of the lake. The physical condition of drains of different lakes is compared in the **Table 4**.

From **Table 2** and **Table 3**, Rachenahalli, Jakkur, Yelahanka Lakes and their drains are found to be in critical state. From **Figure 11**, it is evident that the Southern half of the Hebbal catchment area is the urban development while the Northern half is predominately agricultural area.

From the **Table 5**, it is evident that the Rachenahalli, Jakkur, Kalkeri, Rampur lakes are in critical state. From the above physical and chemical status comparison of major lakes of Hebbal lake system, it is found that the vertical chain with lakes namely Yelahanka chain connecting Jakkur and Rachenahalli are in a critical state with sewage inflow, industrial effluents and its drains carrying sewage and some are dried drains. The issues are located spatially in the **Figure 12**.

From the above analysis, Rachenahalli Lake is found to have major impacts due to urban development and should be studied in detail. Solutions given for the betterment of rachanahalli lakes solves other lakes.

The major issues at meso level in the Hebbal lake system are related to pollution of the lake and illegal encroachments (**Figure 12**). Different issues identified for Hebbal lake system are shown in **Table 6.**

Analysis at Micro level (Rachenahalli Lake)

Rachenahalli lake is located on the North-East of Bangalore city and 150 meters East of NH-4. It has an area of 128 acres. Its lake chain is Yelahanka Lake – Jakkur Lake – Rachenahalli Lake. It is observed that the Lake receives stormwater from two directions. From the North Eastern side, it receives from Jakkuru Lake. Drain carrying water from the Jakkur Village is on the Northwest portion. In the Western side of Dasarahalli village. The area covered under the catchment of Rachenhalli lake and its morphometric details are shown in the **Table 7** and **Table 8** respectively.

Type	Issues
Forests	a. More than half of the forest area (38.2 sq.km) is transformed into a built-up area. b. 9.52 sq.km of the forest area is degraded.
Lakes	a. 100 sq.km of the lake area is degraded.
Parks	Solid waste disposal into Lalbagh and Cubbon parks by visitors.
Policy conflicts	The proposed industrial area in the Eastern sector. (Dark area or the maximum groundwater extraction zone).
Urban development	Existing development pattern is along CBD to Bangalore international airport, which is eco-fragile land

Table 2: Various issues at BMA.

Sl. no	Lakes	Degraded chain	Sewage Disposal	Solid Waste Disposal	Vegetation growth	Industrial effluent	Silted	Mud lifting
1	Yelahanka lake	Y	Y	N	Y	Y	N	N
2	Jakkur Lake	Y	Y	Y	Y	N	N	N
3	Rachenahalli lake	Y	Y	Y	Y	N	N	Y
4	Mathikere	N	N	N	N	N	N	Y
5	D.bommasandra	N	Y	N	Y	N	N	N
6	Hebbal	N	Y	N	N	N	N	N
7	Nagwara	N	Y	Y	Y	N	N	N
8	Hennur	N	N	N	N	Y	N	N
9	Kalkeri	N	N	N	Y	N	N	N
10	Rampur kere	N	N	N	N	N	Y	N
11	Yellamallapa	N	N	N	Y	N	N	N

Table 3: Physical conditions of the Hebbal lake system.

Sl. no	Lakes	Inlet drain				Outlet drain			
		Sewage	Solid waste	Silted	Dried	Sewage	Solid waste	Silted	Dried
1	Yelahanka lake	Y	Y	N	N	Y	Y	N	N
2	Jakkur Lake	Y	Y	N	N	Y	Y	N	N
3	Rachenahalli lake	Y	Y	N	N	Y	Y	Y	Y
4	Mathikere	N	Y	N	Y	N	Y	N	N
5	D.bommasandra	Y	Y	N	N	Y	Y	N	N
6	Hebbal	Y	Y	N	N	Y	Y	N	N
7	Nagwara	N	Y	N	N	N	Y	N	N
8	Hennur	N	Y	N	N	N	Y	N	N
9	Kalkeri	N	N	N	N	N	N	N	N
10	Rampur kere	N	N	Y	N	N	N	N	N
11	Yellamallapa	N	Y	N	N	N	Y	N	N

Table 4: *Physical condition of drains of Hebbal lake system.*
Source: *Author.*

Morphometric Details of the Rachenahalli Lake

The main bund for the Lake on the South-Western side of the lake connects Mestripalya hamlet on the Southeastern side & Dasarahalli village on the southwestern side. The catchment area is about 850 Ha. The catchment is constrained by the large urban settlements.

Ecological Profile of Lake: The most troublesome aquatic weed is water hyacinth. About 40 % of the Lake is covered by Water Hyacinth (Eichhornia crassipes) all along the periphery at the locations where sewage enters the Lake.

Land Use Activity: This analysis is presented in **Table 11.**

Analysis of Lake Water: From the analysis of Rachenahalli lake water, it is found that TDS - 660 mg/l, BOD- 2 mg/liter, Chlorides- 269 mg/liter (Slightly high), Chlorophyll - 5 mg/liter. The waste water flowing into the Lake through the Inlets is in septic condition with BOD - 38 mg/L to 44 mg/L, COD - 100 mg/L to 122 mg/L, pH - 7.7 Suspended solids - 8 mg/L to 32 mg/L Nitrogen - 6 mg/L to 12 mg/L.

Sediments Analysis: From the analysis of the sediments collected from the bottom strata of the lake, it is found that the Oxidisable organic

S. no	Lakes	COD	BOD	DO	TDS	TSS	pH
	Standards	>250	<30	>5	500-2000	100	6.5-8.5
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	
1	Yelahanka lake	201	38	4.38	1023	61	7.9
2	Jakkur Lake	158	40	2.1	2101	76	8.3
3	Rachenahalli lake	129	44	1.8	2370	98	8.6
4	Mathikere	149	34	2.7	1312	39	7.2
5	Doddabom-masandra	448	31	2.4	1364	32	7.8
6	Hebbal	375	25	7	450	18	7.9
7	Nagwara	232	45	2.9	1657	22	7.1
8	Hennur	198	27	3.2	1789	86	7.9
9	Kalkeri	178	42	4.1	2007	79	8
10	Rampur kere	243	36	4.3	2091	59	7.4
11	Yellamallapa	258	38	3.8	2018	56	7.7

Table 5: *Chemical composition of lakes of the Hebbal lake system.*
Source: *Lake Development Authority (LDA).*

matter - 0.49 to 0.87 % w/w, Total Phosphorus - 242.60 mg/kg to 730.0 mg/kg, Nitrogen -2345 mg/kg to 3093 mg/kg.

From the analysis of Lake Water of the Lakes as brought out above, the water found in the lakes is assessed to be in a mesotrophic/ eutrophic condition.

Other Pollutants: They are indiscriminate disposal of solid waste due to intense residential activity around the lake and improper boundary protection. Also, the lake is not used for recreational purpose.

Waste floating bodies: Waste floating bodies like rubber, wood, plastics, thermocol packaging materials and other synthetic material in the lake leads to the foul smell after decomposition of organic floating bodies and also the surface of the water body will lose its beauty and looks ugly and acts as a breeding place of mosquitoes.

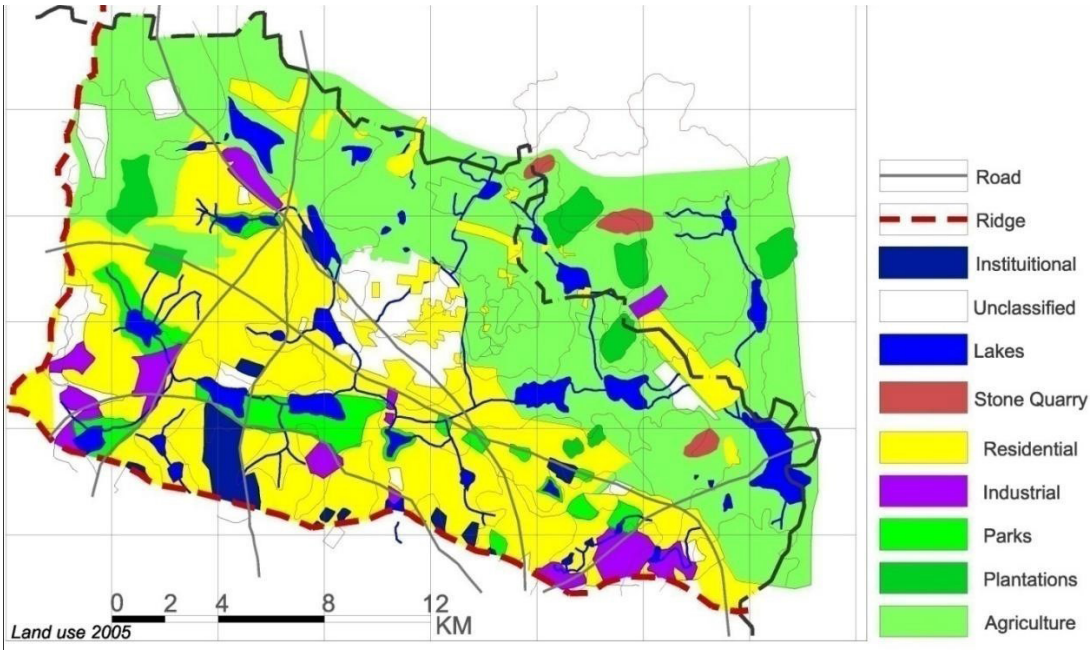

Figure 11: Land use map - 2005 of Hebbal catchment area.
Source: Master plan of Bangalore 2015, Bangalore Development Authority(BDA).

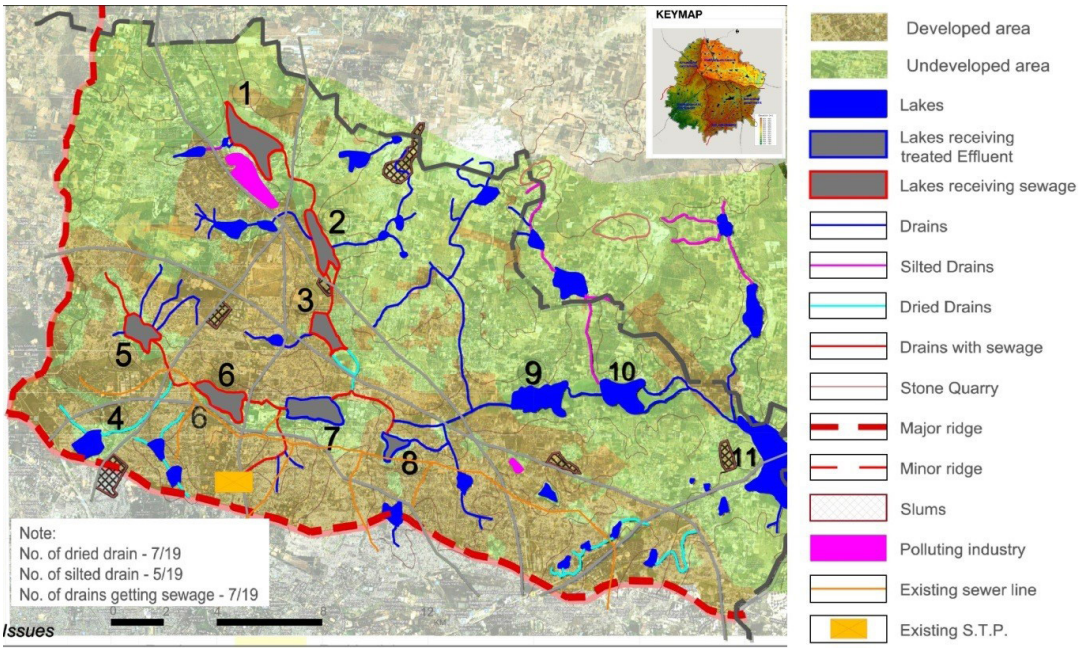

Figure 12: Map showing the various issues of Hebbal lake system.
Source: Lake Development Authority (LDA), 2010. Drawn by Author.

Type	Issues
Infrastructure	Yelahanka, Jakkur, Rachenahalli, Nagwara, Hebbal and Doddabommasandra lakes and Yelahanka, Jakkur, Rachenahalli, Hebbal and Doddabommasandra, Nagwara and Hennur drains are getting sewage.
	Solid wastes are disposed into Jakkur, Rachenahalli and Nagwara lakes and Yelahanka, Jakkur, Rachenahalli Mathikere, Doddabomasandra, Hebbal, Nagwara and Hennur drains.
	Lake catchments do not recharge groundwater and stormwater runoff is maximum.
Industrial	Untreated Industrial effluents are disposed in Yelahanka and Hennur lakes.
stone quarry	Rampura Lake and its inlets are silted.
Maintenance	Rachenahalli and Mathikere Lake and drains are dried and mud lifting is done.
Encroachment	Informal sector encroachment in Yelahanka, Jakkur, Rachenahalli, Nagwara, Hebbal, Doddabommasandra, Mathikere Lake drains.

Table 6: *Categories and various issues at Hebbal lake system.*

Encroachments: Due to rampant urban development in the catchment which includes the valleys.

Summary of analysis of Rachenahalli Lake is as follows.

- The sewage and wastewater flowing into the lakes are in septic condition.
- The inlets bring stormwater run-off, as well as wastewater, let out into the drain from the urban settlements on the upper reaches of the Lake.
- The stormwater is the major contributor to sediments; the sediments contain a mixture of silt, sand, and stones.
- Silting disturbs groundwater recharge.

Issues Micro level (Rachenahalli Lake)

The major issues are related to Rachenahalli lakes are pollution of the lake, Vegetation growth, and Mud lifting as shown in **Table 12.** List of Plans that have discussed so far about the water resources:

- Structure plan 2003 - BMRDA
- Bangalore master plan 2015 - BDA
- Lake development Authority report 2005

Conflicts in the Reviewed Policies/ Plan

According to Structure Plan 2003 under Policy GL16, urban and industrial development should be encouraged more in the Western segment rather than the Eastern segment of the BMR. The Southwestern arc from Hosur road to Nelamangala-Tumkur road has less of a water resource problem than the Northeastern segment of the BMR (refer **Figure 13**). Therefore,

Sl.No	Name of the Village	Area in Ha
1	Dasarahalli	30
2	Jakkur	15
3	Rachenahalli	8
	Total	**53**

Table 7: *Catchment of Rachenahalli lake.*
Source: *Lake Development Authority (LDA), 2010*

Water	Quantity
Evaporation/percolation	2.218 MLD
Runoff from catchment(850Ha)	2650.75 ML (Yr)
Flood Discharge	40.60

Table 8: *Water in catchment basin.*
Source: *Lake Development Authority (LDA) 2010*

Sl.No	Description	Area in Ha
1	Water	44.30
2	Weed/plant coverage	2.1
3	Land portion	1.0

Table 9: *Physical composition of Rachenahalli Lake.*
Source: *Lake Development Authority (LDA) 2010*

S.No	Structural features of Lake	
1	Catchment area	850.00 Ha
2	Maximum water spread area	44.35 Ha (51.86 Ha – area of lake)
3	Shoreline Length	4908.87 metres
4	Maximum Depth of the Lake	3.30 meters (1.7m average depth)
5	Number of Inlets & Outlets	Five Inlets (Two Inlet points) & Two Outlets
6	Volume of water	760.105 Million Litres (ML)
7	Main tank bund Level	886.334
8	Hydraulic retention time (HRT)	22 to 24 Hours
9	Length, Height, Width of Bund	539.04 m,3.30m, 4-5 m respectively
10	Freeboard	1.20 m
11	Sluice gate	Not operational

Table 10: *Physical composition of Rachenahalli Lake.*
Source: *Lake Development Authority (LDA) 2010*

with comprehensive water resource operational maintenance management measures, it is more able to sustain development at acceptable standards than the North Eastern segment. However, this policy was not followed in the development of the International airport in an area of poor groundwater level and in the proposal for two industrial centers in the Eastern segment.

The Bangalore International Airport is already working and neighbouring townships have been developed. But there is a scope for controlling the development of two industrial centers in the Eastern segment. For making such changes, the Bangalore Development Authority (BDA) should work with Bangalore Metropolitan Regional Development Authority (BMRDA). This will protect the groundwater depletion both in terms of quality and quantity.

Proposals for Improvement

After reviewing the analysis of the condition of lakes at the macro, meso and micro level, few proposals are made to improve the lakes' conditions and improve water quality of Bangaluru Metropolitan Area.

Landuse	Activity	Lake fringe area										
		Dhobighat	Animal Waste	Garbage Dumping	Boating	Swimming	Pleasure View	Restaurant	Construction Activity	Garbage Dumped	Hoad and Drainage	Chemical Use
Residential		8	9	10	1	2	4	6	3	10	6	7
Comercial								6		10	6	
Institutional								6			6	
Recreational			9	10	1		4	6	3		6	7
Lakes		8	9	10	1		4	6	3		6	7
Transportation				10								
Agriculture				10						10		7

Table 11: *Land use – activity analysis. Source: Primary survey by author.*

Magnitude of problem: 0 - 3 low magnitude, 3 - 6 Medium magnitude, 6 -10 High magnitudes

Type	Issues
Infrastructure	Solid wastes are disposed at East, West and South side of the lake and its drain.
Maintenance	Vegetation growth (Water Hyacinth) found near inlet covering 2.1 Ha in the area.
	Mud lifting are done is South Western area.
Encroachment	Informal sector encroaches into drain inlets.

Table 12: *Water in catchment basin.*
Source: *Lake Development Authority (LDA) 2010*

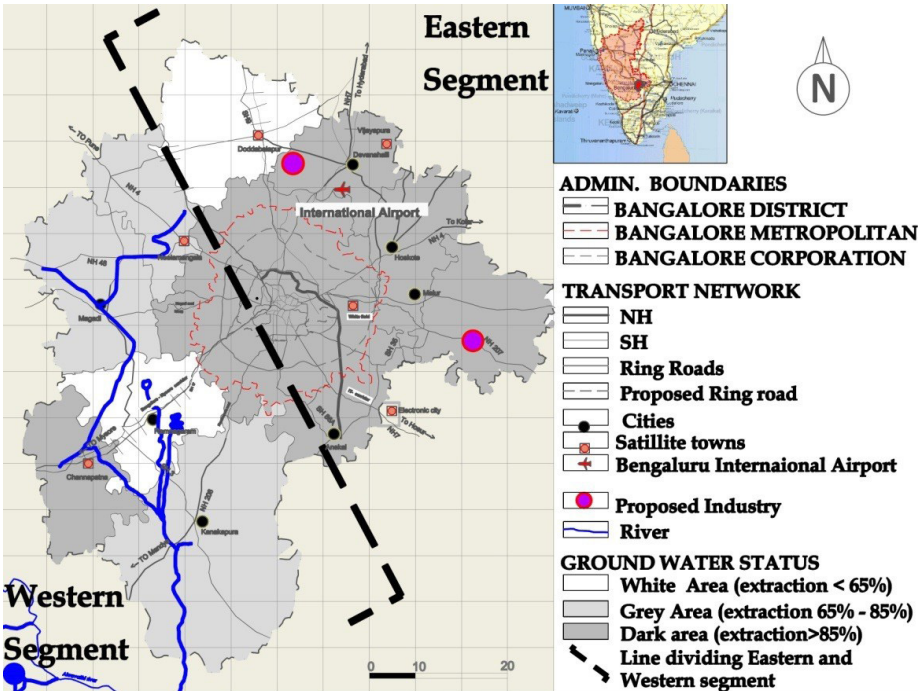

Figure 13: Map showing the conflict points of various plans and policies.
Source: BMRDA

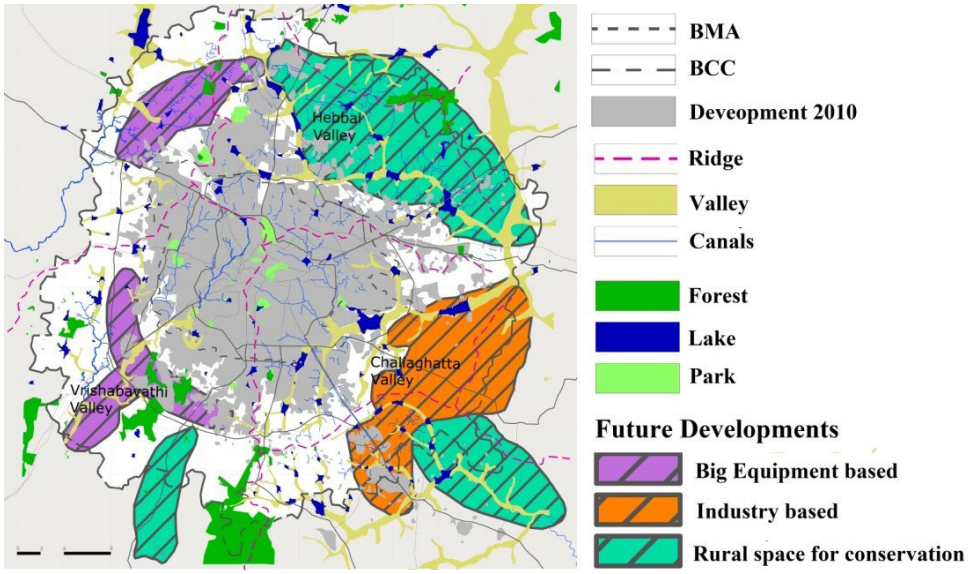

Figure 14: Map showing proposal at Bangalore Metropolitan areaSource: Bangalore Development Authority, 2005.

Macro Level (BMA)

The proposals with respect to above-mentioned issues are in sequence (refer **Figure 14**).

- Afforestation programs should be conducted by the forest department by finding a vacant area within the BMA limits and developing forest.
- The degraded forests are to be reforested by planting low water consuming trees which has commercial values.
- Proper measures are to be taken by the Lake Development Authority in restoring the degraded lakes. The lakes which are totally dried are to be converted into parks for groundwater recharge.
- Development of two proposed Industrial areas in the Eastern sector (high ground water extraction zone) should be relocated in western sector with TDR before construction.
- Eco fragile areas (North-eastern) of the Eastern sector should be conserved. Large-scale industrial development should be along the West side of BMA. IT townships development should be in South Eastern side of Bengaluru.

Meso Level (Hebbal Lake system)

1. Sewerage system with adequate capacity S.T.P is to be implemented by Bangalore water supply and Sewerage Board (BWSSB). Proper solid waste management systems are to be carried by Bengaluru Managara Palike (BMP). For current and future benefits, Special rules to be formulated to the sensitive catchment area (to be identified by further detailed study for developed area and undeveloped area). Industrial Effluent treatment plants are to be implemented by the industries.
2. Silt traps should be set up for Rampura lake inlet.
3. The Proper security system should be provided for Rachenahalli and Mathikere lakes.
4. No activities are to be permitted within 30M on the sides on any drain and informal sector are to be removed with R&R plans.

Micro level (Rachenahalli Lake)

1. Fencing of 4M around the lake is to be provided by Lake Development Authority (LDA). Sluice gates are to be provided for the lake inlet entry points.
2. Vegetation growth is to be cleared by LDA.
3. Lake gates and other security systems are to be improved.
4. No activities are to be permitted within 30M on the sides on Rachenahalli drains. ■

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