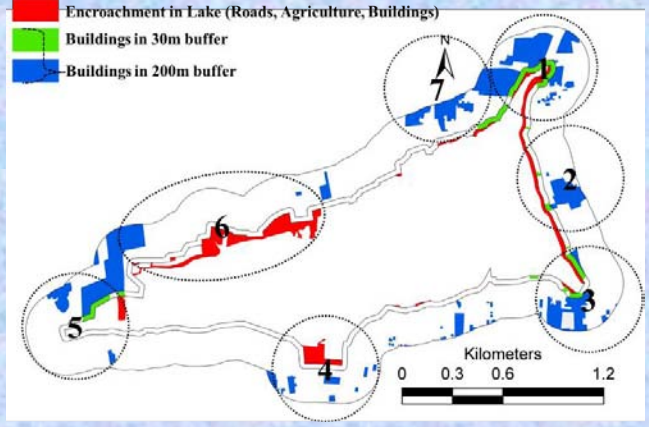
PATHETIC STATUS OF WETLANDS IN BANGALORE: EPITOME OF INEFFICIENT AND UNCOORDINATED GOVERNANCE

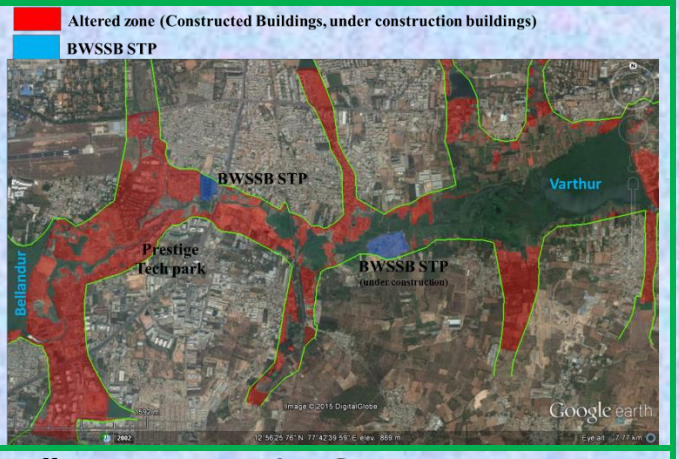
Froth

Fire

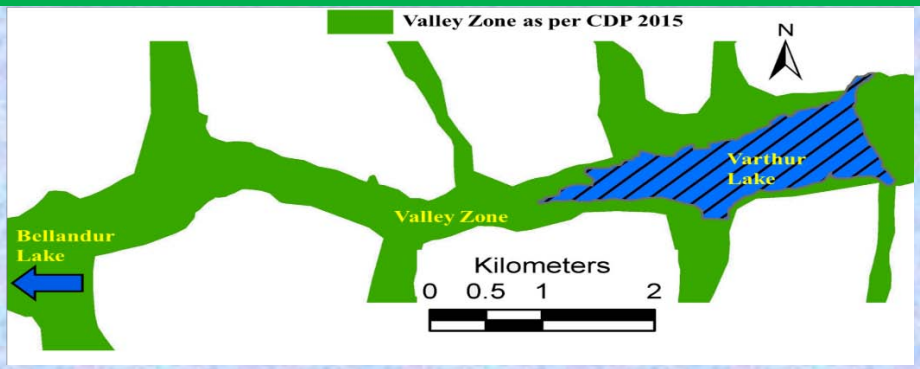
Ramachandra T V	Asulabha K S	Sincy V.	Vinay S
Bharath H Aithal	Sudarshan P.Bhat	Durga M. Mahapatra	



Violations in the lake bed and buffer zones



Valley Zone as per 2015 CDP



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PATHETIC STATUS OF WETLANDS IN BANGALORE: EPITOME OF INEFFICIENT AND UNCOORDINATED GOVERNANCE

Citizens of Bangalore allowed the development in the region with "utmost good faith".

- Contaminated air, land and water are the penalty citizens have to pay for exercising tolerance with good faith.
- Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity (insufficient water, clean air and water, inadequate electricity, traffic bottlenecks, etc.) and assimilative capacity (polluted water and sediments in water bodies, enhanced GHG – Greenhouse gases, etc.)
- There has been a 925% increase in built up area (concretisation, paved surfaces) in Bangalore from 1973 to 2013 with a sharp decline of 79% area in water bodies affecting the micro-climate, water availability, etc..
- Higher level of GHGs (Greenhouse gases) in the air environment, nutrient and heavy metal rich water bodies and land, highlight the penalty to be paid for allowing unplanned urbanisation.

Numerous para-state agencies with un-coordinated actions, inefficient regulatory agency and negligent industries have converted the garden city to unlivable city.

Solution is

"**Decongest and decontaminate Bangalore**"

so that at least next generation enjoys better environment in Bangalore

Need to ensure the ecosystem integrity to sustain goods and services for maintaining inter-generation equity.

Clean air, water and environment are the fundamental rights of citizens as per the Constitution of India (Article-21 of the *Indian Constitution*)

PATHETIC STATUS OF WETLANDS IN BANGALORE: EPITOME OF INEFFICIENT AND UNCOORDINATED GOVERNANCE

Executive Summary:

Wetlands (and lakes) constitute the most productive ecosystems with a wide array of goods and services. These ecosystems serve as life support systems; serve as habitat for a variety of organisms including migratory birds for food and shelter. They aid in bioremediation and hence aptly known as 'kidneys of the landscape'. Major services include flood control, wastewater treatment, arresting sediment load, drinking water, protein production, and more importantly recharging of aquifers apart from aiding as sinks and climate stabilizers. The wetlands provide a low cost way to treat the community's wastewater, while simultaneously functioning as wild fauna sanctuary, with public access. These ecosystems are valuable for education and scientific endeavours due to rich biodiversity.

Bangalore city (Karnataka State, India) has been experiencing unprecedented urbanisation and sprawl due to concentrated developmental activities in recent times with impetus on industrialisation for the economic development of the region. This concentrated growth has resulted in the increase in population and consequent pressure on infrastructure, natural resources and ultimately giving rise to a plethora of serious challenges such as climate change, enhanced green-house gases emissions, lack of appropriate infrastructure, traffic congestion, and lack of basic amenities (electricity, water, and sanitation) in many localities, etc. Temporal data analysis reveals that that there has been a growth of 925% in urban areas of Bangalore across four decades (1973 to 2013). Sharp decline in natural resources – 78% decline in trees and 79% decline in water bodies highlight unplanned urbanisation process in the city. Urban heat island phenomenon is evident from large number of localities with higher local temperatures. The city once enjoyed salubrious climate (about 14-16 °C during peak summer – May month in early 18th century), now has been experiencing higher temperatures (34 to 37° C) with altered micro climate and frequent flooding during rainy days. The study reveals the pattern of growth in Bangalore and its implication on local climate (an increase of ~2 to 2.5 ºC during the last decade) and also on the natural resources, necessitating appropriate strategies for the sustainable management of natural resources (water bodies, tree cover, etc.). The frequent flooding (since 2000, even during normal rainfall) in Bangalore is a consequence of the increase in impervious area with the high-density urban development in the catchment and loss of wetlands and vegetation.

Urban ecosystems are the consequence of the intrinsic nature of humans as social beings to live together (Ramachandra *et al.*, 2012; Ramachandra and Kumar, 2008). The process of urbanisation contributed by infrastructure initiatives, consequent population growth and migration results in the growth of villages into towns, towns into cities and cities into metros. 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. (Kulkarni and Ramachandra, 2006). Apart from this, major implications of urbanisation are:

- **Loss of wetlands and green spaces:** Urbanisation (925% concretisation or paved surface increase) has telling influences on the natural resources such as decline in green spaces (78% decline in vegetation) including wetlands (79% decline) and / or depleting groundwater table. Quantification of number of trees in the region using remote sensing data with field census reveal 1.5 million trees and human population is 9.5 million, indicating one tree for seven persons in the city. This is insufficient even to sequester respiratory carbon (due to breathing which ranges from 540 -900 g per person per day).
- **Floods:** Conversion of wetlands to residential and commercial layouts has compounded the problem by removing the interconnectivities in an undulating terrain. Encroachment of natural drains, alteration of topography involving the construction of high-rise buildings, removal of vegetative cover, reclamation of wetlands are the prime reasons for frequent flooding even during normal rainfall post 2000.
- **Decline in groundwater table:** Studies reveal the removal of wetlands has led to the decline in water table. Water table has declined to 300 m from 28 m over a period of 20 years after the reclamation of lake with its catchment for commercial activities. In addition, groundwater table in intensely urbanized area such as Whitefield, etc. has now dropped to 400 to 500m.
- **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.
- **Increased carbon footprint**: Due to the adoption of inappropriate building architecture, the consumption of electricity has increased in certain corporation wards drastically. The building design conducive to tropical climate would have reduced the dependence on electricity. Adoption of building architecture unsuitable for Bangalore climate has contributed to higher electricity consumption and hence higher GHG (Greenhouse gases). Per capita electricity consumption in the zones dominated by high rise building with glass facades require 14000-17000 units (kWh) per year compared to the zones with eco-friendly buildings (1300-1500 units/person/year)Higher energy consumption, enhanced pollution levels due to the increase of private vehicles, traffic bottlenecks have contributed to carbon emissions significantly. Apart from these, mismanagement of solid and liquid wastes has aggravated the situation.

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 blocked due to indiscriminate disposal of solid wastes. Encroachment of wetlands, floodplains, etc. obstructs flood-ways causing loss of natural flood storage.

THREATS FACED BY WETLANDS IN BANGALORE

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 (Ramachandra and Shwetmala, 2009). Vegetation has decreased by 32% (during 1973 to 1992), 38% (1992 to 2002) and 63% (2002 to 2010).

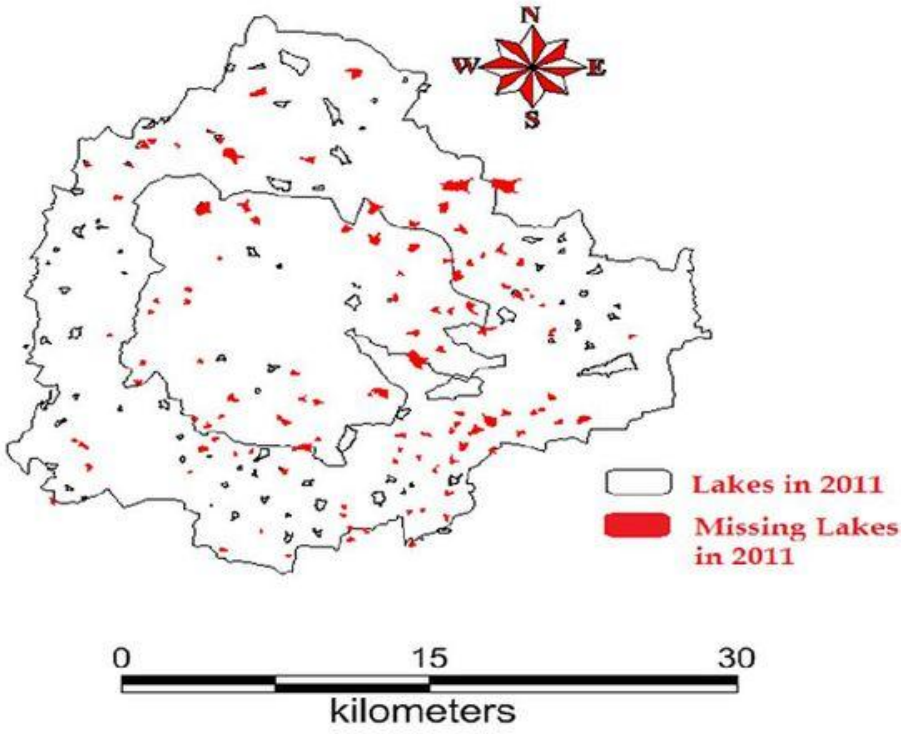


Figure 1: Lakes encroached by land mafia

Disappearance of water bodies or sharp decline in the number of water bodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Many lakes (54%) were encroached for illegal buildings. Field survey of all lakes (in 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 (Ramachandra, 2009a; 2012a). 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 water bodies. 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 water bodies. Some of the lakes have been restored by the city corporation and the concerned authorities in recent times. Threats faced by lakes and drainages of Bangalore:

1. Encroachment of lakebed, flood plains, and lake itself;
2. Encroachment of rajakaluves / storm water drains and loss of interconnectivity;
3. Lake reclamation for infrastructure activities;
4. Topography alterations in lake catchment;
5. Unauthorised dumping of municipal solid waste and building debris;
6. Sustained inflow of untreated or partially treated sewage and industrial effluents;
7. Removal of shoreline riparian vegetation;
8. Pollution due to enhanced vehicular traffic;
9. Too many para-state agencies and lack of co-ordination among them.
10. Different custodians for upstream and downstream lakes in the valley (Figure 2 and Table 1).

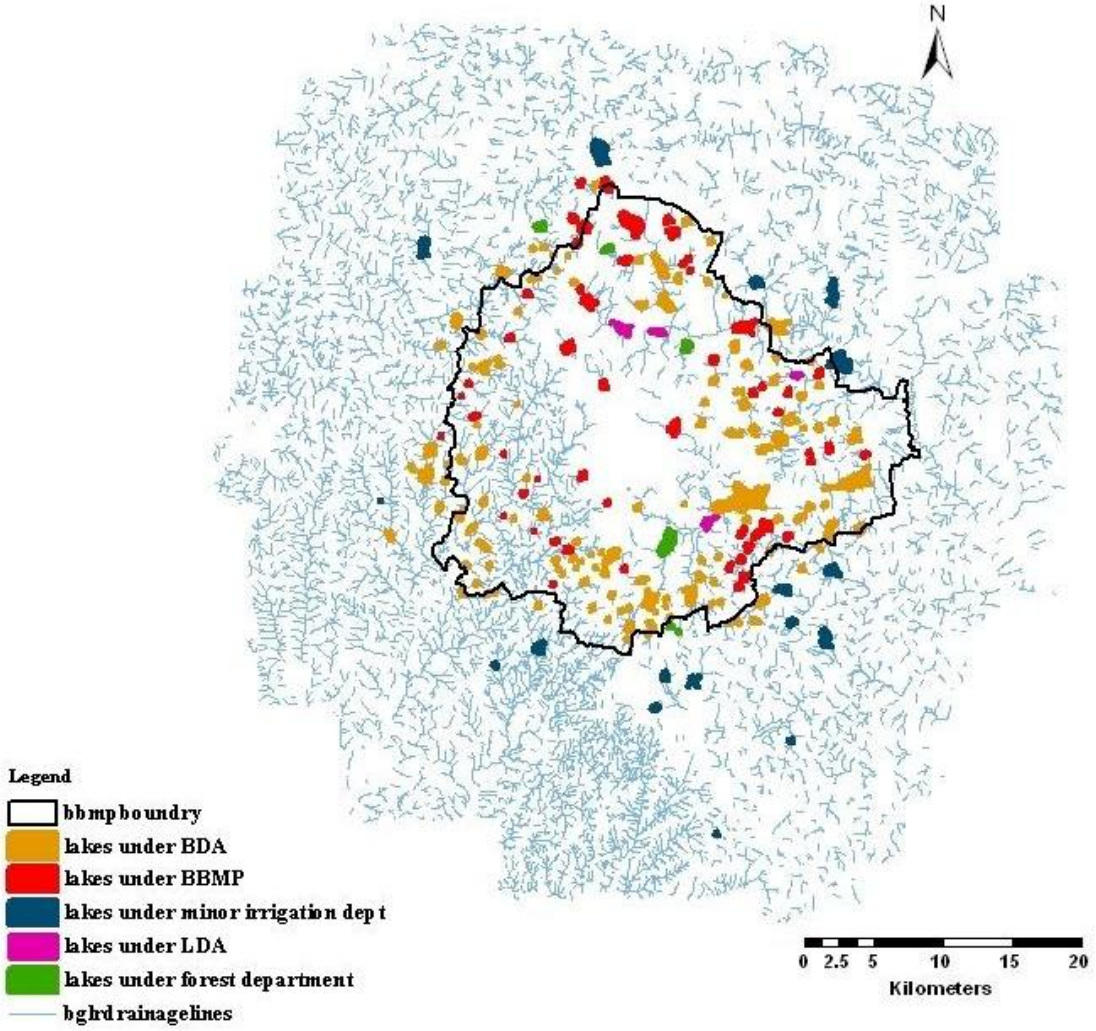


Figure 2: Spatial spread of lakes and custodians (too many – BBMP, BDA, LDA…. But too less effort to protect these lakes)

Table 1: Lakes with BBMP (A: Area in acres, G: Gunta, T: Total)

Sl.No	Name of the lake	Taluk	Hobli	Name of the village Survey No.	Extent (A-G) as per RTC
1	Agrahara Lake	B'lore North	Yelahanka	Agrahara -33	**15-34**
2	Allalasandra kere	B'lore North	Yalahanka	Allalsandra -15	**41-23**
3	Ambalipura Kelagina kere	B'lore East	Varthur	Ambalipura-40 & 41	3-0, 4-09 T-**7-09**
4	Amblipura Melinakere	B'lore East	Varthur	Ambalipura-36	**12-16**
5	Attur kere	B'lore North	Yalahanka	Attur kere-81 Ananthapura-92 Ramagondanahalli- 39 Kempanahalli-12	56-29 6-15 7-22 19-18 **T-90-04**
6	Avalahalli	B'lore North	Yalahanka	Avalahalli -10 & Singanayakanahalli 64	11-01 2-10 **T-13-11**
7	Bhimmana katte	B'lore South	Kengeri	Halagevaderahalli-138	1-23
8	Bayappanapalya Kunte (Munniyappana katte)	B'lore South	Uttarahalli	Vajarahalli -36	2-31
9	Challakere Lake	B'lore East	K.R. Puram	Challakere - 85	38-05
10	Chinnapanhalli kere	B'lore East	K.R. Puram	Chinnapanahalli 15 & 17	11-33 11-10
11	Chokkanahalli lake	B'lore North	Yelahanka	Chokkanahalli Sy-2	8-02
12	Dasarahalli kere (Chokkasandra)	B'lore North	Yeshwanthapura	Dasarahalli - 24 Chokkasandra - 5	3-29 24-04 **T-27-33**
13	Deepanjali kere	B'lore South	Kengeri	Devatige Ramanahalli-32	**7-22**
14	Devsandra kere	B'lore East	K.R. Puram	Devasandra 31	**16-08**
15	Doddabommasandra	B'lore North	Yelahanka	Dodda Bommasandra-56 Kodigehalli- 175 Thindlu - 53	39-10 49-21 35-28 **T-124-19**
16	Doddakanenahalli kere	B'lore East	Varthur	Doddakanenahalli - 109	**18-14**
17	Dore kere	B'lore South	Uttarahalli	Uttarahalli -22 Vasanthapura -06	19-11 '9-06 **T-28-17**
18	H Gollahalli Lake (Varahasandra Lake)	B'lore South	Kengeri	Kengeri Gollahalli-9 Varahasandra-9 Hemgepura-25	7-08 4-33 7-25 **T-19-26**
19	Halagevaderahalli Lake	B'lore South	Kengeri	Halagevaderahalli-1	**17-10**
20	Handrahalli	B'lore North	Yeshwanthapura	Handrahalli -8	**16-06**
21	Haraluru kere	B'lore East	Varthur	Haraluru-95	**34-70**
22	Herohalli	B'lore North	Yeshwanthapura	Herohalli-99	**34-33**
23	Harohalli lake	B'lore North	Yelahanka	Harohalli-91	**74-32**

24	Jogi kere	B'lore South	Uttarahalli	Mallasandra-30	**3-20**
25	J.P. Park (Mathikere)	B'lore North	Yeshwanthapura	Jalahalli-32 Mathikere-59 Thaniranahalli-01 Kasaba Yeshwanthpura-114	47-26 -- 20-39 -- **T-**
26	Kaikondanahalli kere	B'lore East	Varthuru	Kaikondanahalli -8 Kasavanahalli -70	18-18 30-05 **T-48-23**
27	Kalkere Agra kere	B'lore East	K.R. Puram & Bidarahalli	Kalkere-45 Kyalasanahalli-36 Beelisivale-101 & 106 Horamavu Agra-36	73-11 51-19 0-37 & 0-14 61-11 **T-187-12**
28	Kammagondanahalli	B'lore North	Yeshwanthapura	Kammagondanahalli-18 Shettyhalli-67 Myadarahalli (Medarahalli)-26	15-26 5-32 1-32 **T-23-10**
29	Kasavanhalli	B'lore East	Varthur	Kasavanahalli-50 Haralur-32	21-30 33-18 **T-56-08**
30	Kattiganahalli Kere-136	B'lore North	Jala	Kattiganahalli -136	**25-28**
31	Kattiganahalli Kere-31	B'lore North	Jala	Kattiganahalli -31	**20-10**
32	Kempambudhi Lake	B'lore North	B'lore	Kempambudhi-2	
33	Kodigehalli kere	B'lore North	Yeshwanthapura	Kodigehalli - 30	**9-25**
34	Kogilu Lake	B'lore North	Yelahanka Jala	Kogilu - 84 Kattigenahalli - 117	40-04 38-24 **T-78-28**
35	Koudenahalli kere	B'lore East	K.R. Puram	Koudenahalli -27	**55-05**
36	Kudlu Chikere	Anekal Taluk	Sarjapura	Koodlu-70	**13-05**
37	Kudlu doddakere	Anekal Talulk and B'lore South	Sarjapur & Begur	Koodlu-150 Parapanaagrahara-37	26-38 17-01 T-43-39
38	Kundalahalli Lake	B'lore East	K.R. Puram	Kundalahalli -05	30-20
39	Lingadiranahalli	B'lore North	Yeshwanthapura	Lingadiranahalli-2 & 4	5-32 4-08 **T-10-00**
40	Mahadevapura Lakde	B'lore East	K.R. Puram	Mahadevapura -7	26-23
41	Malgala kere	B'lore North	Yeshwanthapura	Malgala - 46	**6-26**
42	Munnekolalu kere	B'lore East	Varthur	Munnekolalu-25	**15-38**
43	Narasipura-20	B'lore North	Yelahanka	Narasipura-20	**15-30**
44	Narasipura-26	B'lore North	Yelahanka	Narasipura-26	**9-07**
45	Nayandanahalli kere	B'lore South	Kengeri	Nayadahalli -31	**15-18**
46	Parappana Agrahara	B'lore South	Beguru	Parappana Agrahara-23	**16-11**
47	Puttenahalli kere	B'lore South	Uttarahalli	Puttenahalli -42	**13-25**

48	Ramagondanahalli	B'lore North	Yelahanka	Ramagondanahalli-52	**36-26**
49	Sankey Tank	B'lore North	Vyalikaval	Vyalikaval - 21	35-00
50	Shilavantana kere	B'lore East	K.R. Puram	Whitefeild-41	19-32
51	Sigehalli	B'lore East	K.R Puram	Sigehalli-32	31-13
52	Singasandra Lake	B'lore South	Begur	Basapura-15 Singasandra -52	9-34 1-08 **T-11-02**
53	Sowl kere	B'lore East	Varthur	Bellandur-65 Doddakanelli-68 Kaigondanahalli-36	23-33 7-28 30-16 **T-61-37**
54	Thirumenahalli	B'lore North	Yelahanka	Thirumenahalli-63	7-10
55	Ulsoor	B'lore North	B'lore	Ulsoor	
56	Uttarahalli kere (Mogekere)	B'lore South	Uttarahalli	Uttarahalli -111	**15-16**
57	Veerasagara lake	B'lore North	Yelahanka	Veerasagara-26 Attur-25	'17-24 3-30 **T-21-14**
58	Vijanapura kere	B'lore East	K.R. Puram	Kowdenahalli -85 Krishnarajpura-97	11-28 2-07 **T-13-35**
59	Yediyur Lake	B'lore South	Utharahalli	Dasarahalli -01 Yediyur -59	No extent
60	Yelahanka kere (Kasaba Amanikere)	B'lore North	Yelahanka	Yelahanka-29 Kenchenahalli -15 Venkatala-39 Manchenahalli-19 Puttenahalli-49	53-36 30-23 199-31 7-34 18-04 **T-310-08**

Lakes with BDA

Sl. No.	**Name of the Lake**	**Taluk**	**Hobli**	**Name of the village Sy No.**	**Extent (A-G) as per RTC**
1	Abbigere kere	B'lore North	Yeshwanthpur	Abbigere-75 Singapura-95	26-06 21-7 **T-47-13**
2	Alahalli kere / Anjanapura	B'lore South	Uttarahalli	Allahalli -30 Gollahalli-3	15-35 5-30 **T-21-25**
3	Amruthalli kere	B'lore North	Yelahanka	Amruthalli-115	**24-36**
4	Annappahalli/ Yelachenahalli Lake	B'lore South	Uttarahalli	Yelachenahalli-06, Govinayakanahalli-14	4-39 1-33 **T-6-32**
5	Arakere	B'lore South	Beguru	Arakere-34	**37-21**
6	Avalahalli	B'lore North	Yelahanaka	Avalahalli-10 Shiganayakanahalli-64	11-01 2-10 **T-13-11**

7	B.Narayanapura	B'lore East	K.R. Puram	B.Narayanapura-109	15-06
8	Baiyappanahalli kere	B'lore East	K.R. Puram	Baiyappanahalli-61	8-09
9	Basapura Lake-2	B'lore South	Beguru	Basapura-66	10-29
10	Basavanapura Lake	B'lore South	Beguru	Basavanapura-14	**7-34**
11	Begur Lake	Bl'lore South	Begur	Begur-94	**137-24**
12	Bellahalli	B'lore North	Yelahanka	Bellahalli-68	**18-32**
13	Bellandur	B'lore East	Varthur	Yamaluru-62 Amanikere Bellandur Kahne-1 Ibbalur-12 Kempapura-6 Beluru-2	3-04 284-20 399-14 13-15 2-00 **T-700-13**
14	Beratena Agrahara Lake (Chowdeshwari Layout	B'lore South	Begur	Beratena Agrahara (Chowdeshwari)-18	**11-18**
15	Bhattralli kere	B'lore East	Bidarahalli	Bhattralli-2	**18-10**
16	Bheemanakuppe	B'lore South	Kengeri	Bheemanakuppe-180	75-15
17	Bhoganalli kere	B'lore East	Varthur	Bhoganalli-21	12-24
18	Byrasandra	B'lore South	Utharahalli	Byrasandra-56	15-11
19	Byrasandra kere (Chikkepet) (Melinakere)	B'lore East	K.R. Puram	Byrasandra-109	14-19
20	Chennasandra-2	B'lore East	K.R. Puram	Banasawadi-211	47-38
21	Chikka Banavara	B'lore North	Yeshwanthpur	Chikka Banavara-3, Somashettyhalli-73, Kere gullada halli-22 and Ganigarahalli-11,15	67-38 3-21 26-32 4-14 2-30 **T-105-15**
22	Chikka Bellandur kere	B'lore East	Varthur	Chikka Bellandur-9 Mullur -63	67-14 8-07 **T-75-21**
23	Chikkabasavanapura kere	B'lore East	K.R. Puram	Basavanapura-14	14-07
24	Chikkabasthi	B'lore South	Kengeri	Ramasandra-6	7-06
25	Chikkabettahalli	B'lore North	Yelahanka	Chikkabettahalli-52	1-32
26	Chick begur Lake	B'lore South	Begur	Begur-168, Singanadra-86	32-19 9-37 **T-42-16**
27	Chikkammanahalli Lake	B'lore South	Begur	Kammanahalli -22 Vamadevanahalli-	5-19
28	Chikkegowdana palya Lake	B'lore South	Kengeri	Hemmagepura-92	
29	Chunchanaghatta	B'lore South	Utharahalli	Chunchanaghatta-70, 70/2, 70/3	20-31 1-0 1-0 **T-22-31**

30	Chowdeshwari Layout Lake	B'lore South	Begur		
31	Devarakere Lake	B'lore South	Uttarahalli	Bikasipura-9	7-15
32	Doddabidarakallu	B'lore North	Yeshwanthpur	Doddabidarakallu-125 Nagasandra -06	23-21 16-36 **T-40-17**
33	Doddakallasandra	B'lore South	Uttarahalli	Doddakallasandra-27	**21-16**
34	Doddanakundi	B'lore East	K.R. Puram (village map) Varthur (In RTC-Bhoomi)	Doddanekundi -200 Kaggadasapura - 25 Vibhutipura -13	56-39 75-16 3-15 **T-135-30**
35	Dubasipalya Lake	B'lore South	Kengeri	Valagerehalli-43, 43/P1	23-35 1-0 **T-24-35**
36	Gangasetty kere (Diesel shed kere (Gangadhariahnakere) (Dyavasandrakunte kere)	B'lore East	K.R. Puram	KR Pura-58 Devasandra-46	18-32 2-35 **T-21-27**
37	Gandhinagara Lake	B'lore North			
38	Garudachar Palya Kere -1 (Achanakere)	B'lore East	K.R. Puram	Mahadevapura-31	**5-36**
39	Garudachar Palya Kere -2 (Goshala) Yekkalagatta kere	B'lore East	K.R. Puram	Mahadevapura-86	**5-14**
40	Garvebhavi Palya	B'lore South	Begur	Hongasandra -41	**18-04**
41	Gattigere palya Lake	B'lore South	Kengeri	Somapura-27/53	0-37
42	Gottigere Lake	B'lore South	Uttarahalli	Gottigere-71	**37-13**
43	Gowdana Palya Lake	B'lore South	Uttarahalli	Kadirenahalli-33	**9-30**
44	Gubbalala	B'lore South	Uttarahalli	Gubbalala-25 Vajarahalli-	**8-10**
45	Gunjur Kere (Carmelarm)	B'lore East	Varthur	Gunjur-95	**9-17**
46	Gunjur Mouji kere	B'lore East	Varthur	Gunjur-301, Kachamaranhalli-74	59-13 4-26 **T- 63-39**
47	Gunjur Palya kere	B'lore East	Varthur	Gunjur-83	**36-27**
48	Haralakunte Lake (Somasandrakere)	B'lore South	Begur	Haralakunte-51	**16-29**
49	Hoodi kere (GIDDANA KERE)	B'lore East	K.R. Puram	Hoodi-138	**28-31**
50	Hoodi kere -1	B'lore East	K.R. Puram	Hoodi-79	**15-10**
51	Horamavu Agara	B'lore East	K.R. Puram	Horamavu Agra-77	**51-34**
52	Horamavu kere	B'lore East	K.R. Puram	Horamavu-83	**37-14**
53	Hosakerehalli	B'lore South	Uttarahalli	Hosakerehalli-15	**59-26**
54	Hosakere	B'lore South			
55	Hulimavu	B'lore South	Beguru	Hulimavu-42 Kammanahalli -110	124-25 5-32 **130-17**
56	Ibbalur Lake	B'lore South	Beguru	Ibbalur-36	18-06

57	Jakkur & Sampigehalli	B'lore North	Yelahanka	Jakkur-15, 23 Yalahanka Amanikere-55 Sampigehalli-12 Agrahara-13	39-21,36-33 58-16 19-25 3-17 **T-157-32**
58	Jaraganahalli/Sarakki/Puttenahalli Lake	B'lore South	Uttarahalli	Jaraganahalli-7 Sarrakki-26 Puttenahalli - 5 Kothanuru-103 Chunchaghatta-28	38-14 38-0 6-10 11-21 13-07 **T-107-12**
59	Jimkenalli kere	B'lore East	Bidarahalli	Varanasi-47	**8-24**
60	Junnsandra kere	B'lore East	Varthur	Junnasandra-32	**24-33**
61	Kadirenapalya kere	B'lore East	KR Puram	Binnamangala-99	
62	K R Puram (BEML) Bendiganahalli kere	B'lore East	K.R. Puram	Benniganahalli-47 & 55	18-24, 27-14 **T- 45-39**
63	Kaggadasanapura	B'lore East	K.R. Puram (village map) Varthur (In RTC-Bhoomi)	Byrasandra -5 Kaggadasapura-141 Bendiganahalli - 24/3	14-24 32-16 3-26 **T-51-26**
64	Kalena Agrahara Lake	B'lore South	Begur	Kalena Agrahara-43	**7-30**
65	Kalkere Rampura kere	Anekal Taluk (B'lore East)	Jigani Bidarahalli	Kalkere-162 Rampura-22 Maragondanahalli-71 Huvineane-86	64-25 3-04 11-35 108-07 **T-187-31**
66	Kalyani / Kunte (Next to Sai Baba Temple)	B'lore South	Uttarahalli	Vasanthpura-21	**1-33**
67	Kannenahalli	B'lore North (Bng South)	Kengeri Yeshwanthpur		
68	Kelagina kere / Byrasandra	B'lore East	K.R. Puram	Byrasandra-112	**12-21**
69	Kembatha halli	B'lore South	Uttarahalli	Kembathahalli-3 Kathnuru-32/3	5-16 1-33 **T-7-20**
70	Kenchanapura	B'lore South	Kengeri	Kenchanapura-10	**17-20**
71	Kengeri Lake	B'lore South	Kengeri	Kengeri-15, Valagerehalli-85	27-03 5-13 **T-32-16**
72	Kommaghatta	B'lore South	Kengeri	Komaghatta-03 Ramasandra-46	9-04 28-01 **T-37-05**
73	Konankunte	B'lore South	Uttarahalli	Konanakunte - 2	**09-18**

74	Konasandra	Anekal Taluk	Jigani	Dyavasandra-9 Bommandahalli-18 Konasandra-17	21-13 7-39 3-20 **T-32-32**
75	Konnappana agrahara	B'lore South	Begur	Naganathpura (South)81	**5-17**
76	Kothnur	B'lore South	Utharahalli	Kothnur-54	**18-09**
77	Lakshmipura lake	B'lore North	Yeshwanthpur	Lakshmipura-25	**10-06**
78	Lingadheeranahalli	B'lore South	Kengeri	Lingadheeranahalli-13	**5-22**
79	Madavara	B'lore North	Dasanapura Yeshwanthpur	Madavara -48 Chikkabidarakallu-21 Tirumalapura-32 (from Yeshwanthpura hobli) Doddabidarakallu -98 (From Yeshwanthpura hobli	35-31 20-20 8-36 2-39 **T-68-06**
80	Mahadevapura (Bandemahadevpura kere)	B'lore East	K.R. Puram	Mahadevapura-187	**13-11**
81	Mallasandra Gudde lake	B'lore North	Dasanapura	Mallasandra-49, Mallasandra-50	11-28 5-23 **T-17-11**
82	Mallathahalli	B'lore North	Yeshwanthpur	Mallathahalli-101 Giddadakonenahalli-6	50-38 20-08 **T-71-06**
83	Manganahalli	B'lore North	Yeshwanthpur	Manganahalli - 43	**6-22**
84	Medi Agrahara	B'lore North	Yelahanka	Medi Agrahara-33	**13-15**
85	Meenakshi Kere	B'lore South	Begur	Kammanahalli (Meenakshi)-38	**18-37**
86	Mesthripalya Lake	B'lore South	Begur	Jakkasandra- 30	11-21
87	Nagarabhavi	B'lore North (Bng South)	Yeshwanthpur	Nagarabhavi-17	**17-39**
88	Nagareshwara-Nagenahalli Lake	B'lore East	K.R. Puram	Nagareshwara-Nagenahalli -10	11-08
89	Nellagaderanahalli	B'lore North	Yeshwanthpur	Nallagaderanahalli - 62	19-22
90	Nalluralli tank	B'lore East	K.R. Puram	Nalluralli-4 Pantandur Agrahara-85	20-34 27-05 **T-47-39**

91	Narasappanahalli	B'lore North	Yeshwanthpur	Karivabanahalli-40 Nelagadiranahalli - 90 Nelagadiranahalli -89 Doddabidarakallu - 24	27-13 19-05 5-26 1-20 **T-53-24**
92	Nyanappanahalli Lake	B'lore South	Begur	Begur-344	**6-07**
93	Panathur kere -38	B'lore East	Varthur	Panathur - 38	**27-17**
94	Panathur kere -48	B'lore East	Varthur	Panathur - 48	**6-30**
95	Pattandur Agrahara	B'lore East	K.R. Puram	Pattandur Agrahara-124	**16-35**
96	Pattandur Agrahara	B'lore East	K.R. Puram	Pattandur Agrahara-54	12-37
97	Pattanagere Kenchenhalli	B'lore South		Kenchenahalli-33 Pattanagere-43	3-39 0-31 **T-4-30**
98	Rachenahalli	B'lore North B'lore East	Yelahanka K.R Puram	Dasarahalli-61 (Bng East- KR Puram) Jakkur - 82 (Bng North-Yelahanka) Rachenahalli - 69 (Bng East-KR Puram)	73-23 39-07 18-16 **T-131-06**
99	Ramsandra (Hirekere)	B'lore South B'lore North	Kengeri Yeshwanthpur	Ramasandra-159 Kenchanpura-36/* Kenchenapura - 36/¥ÉÊQ Kannahalli-37 (Bng north-Yeshwanthpura)	66-20 56-05 5-0 12-29 **T-140-14**
100	Sadaramangala kere	B'lore East	K.R. Puram	Sadaramangala-61, Kodigehalli-8	51-04 1-17 **T-52-21**
101	Shivanahalli	B'lore North	Yelahanka	shivanahalli-48 Allalasandra-38, 48	14-30 3-22 0-27 **T-18-39**
102	Siddapura kere	B'lore East	Varthur	Siddapura -18	**27-38**
103	Singapura Kere	B'lore North	Yelahanka	Singapura-102	**66-18**
104	Singasandra	B'lore South	Beguru	Singasandra -99, 100	10-14 0-34 **T-11-08**
105	Sitaram Palya	B'lore East	K R Puram	Sonnenahalli (Seetharmapalya)-33	**23-37**
106	Sompura	B'lore South	Kengeri	Sompura - 11	17-38
107	Srigandadakaval (near Rajivgandhi nagar)	B'lore North	Yeshwanthpur	Srigandakavalu-15	**6-33**

108	Srinivasapura Kere	B'lore North	Yelahanaka	Srinivasapura-2	**3-14**
109	Subbarayanakere	B'lore South	Uttarahalli	Gottigere-12	**5-10**
110	Subedeharanakere	B'lore South	Begur	Begur-48	**6-05**
111	Subramanyapura Lake	B'lore South	Uttarahalli	Uttarahalli-64	**18-06**
112	Sulekere (Soolikere)	B'lore South	Kengeri	Maragondanahalli Krishnasagara	
113	Swarnakunte gudda kere	B'lore South	Begur	Chandrashekarpura-1	**09-05**
114	Talaghattapura (Gowdarakere)	B'lore South	Uttarahalli	Talaghattapura -73	**19-16**
115	Ullal	B'lore North	Yeshwanthpur	Ullal-93	**24-12**
116	Vaderahalli	B'lore North	Yelahanka	Vaderahalli-32	**9-34**
117	Varahasandra Lake	B'lore South	Kengeri	Hemigepura-4, Varahasandra-24	4-11 13-09 **T-17-20**
118	Varthur	B'lore East	Varthur	Varthur-319	**445-14**
119	Vasanthapura (Janardhanakere)	B'lore South	Utharahalli	Vasanthpura-28	**7-10**
120	Venkateshpura	B'lore North	Yelahanka	Ventateshpura-12 Sampigehalli-37	6-35 11-29 **T-18-24**
121	Vibhuthipura kere	B'lore East	Varthur	Vibhuthipura-175	**45-18**
122	Vishwa nidam lake	B'lore North	Yeshwanthpur	Herohalli-50	**4-30**
123	Yellenhalli Lake (Elenahalli)	B'lore South	Begur	Yellenhalli-55	**4-39**

Lakes under Lake Development Authority (LDA)

Sl.No	Name of the Lake	Taluk	Hobli	Name of the village Sy No.	Extent (A-G) as per RTC
1	Agaram Lake	B'lore South	Kengeri	Agara-11 Venkojiraokhane-11	5-39 136-30 **T-142-29**
2	Hebbal Lake	B'lore North	Kasaba	Hebbla-38 Kodigehalli-37	92-26 99-33 **T-192-19**
3	Nagavara Lake	B'lore North	Kasaba	Nagawara-58 Vishwanatanagenahalli - 12,13	56-17 12-35 6-01 **T-75-13**
4	Vengaiahnakere	B'lore East	K.R. Puram	Krishnarajapura-9 Sannathammanahalli-46	38-12 26-23 **T-64-35**

Lakes - Karnataka Forest Department

Sl.No	Name of the Lake	Taluk	Hobli	Name of the village Sy No.	Extent (A-G) as per RTC
1	Hennur (K.R.Puram Range)	B'lore North	Kasaba	Hennur - 53 Nagawara - 13	58-30 14-11 **T-73-01**

2	J.B.Kaval Tank (Bangalore Range)	B'lore North	Yelahanka	Jyarakabande Kavalu- P1-36	44-21 2-04
3	Madiwala (K.R.Puram Range)	B'lore South	Begur	Madivala- 7 Kodichikkanahalli-23 Belekannahalli-64 Rupena Agrahara-11	166-39 80-09 21-35 6-10 T-275-13
4	Mylsandra (Kaggalipura Range) Gumaiahanakere (Mylasandra 1) Mylasandra 2	B'lore South	Kengeri	Mylasandra-37 Kasaba Kengeri-58 Mylasandra - 27 Kasaba Kengeri-66	6-24 6-02 **T-12-26** 10-14 5-28 **T-16-02**
5	Puttenahalli (Yelahanka Range)	B'lore North	Yelahanka	Puttenehalli - 36 Attur - 49	29-14 7-26 **T-37-00**

Lakes - Minor Irrigation Department

Sl.No	Name of the Lake	Taluk	Hobli	Name of the village Sy No.	Extent (A-G) as per RTC
1	Agara kere	Bangalore South	Kengeri	Agara - 103 Agara -102 Agara - 104	13-11 0-08 0-06 **T-13-25**
2	Alluru kere	Bangalore North	Dasanapura	Aluru-132 Vaderahalli - 8 Mathahalli - 25 Narasipura - 41	39-38 27-23 5-32 1-21 **T-75-34**
3	Bhimanakuppe kere	Bangalore South	Kengeri	Bheemanakuppe-180	75-15
4	Bidara Amanikere	Anekal			
5	Bidarahalli kere	Bangalore East	Bidrahalli	Bidarahalli-8 Byappanahalli - 21	15-10 81-16 **T-96-26**
6	Chikkanahalli	Bangalore East			
7	Doddagubbi kere	Bangalore East	Bidarahalli	Doddagubbi-38 NadagowdaGollahalli-39 Chikkagubbi-9	105-18 16-37 1-32 **T-124-07**
8	Ghattahalli Bommankere	Anekal	Sarjapura	Gattahalli-62 Rayasandra - 33	51-17 21-22 **T-72-39**
9	Hoskuru kere (Huskur Lake)	Anekal	Sarjapura	Huskur - 163 Harohalli - 51 Avalahalli - 50	91-10 23-0 --- T-114-10
10	Hulimangala Doddakere	Anekal	Jigani	Hulimangala - 22	67-07

11	Kodatikere	Bangalore East	Varthru	Kodati-8 Solikunte - 52	40-32 37-09 T-78-01
12	Margondanahalli kere	Bangalore South	Kengeri	Margondanahalli -45	5-33
13	Rampura kere	Bangalore East			
14	Sakalavara Bujangadasana kere	Anekal	Jigani	Sakalavara - 93	23-34
15	Singanayakana halli kere	Bangalore North			
16	Singena Agrahara kere	Anekal	Sarjapura	Singena Agrahara-94 Narayanaghatta - 128 Gottammanahalli - 13	95-39 19-32 8-04 **T-123-35**
17	Vaderahalli kere	Bangalore South	Kengeri	B.M.Kaval P1 -136	21-07
18	Yellemallappa Shetty kere	Bangalore East	K.R. Puram	Avalahalli -57 Avalahalli -12 Heerandahalli - 95 Heerandahalli -96 Kurudu Sonnenahalli -2 Medahalli -63 Veerenahalli -29	13-26 17-26 170-16 33-24 31-2 91-35 132-06 **T-490-15**

Source: https://www.karnataka.gov.in/ldakarnataka/documents/Listof-210Lake-BDA,BBMP,LDA, KFD, MILIst.xlsx

The anthropogenic activities particularly, indiscriminate disposal of industrial effluents and sewage wastes, dumping of building debris have altered the physical, chemical as well as biological integrity of the ecosystem. This has resulted in the ecological degradation, which is evident from the current ecosystem valuation of wetlands. Global valuation of coastal wetland ecosystem shows a total of 14,785/ha US$ annual economic value. Valuation of relatively pristine wetland in Bangalore shows the value of Rs. 10,435/ha/day while the polluted wetland shows the value of Rs.20/ha/day (Ramachandra et al., 2005). In contrast to this, Varthur, a sewage fed wetland has a value of Rs.118.9/ha/day (Ramachandra et al., 2011). The pollutants and subsequent contamination of the wetland has telling effects such as disappearance of native species, dominance of invasive exotic species (such as African catfish, water hyacinth, etc.), in addition to profuse breeding of disease vectors and pathogens. Water quality analyses revealed of high phosphates (4.22-5.76 ppm) levels in addition to the enhanced BOD (119-140 ppm) and decreased DO (0-1.06 ppm). The amplified decline of ecosystem goods and services with degradation of water quality necessitates the implementation of sustainable management strategies to recover the lost wetland benefits.

Conservation and Management of Wetlands:

In recent years, there has been concern over the continuous degradation of wetlands due to unplanned developmental activities (Ramachandra, 2002)**.** Urban wetlands are seriously threatened by encroachment of drainage through landfilling, pollution (due to discharge of

domestic and industrial effluents, solid wastes dumping), hydrological alterations (water withdrawal and inflow changes), and over-exploitation of their natural resources. This results in loss of biodiversity of the wetland and loss of goods and services provided by wetlands (Ramachandra, 2009). The mitigation of frequent floods and the associated loss of human life and properties entail the restoration of interconnectivity among wetlands, restoration of wetlands (removal of encroachments), conservation and sustainable management of wetlands (Ramachandra et al., 2012).

Despite good environmental legislations, loss of ecologically sensitive wetlands is due to the uncoordinated pattern of urban growth happening in Bangalore. Principal reason is lack of good governance and decentralized administration evident from lack of coordination among many Para-state agencies, which has led to unsustainable use of the land and other resources. Failure to deal with water as a finite resource is leading to the unnecessary destruction of lakes and marshes that provide us with water. This failure in turn is threatening all options for the survival and security of plants, animals, humans, etc. There is an urgent need for:

- **Restoring and conserving the actual source of water -** the water cycle and the natural ecosystems that support it - are the basis for sustainable water management
- **Reducing the environmental degradation that is preventing us from reaching goals** of good public health, food security, and better livelihoods world-wide
- **Improving the human quality of life** that can be achieved in ways while maintaining and enhancing environmental quality
- **Reducing greenhouse gases to avoid the deleterious effects of climate change** is an integral part of protecting freshwater resources and ecosystems.
- **Maintaining intergeneration Equity**

A comprehensive approach to water resource management is needed to address the myriad water quality problems that exist today from non-point and point sources as well as from catchment degradation. Watershed-based planning and resource management is a strategy for more effective protection and restoration of aquatic ecosystems and for protection of human health. The watershed approach emphasizes all aspects of water quality, including chemical water quality (e.g., toxins and conventional pollutants), physical water quality (e.g., temperature, flow, and circulation), habitat quality (e.g., stream channel morphology, substrate composition, riparian zone characteristics, catchment land cover), and biological health and biodiversity (e.g., species abundance, diversity, and range). The suggestions to implement in lakes in order to maintain its healthy ecosystem include:

- ❖ Good governance (too many para-state agencies and lack of co-ordination) - Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance) and action against polluters (encroachers as well as those let untreated sewage and effluents, dumping of solid wastes).
- ❖ De-congest Bangalore: Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity (insufficient water, clean air and water, electricity, traffic bottlenecks, etc.) and assimilative capacity (polluted water and sediments in water

bodies, enhanced GHG – Greenhouse gases, etc.). No new projects shall be sanctioned and the emphasis would be on increasing green cover and restoration of lakes.

- Disband BDA – creation of Bangalore Development Agency has given impetus to inefficient governance evident from Bangalore, the garden city turning into 'dead city' during the functional life of BDA.
- Digitation of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query option (Spatial Decision Support System) to public.
- Comprehensive development plan (CDP) for the city has to be developed through consultative process involving all stakeholders and should not be outsourced to outside agencies / consultants (from other countries).
- Removal of encroachment near to lakes after the survey based on reliable cadastral maps;
- Effective judicial system for speedy disposal of conflicts related to encroachment;
- Apply principles of 'polluter pays' principle to agencies responsible for contamination of Bangalore surface and ground water (Agency: BWSSB, industries);
- Action against regulatory agency (KSPCB) for dereliction of statutory duties and other responsibilities by allowing sustained contamination of water, land and air;
- Restriction of the entry of untreated sewage into lakes;
- To make land grabbing cognizable non-bailable offence;
- Letting off only treated sewage into the lake through constructed wetlands and shallow algae ponds (as in Jakkur lake);
- Regular removal of macrophytes in the lakes;
- Implementation of 'polluter pays' principle as per water act 1974;
- Plant native species of macrophytes in open spaces of lake catchment area;
- Stop solid wastes (municipal and demolition debris) dumping into lakes; treatment and management of solid waste shall be as per MSW Rules 2000, GoI.
- Ensure proper fencing of lakes
- Restrictions on the diversion of lake for any other purposes;
- Complete ban on construction activities in the valley zones;
- Monitoring of lakes through network of schools and colleges;
- Mandatory environment education at all levels (schools and colleges including professional courses).

Wetlands in Bangalore are to be restored considering:

Activities around lakes	**Norms to protect and conserve Wetlands**
Encroachment of lake bed and loss of interconnectivity among lakes	The Hon'ble Supreme Court in Civil appeal number 1132/2011 at SLP (C) 3109/2011 on January 28,2011 has expressed concern regarding encroachment of common property resources, more particularly lakes (and raja kaluves) and it has directed the state governments for removal of encroachments on all community lands.

	Eviction of encroachment: Need to be evicted as per Karnataka Public Premises (eviction of unauthorised occupants) 1974 and the Karnataka Land Revenue Act, 1964
Buildings in the buffer zone of lakes	In case of water bodies, a 30.0 m buffer of 'no development zone' is to be maintained around the lake (as per revenue records) • As per BDA, RMP 2015 (Regional Master Plan, 2015) • Section 17 of KTCP (Karnataka Town and Country Planning) Act, 1961 and sec 32 of BDA Act, 1976 • Wetlands (Conservation and Management) Rules 2010, Government of India; Wetlands Regulatory Framework, 2008.
Construction activities in the valley zone (SEZ by Karnataka Industrial Areas Development Board (KIADB)) **in the valley zone**	This is contrary to sustainable development as the natural resources (lake, wetlands) get affected, eventually leading to the degradation/extinction of lakes. This reflects the ignorance of the administrative machinery on the importance of ecosystems and the need to protect valley zones considering ecological function and these regions are 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015
Alterations in topography	Flooding of regions would lead to loss of property and human life and, spread of diseases.
Increase in deforestation in catchment area	Removing vegetation in the catchment area increases soil erosion and which in turn increases siltation and decreases transpiration
Documentation of biodiversity	• The biodiversity of every water body should form part of the School, College, People's Biodiversity Registers (SBR, CBR, PBR). • The local Biodiversity Management Committees (BMC) should be given necessary financial support and scientific assistance in documentation of diversity. • The presence of endemic, rare, endangered or threatened species and economically important ones should be highlighted • A locally implementable conservation plan has to be prepared for such species
Implementation of sanitation facilities	• The lakes are polluted with sewage, coliform bacteria and various other pathogens • Preserving the purity of waters and safeguarding the biodiversity and productivity, dumping of waste has to be prohibited • All the settlements alongside the water body should be provided with sanitation facilities so as not to impinge in anyway the pristine quality of water

Violation of regulatory and prohibitory activities as per Wetlands (Conservation and Management) Rules, 2010; Regulatory wetland framework, 2008	Environment Impact Assessment (EIA) Notification, 2009. **Wetlands (Conservation and Management) rules 2010, Government of India; Regulatory wetland framework, 2008** **Regulated activity** • Withdrawal of water/impoundment/diversion/interruption of sources • Harvesting (including grazing) of living/non-living resources (may be permitted to the level that the basic nature and character of the biotic community is not adversely affected) • Treated effluent discharges – industrial/ domestic/agro-chemical. • Plying of motorized boats • Dredging (need for dredging may be considered, on merit on case to case basis, only in cases of wetlands impacted by siltation) • Constructions of permanent nature within 50 m of periphery except boat jetties • Activity that interferes with the normal run-off and related ecological processes – up to 200 m **Prohibited activity** i. Conversion of wetland to non-wetland use ii. Reclamation of wetlands iii. Solid waste dumping and discharge of untreated effluents
Damage of fencing, solid waste dumping and encroachment problems in Varthur lake series	High Court of Karnataka (WP No. 817/2008) had passed an order which include: • Protecting lakes across Karnataka, • Prohibits dumping of garbage and sewage in Lakes • Lake area to be surveyed and fenced and declare a no development zone around lakes • Encroachments to be removed • Forest department to plant trees in consultation with experts in lake surroundings and in the watershed region • Member Secretary of state legal services authority to monitor implementation of the above in coordination with Revenue and Forest Departments • Also setting up district lake protection committees
Polluter Pays principle	**National Environment Policy, 2006** The principal objectives of NEP includes : • Protection and conservation of critical ecological systems and resources, and invaluable natural and man-made heritage • Ensuring judicious use of environmental resources to meet the needs and aspirations of the present and future generations

	• It emphasizes the "Polluter Pays" principle, which states the polluter should, in principle, bear the cost of pollution, with due regard to the public interest
Prevention of pollution of lake	**National Water Policy, 2002** Water is a scarce and precious national resource and requires conservation and management. Watershed management through extensive soil conservation, catchment-area treatment, preservation of forests and increasing the forest cover and the construction of check-dams should be promoted. The water resources should be conserved by retention practices such as rain water harvesting and prevention of pollution.
Discharge of untreated sewage into lakes	**The Environment (Protection) Act, 1986** • Lays down standards for the quality of environment in its various aspects • Laying down standards for discharge of environmental pollutants from various sources and no persons shall discharge any pollutant in excess of such standards • Restriction of areas in which industries, operations or processes shall not be carried out or carried out subject to certain safeguards
The water pollution, prevention and its control measures were not looked upon	**Water (Prevention and Control of Pollution) Act, 1974** • It is based on the **"**Polluter pays**"** principle. The Pollution Control Boards performs the following functions : • Advice the government on any matter concerning the prevention and control of water pollution. • Encourage, conduct and participate in investigations and research relating to problems of water pollution and prevention, control or abatement of water pollution. • Inspects sewage and effluents as well as the efficiency of the sewage treatment plants. • Lay down or modifiy existing effluent standards for the sewage. • Lay down standards of treatment of effluent and sewage to be discharged into any particular stream. • Notify certain industries to stop, restrict or modify their procedures if the present procedure is deteriorating the water quality of streams.
Pathetic water scenario and insufficient drinking water in Bangalore	The depletion of ground water and drying up off lakes has affected the water availability to meet the current population. At the 4% population growth rate of Bangalore over the past 50 years, the current population of Bangalore is 8.5 million (2011). Water supply from Hesaraghatta has dried, Thippagondanahalli is

	drying up, the only reliable water supply to Bangalore is from Cauvery with a gross of 1,410 million liters a day (MLD). There is no way of increasing the drawal from Cauvery as the allocation by the Cauvery Water Disputes Tribunal for the entire urban and rural population in Cauvery Basin in Karnataka is only 8.75 TMC ft (one thousand million cubic – TMC ft equals 78 MLD), Bangalore city is already drawing more water-1,400 MLD equals 18 TMC—than the allocation for the entire rural and urban population in Cauvery basin

The restoration and conservation strategies has to be implemented for maintaining the ecological health of aquatic ecosystems, aquatic biodiversity in the region, inter-connectivity among lakes, preserve its physical integrity (shorelines, banks and bottom configurations) and water quality to support healthy riparian, aquatic and wetland ecosystems. The regular monitoring of waterbodies and public awareness will help in developing appropriate conservation and management strategies (Ramachandra, 2005).

Ecological and Environmental Implications:

- Land use change: Conversion of watershed area especially valley regions of the lake to paved surfaces would alter the hydrological regime.
- Loss of Drainage Network: Removal of drain (Rajakaluve) and reducing the width of the drain would flood the surrounding residential as the interconnectivities among lakes are lost and there are no mechanisms for the excessive storm water to drain and thus the water stagnates flooding in the surroundings.
- Alteration in landscape topography: This activity alters the integrity of the region affecting the lake catchment. This would also have serious implications on the storm water flow in the catchment.
- The dumping of construction waste along the lakebed and lake has altered the natural topography thus rendering the storm water runoff to take a new course that might get into the existing residential areas. Such alteration of topography would not be geologically stable apart from causing soil erosion and lead to siltation in the lake.
- *Loss of Shoreline:* The loss of shoreline along the lakebed results in the habitat destruction for most of the shoreline birds that wade in this region. Some of the shoreline wading birds like the Stilts, Sandpipers; etc will be devoid of their habitat forcing them to move out such disturbed habitats. It was also apparent from the field investigations that with the illogical land filling and dumping taking place in the Bellandur lakebed, the shoreline are gobbled up by these activities.
- *Loss of livelihood:* Local people are dependent on the wetlands for fodder, fish etc. estimate shows that wetlands provide goods and services worth Rs 10500 per hectare per day (Ramachandra et al., 2005). Contamination of lake brings down goods and services value to Rs 20 per hectare per day.

Decision makers need to learn from the similar historical blunder of plundering ecosystems as in the case of Black Swan event (http://blackswanevents.org/?page_id=26) of evacuating half of the city in 10 years due to water scarcity, contaminated water, etc. or abandoning of FatehpurSikhri and fading out of AdilShahi'sBijapur, or ecological disaster at *Easter Island or* Vijayanagara empire

It is the responsibility of Bangalore citizens (to ensure intergeneration equity, sustenance of natural resources and to prevent human-made disasters such as floods, etc.) to stall the irrational conversion of land in the name of development and restrict the decision makers taking the system (ecosystem including humans) for granted as in the case of wetlands by KIADB, BDA, BBMP and many such para-state agencies.

Recommendations for Conservation and Sustainable Management of Wetlands

1. **Carrying capacity studies for all macro cities:** Unplanned concentrated urbanisation in many cities has telling impacts on local ecology and biodiversity, evident from decline of water bodies, vegetation, enhanced pollution levels (land, water and air), traffic bottlenecks, lack of appropriate infrastructure, etc. There is a need to adopt holistic approaches in regional planning considering all components (ecology, economic, social aspects). In this regard, we recommend carrying capacity studies before implementing any major projects in rapidly urbanizing macro cities such as Greater Bangalore, etc. Focus should be on
   - Good governance (too many para-state agencies and lack of co-ordination) - Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance) and action against polluters (encroachers as well as those let untreated sewage and effluents, dumping of solid wastes).
   - De-congest Bangalore: **Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity** (insufficient water, clean air and water, electricity, traffic bottlenecks, etc.) **and assimilative capacity** (polluted water and sediments in water bodies, enhanced GHG – Greenhouse gases, etc.)
   - Disband BDA – creation of Bangalore Development Agency has given impetus to inefficient governance evident from Bangalore, the garden city turning into 'dead city' during the functional life of BDA.
   - Digitation of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query option (Spatial Decision Support System) to public.

2. **Demarcation of the boundary of water bodies:**
   - The existing regulations pertaining to boundary demarcations within different states need to be reviewed according to updated norms and based on

geomorphology and other scientific aspects pertaining to individual water bodies.

- Maximum Water Level mark should form the boundary line of the water body.
- In addition, a specified width, based on historical records/ survey records etc. may be considered for marking a buffer zone around the water body. In case such records are not available, the buffer zones may be marked afresh considering the flood plain level and also maximum water levels.
- The width of the buffer zone should be set considering the geomorphology of the water body, the original legal boundaries, etc.
- The buffer zone should be treated as inviolable in the long term interests of the water body and its biodiversity.
- Declare and maintain floodplains and valley zones of lakes as no activity regions
- Remove all encroachments – free flood plains, valley zones, storm water drains, etc. of encroachments of any kind.
- Ban conversion of lake, lake bed for any other purposes.
- Urban wetlands, mostly lakes to be regulated from any type of encroachments.
- Regulate the activity which interferes with the normal run-off and related ecological processes – in the buffer zone (200 m from lake boundary / flood plains is to be considered as buffer zone)

3. **Mapping of water-bodies:** The mapping of water bodies should also include smaller wetlands, particularly streams, springs etc. The neglect of these hydrological systems could cause considerable impoverishment of water flow in the river systems as well as turn out to be threats to rare kinds of biodiversity. The waters of many of these streams are being diverted for private uses. This causes diminished water flow especially in the during the summer months. A judicious water sharing mechanism has to be worked out at the local level taking into account also the broader national interest as well as conservation of dependent biodiversity. The mapping of these smaller water-bodies, along with their catchments needs to be conducted involving also the local Biodiversity Management Committees. The jurisdictional agreements on the water usage and watershed protection need to be arrived at on a case to case basis involving all the stakeholders.
    - Spatial Extent of Water bodies,
    - Spatial extent of its catchment (watershed/basin),
    - Demarcate Flood plains,
    - Demarcate buffer zone – with a list of regulated activities,
    - Land cover in the catchment,
    - Ensure at least 33% of land cover is covered with natural vegetation (to ensure the lake perennial),
    - Identify the natural areas in the catchment,
    - Biodiversity inventory – capture entire food chain,

- The jurisdictional agreements on the water usage and watershed protection need to be arrived at on a case to case basis involving all the stakeholders,
- Develop a comprehensive database (spatial with attribute information) and available to public,
- Development of Spatial Decision Support System to aid decision makers,
- Identify and demarcate the region around the lake where all activities are to be prohibited (Flood plain)
- The biodiversity of every water body should form part of the Biodiversity Registers (BR),
- The local Biodiversity Management Committees (BMC) should be given necessary financial support and scientific assistance in documentation of diversity,
- The presence of endemic, rare, endangered or threatened species and economically important ones should be highlighted,
- A locally implementable conservation plan has to be prepared for such species.

4. **Holistic and Integrated Approaches – Conservation and Management:** Integration of the activities with the common jurisdiction boundaries of Government para-state Agencies for effective implementation of activities related to management, restoration, sustainable utilization and conservation. This necessitates:
    - Common Jurisdictional boundary for all para-state agencies
    - To minimise the confusion of ownership – assign the ownership of all natural resources (lakes, forests, etc.) to a single agency – **Lake Protection and Management Authority** (or Karnataka Forest Department). This agency shall be responsible for protection, development and sustainable management of water bodies).
    - Custodian (single para-state agency) shall manage natural resources - let that agency have autonomous status with all regulatory powers to protect, develop and manage water bodies.
    - All wetlands to be considered as common property resources and hence custodians should carefully deal with these ensuring security.
    - Management and maintenance of lakes to be decentralized involving stakeholders, local bodies, institutions and community participation without any commercialization or commoditization of lakes.
    - Integrated aquatic ecosystem management needs to be implemented to ensure sustainability, which requires proper study, sound understanding and effective management of water systems and their internal relations.
    - The aquatic systems should be managed as part of the broader environment and in relation to socio-economic demands and potentials, acknowledging the political and cultural context.
    - Wetlands lying within the protected area of National Parks and Wildlife Sanctuaries shall be regulated under the Wildlife Protection Act, 1972. Wetlands lying within the notified forest areas shall be regulated by the

Indian Forest Act, 1927 and the Forest Conservation Act, 1980; and the relevant provisions of the Environment (Protection) Act, 1986. The Wetlands outside protected or notified forest areas shall be regulated by the relevant provisions of the Environment (Protection) Act, 1986.

- Immediate implementation of the regulatory framework for conservation of wetlands.
- Socio-economic studies with land use planning in and around the lakes can help in providing ecological basis for improving the quality of lakes.
- Prohibit activities such as conversion of wetlands for non-wetland purposes, dumping of solid wastes, direct discharge of untreated sewage, hunting of wild fauna, reclamation of wetlands.
- Maintain Catchment Integrity to ensure lakes are perennial and maintain at least 33% land cover should be under natural Vegetation.
- Plant native species of vegetation in each lake catchment.
- Create new water bodies considering the topography of each locality.
- Establish laboratory facility to monitor physical, chemical and biological integrity of lakes.
- Maintain physical integrity - Free storm water drains of any encroachments. Establish interconnectivity among water bodies to minimise flooding in certain pockets. The process of urbanization and neglect caused disruption of linkages between water bodies such as ancient lake systems of many cities. Wherever such disruptions have taken place alternative arrangements should be provided to establish the lost linkages.
- Encroachment of lake beds by unauthorized /authorized agencies must be immediately stopped. Evict all unauthorized occupation in the lake beds as well as valley zones.
- Any clearances of riparian vegetation (along side lakes) and buffer zone vegetation (around lakes) have to be prohibited
- Penalise polluters dumping solid waste in the lake bed.
- Implement polluter pays principle for polluters letting liquid waste in to the lake either directly or through storm water drains.
- Lake privatized recently to be taken over and handed over to locals immediately thus restoring the traditional access to these lakes by the stakeholders.
- Restore surviving lakes in urban areas strengthening their catchment area and allowing sloping shorelines for fulfilling their ecological function.
- Alteration of topography in lake / river catchments should be banned.
- Appropriate cropping pattern, water harvesting, urban development, water usage, and waste generation data shall be utilized and projected for design period for arriving at preventive, curative and maintenance of aquatic ecosystem restoration action plan (AERAP).

- Desilting of lakes for removal of toxic sediment, to control nuisance macrophytes; further silting in the catchment should be checked by suitable afforestation of catchment areas and the provision of silt traps in the storm water drains.
- Maintaining the sediment regime under which the aquatic ecosystems evolve including maintenance, conservation of spatial and temporal connectivity within and between watersheds.
- Conversion of land around the lakes particularly in the valley zones and storm water drains for any kind of development must be totally banned.
- Flora in the catchment area should be preserved & additional afforestation programmes undertaken.
- Check the overgrowth of aquatic weeds like *Eichhornia, Azolla, Alternanthera* etc. through manual operations.
- Aquatic plants greatly aid in retarding the eutrophication of aquatic bodies; they are the sinks for nutrients & thereby play a significant role in absorption & release of heavy metals. They also serve as food and nesting material for many wetland birds. Therefore, knowledge of the ecological role of aquatic species is necessary for lake preservation.
- Adopt biomanipulation (Silver carp and Catla– surface phytoplankton feeders, Rohu – Column zooplankton feeder Gambusia and Guppies – larvivorous fishes for mosquito control), aeration, and shoreline restoration (with the native vegetation) in the management of lakes.
- Environmental awareness programmes can greatly help in the protection of the water bodies.

- Government Agencies, Academies, Institutions and NGO's must co-ordinate grass-root level implementation of policies and activities related to conservation of lakes and wetlands (both Inland and Coastal), their sustainable utilization, restoration and development including human health. There is also a need for management and conservation of aquatic biota including their health aspects. Traditional knowledge and practices have to be explored as remedial measures. Cost-intensive restoration measures should be the last resort after evaluating all the cost-effective measures of conservation and management of the wetlands.
- A Committee be constituted consisting of Experts, Representatives of Stakeholders (researchers, industrialists, agriculturists, fishermen, etc.) and Line Agencies, in addition to the existing Committee(s), if any, in order to evolve policies and strategies for reclamation, development, sustainable utilization and restoration of the wetlands and socio-economic development of the local people.
- At regional level, **Lake Protection and Management Authority (LPMA)** with autonomy, corpus funds from plan allocations of state and center and responsibility and accountability for avoiding excessive cost and time over runs.

LPMA shall have stakeholders-representatives from central and state and local body authorities, NGO's and eminent people and experts shall be constituted

- Generous funds shall be made available for such developmental works through the Committee, as mentioned above. Local stakeholders be suggested to generate modest funds for immediate developmental needs in the aquatic systems in their localities.
- Provisions should be made for adoption of lakes and wetlands by the NGO's and Self-help groups for their conservation, management, sustainable utilization and restoration.
- Aquatic ecosystem restoration works taken up by any agency, Govt. or NGO's should have 10% of restoration costs (per annum) spent or set off for creating awareness , research and monitoring compulsorily in future.
- Public education and outreach should be components of aquatic ecosystem restoration. Lake associations and citizen monitoring groups have proved helpful in educating the general public. Effort should be made to ensure that such groups have accurate information about the causes of lake degradation and various restoration methods.

5. **Documentation of biodiversity:** The biodiversity of every water body should form part of the School, College, People's Biodiversity Registers (SBR, CBR, PBR). The local Biodiversity Management Committees (BMC) should be given necessary financial support and scientific assistance in documentation of diversity. The presence of endemic, rare, endangered or threatened species and economically important ones should be highlighted. A locally implementable conservation plan has to be prepared for such species.
    - All kinds of introduction of Exotic species and Quarantine measures be done in consultation with the concerned Authorities and the data bank
    - There is an urgent need for creating a `Data Bank' through inventorisation and mapping of the aquatic biota.
    - Identify water bodies of biodiversity importance and declare them as wetland conservation reserves (WCR)

6. **Preparation of management plans for individual water bodies:** Most large water bodies have unique individual characteristics. Therefore it is necessary to prepare separate management plans for individual water bodies.
    - Greater role and participation of women in management and sustainable utilization of resources of aquatic ecosystems.
    - Impact of pesticide or fertilizers on wetlands in the catchment areas to be checked.
    - Regulate illegal sand and clay mining around the wetlands.

7. **Implementation of sanitation facilities:** It was noted with grave concern that the water bodies in most of India are badly polluted with sewage, coliform bacteria and various other pathogens. This involves:
    - Preserving the purity of waters and safeguarding the biodiversity and productivity, dumping of waste has to be prohibited;
    - In addition to this, all the settlements alongside the water body should be provided with sanitation facilities so as not to impinge in anyway the pristine quality of water.

8. **Management of polluted lakes:** This programme needs priority attention. This involves:
    - Implementation of bioremediation method for detoxification of polluted water bodies.
    - The highly and irremediably polluted water bodies to be restored on priority to prevent health hazards.
    - Based on the concept of **polluter pays**, a mechanism be evolved to set up efficient effluent treatment plants [ETP], individual or collective, to reduce the pollution load. Polluting industries be levied **Environmental Cess,** which can be utilised for conservation measures by the competent authorities. A `waste audit' must be made compulsory for all the industries and other agencies.

9. **Restoration of lakes:** The goals for restoration of aquatic ecosystems need to be realistic and should be based on the concept of expected conditions for individual eco-regions. Further development of project selection and evaluation technology based on eco-region definitions and description should be encouraged and supported by the national and state government agencies.
    - Ecosystem approach in aquatic ecosystem restoration endeavor considering catchment land use plan as of pre-project status and optimal land use plan shall first be prepared for short term (10 to 30 years) and long term (>30) periods keeping in view developmental pressure over time span.
    - Research and development is needed in several areas of applied limnology, and this programme should take an experimental approach which emphasizes manipulation of whole ecosystems.
    - Appropriate technologies for point and non-point sources of pollution and *in situ* measures for lake restoration shall be compatible to local ethos and site condition as well as objectives of Aquatic Ecosystem Restoration Action Plan (AERAP).
    - Traditional knowledge and practices have to be explored as remedial measures. Cost-intensive restoration measures should be the last resort after evaluating all the cost-effective measures of conservation and management of ecosystems.
    - Public needs to be better informed about the rational, goal and methods of ecosystem conservation and restoration. In addition, the need was realized for

scientist and researchers with the broad training needed for aquatic ecosystem restoration, management and conservation.

- Improved techniques for littoral zone and aquatic microphytes management need to be developed. Research should go beyond the removal of nuisance microphytes to address the restoration of native species that are essential for waterfowl and fish habitat.
- Basic research is necessary to improve the understanding of fundamental limnological processes in littoral zones and the interactions between littoral and pelagic zones of lakes.
- Bio manipulation (food web management) has great potential for low-cost and long-term management of lakes, and research in this emerging field must be stimulated.
- Innovative and low-cost approaches to contaminant clean up in lakes need to be developed.
- The relations between loadings of stress-causing substances and responses of lakes need to be understood more precisely. Research should be undertaken to improve predictions of trophic state and nutrient loading relationships.
- Improved assessment programmes are needed to determine the severity and extent of damage in lakes and wetlands and a change in status over time. Innovative basic research is required to improve the science of assessment and monitoring.
- There is a great need for cost effective, reliable indicators of ecosystems function, including those that would reflect long-term change and response to stress.
- Research on indicators should include traditional community and ecosystem measurements, paleoecological trend assessments and remote sensing.
- Effective assessment and monitoring programme would involve network of local schools, colleges and universities.

10. **Valuation of goods and services :** Goods and services provided by the individual water bodies and the respective species to be documented, evaluated through participatory approach and be made part of the Biodiversity Registers (PBR: People's Biodiversity Registers, SBR: School Biodiversity Registers). If in any case the traditional fishing rights of the local fishermen are adversely affected by lake conservation or by declaring it as a bird sanctuary, etc. they should be adequately compensated.
    - Ecological values of lands and water within the catchment / watershed shall be internalised into economic analysis and not taken for granted. Pressure groups shall play as watchdogs in preventing industrial and toxic and persistent pollutants by agencies and polluters.

11. **Regulation of boating:** Operation of motorized boats should not be permitted within lakes of less than 50 ha. In larger lakes the number of such boats should be limited to

restricted area and carrying capacity of the water body. In any case boating during the periods of breeding and congregations of birds should be banned.

12. **Protection of riparian and buffer zone vegetation:** Any clearances of riparian vegetation (along side rivers) and buffer zone vegetation (around lakes) have to be prohibited.
13. **Restoration of linkages between water bodies:** The process of urbanization and neglect caused disruption of linkages between water bodies such as ancient lake systems of many cities. Wherever such disruptions have taken place alternative arrangements should be provided to establish the lost linkages.
14. **Rainwater harvesting:** Intensive and comprehensive implementation of rain water harvesting techniques can reduce taxation of water bodies and also minimize electricity requirements. The country needs in principle a holistic rainwater harvesting policy aimed at directing water literally from "roof-tops to lakes" after catering to the domestic needs.
15. **Environment Education:** It was felt among the participants that public needs to be better informed about the rational, goal and methods of ecosystem conservation and restoration. In addition, the need was realized for scientist and researchers with the broad training needed for aquatic ecosystem restoration, management and conservation. Public education and outreach should include all components of ecosystem restoration. Lake associations and citizen monitoring groups have proved helpful in educating the general public. Effort should be made to ensure that such groups have accurate information about the causes of lake degradation and various restoration methods. Funding is needed for both undergraduate and graduate programmes in ecosystem conservation and restorations. Training programmes should cross traditional disciplinary boundaries such as those between basic and applied ecology: water quality management and fisheries or wildlife management: among lakes, streams, rivers, coastal and wetland ecology. In this regard the brainstorming session proposes:
    - Environmental education program should be more proactive, field oriented and experiential (with real time examples) for effective learning.
    - Environmental education should be made mandatory at all levels – schools, colleges, universities, professional courses, teachers and teacher educators at the teachers' training institutes (C P Ed, B P Ed, B Ed, D Ed)
16. **Adopt Inter-disciplinary Approach:** Aquatic ecosystem conservation and management requires collaborated research involving natural, social, and inter-disciplinary study aimed at understanding various components, such as monitoring of water quality, socio-economic dependency, biodiversity and other activities, as an indispensable tool for formulating long term conservation strategies. This requires multidisciplinary-trained professionals who can spread the understanding of ecosystem's importance at local schools, colleges, and research institutions by initiating educational programmes aimed at rising the levels of public awareness of aquatic ecosystems' restoration, goals and methods. Actively participating schools and colleges in the vicinity of the water bodies may value the opportunity to provide hands-on environmental education, which could entail setting up of laboratory facilities at the

site. Regular monitoring of water bodies (with permanent laboratory facilities) would provide vital inputs for conservation and management.

Wetland Protection Laws and Government Initiatives

The primary responsibility for the management of these ecosystems is in the hands of the Ministry of Environment and Forests. Although some wetlands are protected after the formulation of the Wildlife Protection Act, the others are in grave danger of extinction. Effective coordination between the different ministries, energy, industry, fisheries revenue, agriculture, transport and water resources, is essential for the protection of these ecosystems. Thus, wetlands were not delineated under any specific administrative jurisdiction. Recently the Ministry of Environment and Forests of the Government of India issued Notification 2010 Regulatory Framework for Wetlands Conservation (Wetland Conservation Rules). Wetlands in India are protected by an array of laws given below:

- The Indian Fisheries Act - 1857
- The Indian Forest Act - 1927
- Wildlife (Protection) Act - 1972
- Water (Prevention and Control of Pollution) Act - 1974
- Water (Prevention and Control of Pollution) Cess Act - 1977
- Forest (Conservation) Act - 1980
- The Environment (Protection) Act - 1986
- Wildlife (Protection) Amendment Act - 1991
- National Conservation Strategy and Policy Statement on Environment and Development – 1992
- Environment Impact Assessment Notification, 2009
- Wetlands Regulatory Framework, 2008
- Wetlands (Conservation and Management) Rules 2010, Government of India

In addition to the above laws, India is a signatory to the Ramsar Convention on Wetlands and the Convention of Biological Diversity. According to these formulations India is expected to conserve the ecological character of these ecosystems along with the biodiversity of the flora and fauna associated with these ecosystems. Despite these, there is no significant development towards sustaining these ecosystems due to the lack of awareness of the values of these ecosystems among the policymakers and implementation agencies. The effective management of these wetlands requires a thorough appraisal of the existing laws, institutions and practices. The involvement of various people from different sectors is essential in the sustainable management of these wetlands.

Apart from government regulation, development of better monitoring methods is needed to increase the knowledge of the physical and biological characteristics of each wetland resources, and to gain, from this knowledge, a better understanding of wetland dynamics and their controlling processes. Discussions based on accurate knowledge and increased awareness of

wetland issues can then begin to develop management strategies (to protect, restore and/or mitigate) that account for the function and value of all wetland resources in the face of natural and socioeconomic factors, while continuing to satisfy critical resource needs of the human population.

The Legal framework for the conservation and management of Wetland Ecosystems is provided by the following National and International Legal instruments:

The Wildlife Protection Act, 1972: This act provides for the protection of wild animals, birds and plants. For the purpose of this act, the state government constitutes the Wildlife Advisory board, which performs the following functions: It advices the state government:

- In the selection of areas to be declared as Sanctuaries, National Parks and Closed Areas.
- In the formulation of policy of protection and conservation of wildlife and specified plants.
- In relation to the measures to be taken for harmonizing the needs of the tribals and forest dwellers with the protection and conservation of wildlife.

This Act imposes prohibition on hunting of wild animals, their young ones as well as their eggs except with prior permission of the Chief Wildlife Warden. This acts prohibits the picking, uprooting, destroying, damaging, possessing of any plant in a protected area, except with prior permission of the Chief Wildlife Warden. The State government may declare any area; which it considers to have adequate ecological, faunal, geomorphological, natural or zoological significance for the purpose of protecting, propagating or developing wildlife or its environment; to be included in a sanctuary or a National Park. No person shall, destroy, exploit or remove any wildlife from a National Park and Sanctuary or destroy or damage the habitat or deprive any wild animal or plant its habitat within such National Park and Sanctuary. The State government may also declare any area closed to hunting for a designated period of time if it feels the ecosystem of that area is disturbed by hunting.

Water (Prevention and Control of Pollution) Act, 1974: for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water. To carry out the purposes of this act, the Central and the State government constitutes the Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) respectively. The main functions of the pollution control boards include:

- Advice the government on any matter concerning the prevention and control of water pollution.
- Encourage, conduct and participate in investigations and research relating to problems of water pollution and prevention, control or abatement of water pollution.
- Lay down or modify standards on various parameters for the release of effluents into streams.

- Collect and examine effluent samples as well as examine the various treatment procedures undertaken by the industries releasing the effluent.
- Examine the quality of streams.
- Notify certain industries to stop, restrict or modify their procedures if it feels that the present procedure is deteriorating the water quality of streams.
- Establish or recognize laboratories to perform its functions including the analysis of stream water quality and trade effluents.

Forest (Conservation) Act, 1980: Without the permission of the Central government, no State government or any other authority can:

- Declare that any reserved forest shall cease to be reserved.
- Issue permit for use of forest land for non-forest purpose.
- Assign any forest land or portion thereof by way of lease or otherwise to any private person, authority, corporation, agency or any other organization, not owned, managed or controlled by government.
- Clear off natural trees from a forest land for the purpose of reafforestation.

The Biological Diversity Act, 2002: India is a signatory to the United Nations Convention on Biological Resources, 1992 and in accordance with that convention, brought into force The Biological Diversity Act, 2002. This act prohibits biodiversity related activities as well as transfer of the results of research pertaining to biodiversity to certain persons. It also necessitates the approval of National Biodiversity Authority before applying for Intellectual Property Rights on products pertaining to biological diversity. This act emphasizes the establishment of National Biodiversity Authority to carry out various functions pertaining to the Act, viz guidelines for approving collection, research and patents pertaining to biological diversity. It also notifies the central government on threatened species. The central government to develop plans, programmes and strategies for the conservation, management and sustainable use of the biodiversity. Where the Central Government has reason to believe that any area rich in biological diversity, biological resources and their habitats is being threatened by overuse, abuse or neglect, it shall issue directives to the concerned State Government to take immediate ameliorative measures.

Convention on Wetlands of International Importance, especially as Waterfowl habitats, (Ramsar) 1971: To stem the progressive destruction of the wetlands, Ramsar convention was signed. Waterfowls are birds ecologically dependent on the wetlands. The various points agreed under Ramsar convention includes:

- Each contracting party should nominate at least one wetland having significant value in terms of ecology, botany, zoology, limnology or hydrology to be included in the List of Wetlands of International Importance (Ramsar sites) and precisely describe its boundaries.

- The contracting parties will have right to add further wetland sites to the list, expand the boundaries of the existing sites and also to delete or minimize the boundaries of the existing sites.
- Each contracting party shall strive for the conservation, management and restoration of the wetlands in the list.
- Establishment of nature reserves in the area of wetlands thereby protecting it as well as the biological diversity it supports.
- Restriction of boundaries or deletion of a wetland listed as Ramsar sites should be immediately compensated by the creation of additional nature reserves for the protection of waterfowls and other species habiting that wetland.

International convention for the protection of Birds, 1950: To abate the ever dwindling number of certain bird species (particularly the migratory ones) as well as the other birds, this convention was made. This is an amendment to the "International Convention for the Protection of Birds useful to Agriculture, 1902". The objectives of this convention include:

- Protection to all birds, their young ones and their eggs especially in their breeding season.
- Prohibit hunting, killing, mass capture or captivating birds, except those causing intense damage to crops or other components of the ecosystem, such so that the above said components is in the danger of extinction.
- Adopt measures to prohibit industries and other processes causing contamination of air and water that has adverse effects on the survival of birds.
- Adopt measures to prohibit the destruction of suitable breeding grounds and the bird habitat and also encourage the creation of suitable land and water habitat for the birds.

Bonn Convention on Conservation of Migratory Species, 1979: According to the Bonn Convention on Conservation of Migratory Species, the participating parties:

- Should promote, co-operate in and support research relating to migratory species.
- Shall endeavour to provide immediate protection for migratory species which are endangered.
- Shall strive to conserve and restore those habitats of the endangered species in an effort to eliminate the chances of extinction of that species.
- Shall prohibit or minimize those activities or obstacles that seriously impede or prevent the migration of the species.

Convention on Biological Diversity, 1992: The main objectives of this convention are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits arising out of the utilization of genetic resources. In accordance with this convention, each contracting party shall –

- Identify places supporting immense biological diversity.

- Monitor through sampling or other means the components of biological diversity identified and strive for the conservation of those components requiring urgent attention.
- Develop new or adapt existing strategies, plans and programmes for the conservation and sustainable use of biological diversity.
- Identify activities which have or may have significant adverse impact on the sustainability of the biodiversity in an area.
- It prescribes conservation of biological diversity by either *In situ* conservation mechanisms or *Ex situ* conservation mechanisms or both.

In situ conservation: Each contracting parties shall declare a region harbouring immense biological diversity as a protected area and develop various plans and strategies for the establishment, conservation and management of these protected areas and also strive to conserve biodiversity beyond these protected areas.

- Promote environmentally sound and sustainable development in the areas adjacent to the protected areas so as to further enhance the development and protection of these protected areas.
- Promote the protection of ecosystems, prevent the introduction of alien species likely to have an adverse effect on the existing ecosystem and also rehabilitate & restore degraded ecosystems.
- Enforce legislative measures for the protection of threatened species and population.

Ex situ conservation : Each contracting party shall establish facilities for ex situ conservation and for research on plants, animals and micro-organisms, especially the threatened species, augment their number and take steps for their reintroduction in their own natural habitat.

Relative merits and scope of the respective Indian laws with respect to the wetlands protection and conservation is given in Table 2.

Table 2: Sections applicable to Wetlands in the various environmental laws

No.	Act	Relevant Sections
1	The Wildlife (Conservation) Act, 1972	Prohibits hunting of wild animals, their young ones as well as their eggs Prohibits the picking, uprooting, destroying, damaging, possessing of any plant in a protected area Can declare any area with high ecological significance as a national park, sanctuary or a closed area.
2	The Biological Diversity Act, 2002	Prior approval needed from National Biodiversity Authority for collection of biological materials occurring in India as well as for its commercial utilization.

		Panchayath to document biodiversity and maintain biodiversity registers
3	Forest (Conservation) Act, 1980	Without the permission of the Central government, no State government or any other authority can : • Declare that any reserved forest shall cease to be reserved. • Issue permit for use of forest land for non-forest purpose. • Assign any forest land by way of lease or otherwise to any private person, authority, corporation, agency or any other organization, not owned, managed or controlled by government. • Clear off natural trees from a forest land for the purpose of re-afforestation.
4	Water (Control and Prevention of Pollution) Act, 1974	It is based on the "Polluter pays" principle. The Pollution Control Boards performs the following functions : • Inspects sewage and effluents as well as the efficiency of the sewage treatment plants. • Lay down or modifies existing effluent standards for the sewage. • Lay down standards of treatment of effluent and sewage to be discharged into any particular stream. • Notify certain industries to stop, restrict or modify their procedures if the present procedure is deteriorating the water quality of streams.
5	Wetlands (Conservation and Management) Rules, 2010	Prohibited Activities • Conversion of wetland to non-wetland use • Reclamation of wetlands • Solid waste dumping and discharge of untreated effluents. Regulated activities • Withdrawal of water, diversion or interruption of sources • Treated effluent discharges – industrial/domestic/agro-chemical. • Plying of motorized boats

		• Dredging • Constructions of permanent nature within 50 m • Activity which interferes with the normal run-off and related ecological processes – up to 200 m
6	National Environment Policy, 2006	The principal objectives of NEP includes : • Protection and conservation of critical ecological systems and resources, and invaluable natural and man made heritage. • Ensuring judicious use of environmental resources to meet the needs and aspirations of the present and future generations. • It emphasizes the "Polluter Pays" principle, which states the polluter should, in principle, bear the cost of pollution, with due regard to the public interest.
8	The Environment (Protection) Act, 1986	Lays down standards for the quality of environment in its various aspects. Laying down standards for discharge of environmental pollutants from various sources and no persons shall discharge any pollutant in excess of such standards. Restrictions of areas in which industries, operations or processes shall not be carried out or carried out subject to certain safeguards.
9	National Water Policy, 2002	Water is a scarce and precious national resource and requires to be conserved and management. Watershed management through extensive soil conservation, catchment-area treatment, preservation of forests and increasing the forest cover and the construction of check-dams should be promoted. The water resources should be conserved by retention practices such as rain water harvesting and prevention of pollution.

1.0 Bangalore to Bengaluru (transition from green landscape to brown landscape)

Status	**Disappearing water-bodies and vegetation**
Cause:	**Unplanned urbanisation**
Recommendation	"**Decongest and decontaminate Bangalore**" so that at least next generation enjoys better environment in Bangalore Need to ensure the ecosystem integrity to sustain goods and services for maintaining inter-generation equity. **Carrying capacity studies for all macro cities:** Unplanned concentrated urbanisation in many cities has telling impacts on local ecology and biodiversity, evident from decline of water bodies, vegetation, enhanced pollution levels (land, water and air), traffic bottlenecks, lack of appropriate infrastructure, etc. There is a need to adopt holistic approaches in regional planning considering all components (ecology, economic, social aspects). In this regard, we recommend carrying capacity studies before implementing any major projects in rapidly urbanizing macro cities such as Greater Bangalore, etc.
Action Plan	• Good governance (too many para-state agencies and lack of co-ordination) - Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance and action against polluters (encroachers as well as those let untreated sewage and effluents, dumping of solid wastes). • De-congest Bangalore: Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity (insufficient water, clean air and water, electricity, traffic bottlenecks, etc.) and assimilative capacity (polluted water and sediments in water bodies, enhanced GHG – Greenhouse gases, etc.) • Disband BDA – creation of Bangalore Development Agency has given impetus to inefficient governance evident from Bangalore, the garden city turning into 'dead city' during the functional life of BDA. • Digitation of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query option (Spatial Decision Support System) to public. • Threshold on high raise building in the region. Need to protect valley zones considering ecological function and these regions are 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015 • Evict all encroachments from lake bed and raja kaluves • Reestablish interconnectivity among lakes • Restoration of lakes

1.0 Bangalore to Bengaluru (transition from green landscape to brown landscape)

Bangalore (77°37'19.54'' E and 12°59'09.76'' N), is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka. With an area of 741 sq. km., Bangalore's city administrative jurisdiction was widened in 2006 (Greater Bangalore) by merging the existing area of Bangalore city spatial limits with 8 neighbouring Urban Local Bodies (ULBs), and 111 Villages of Bangalore Urban District (Ramachandra and Kumar, 2008; Ramachandra et al., 2012). Thus, Bangalore has grown spatially more than ten times since 1949 (69 square kilometres) and is a part of both the Bangalore urban and rural districts (figure 1.1). 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° C – 38° C, while the winter temperature ranges from 12° C – 25° C. Bangalore is located at an altitude of 920 meters above mean sea level, delineating three watersheds, viz. Hebbal, Koramangala-Challaghatta and Vrishabhavathi watersheds (Figure 1.2). 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. Bangalore had the distinction of having hundreds of 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 (and spatial extent of Bangalore was 112 sq. km). However, number of lakes and tanks in 1985 was 81 (and spatial extent of Bangalore was 161 sq. km). This forms important drainage courses for the interconnected lake system (Figure 1.2), which carries storm water beyond the city limits. Bangalore, being a part of peninsular India, had the tradition of harvesting water through surface water bodies to meet the domestic water requirements in a decentralised way. After independence, the source of water for domestic and industrial purpose in Bangalore is mainly from the Cauvery River and ground water. Untreated sewage is let into the storm water drains, which progressively converge at the water bodies. Now, Bangalore is the fifth largest metropolis in India currently with a population of about 8.72 million as per the latest population census. Spatial extent of the city has increased from 69 (1941) to 161 (1981), 226 (2001) and 745 (2011) sq.km. Due to the changes in the spatial extent of the city, the population density varies from 5956 (1941) to 18147 (1981), 25653 (1991), 25025 (2001) and 11704 (2011) persons per sq.km.

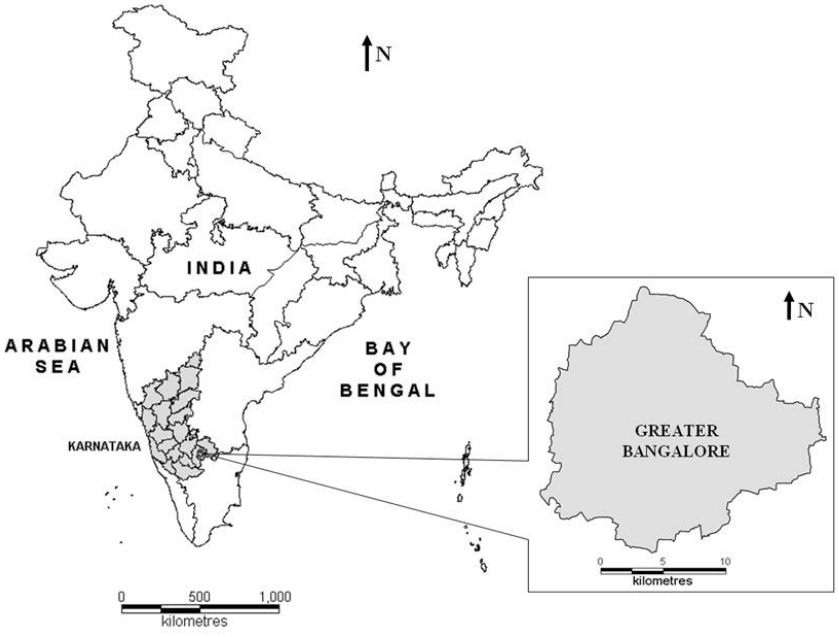


Figure 1.1: Study area –Bangalore

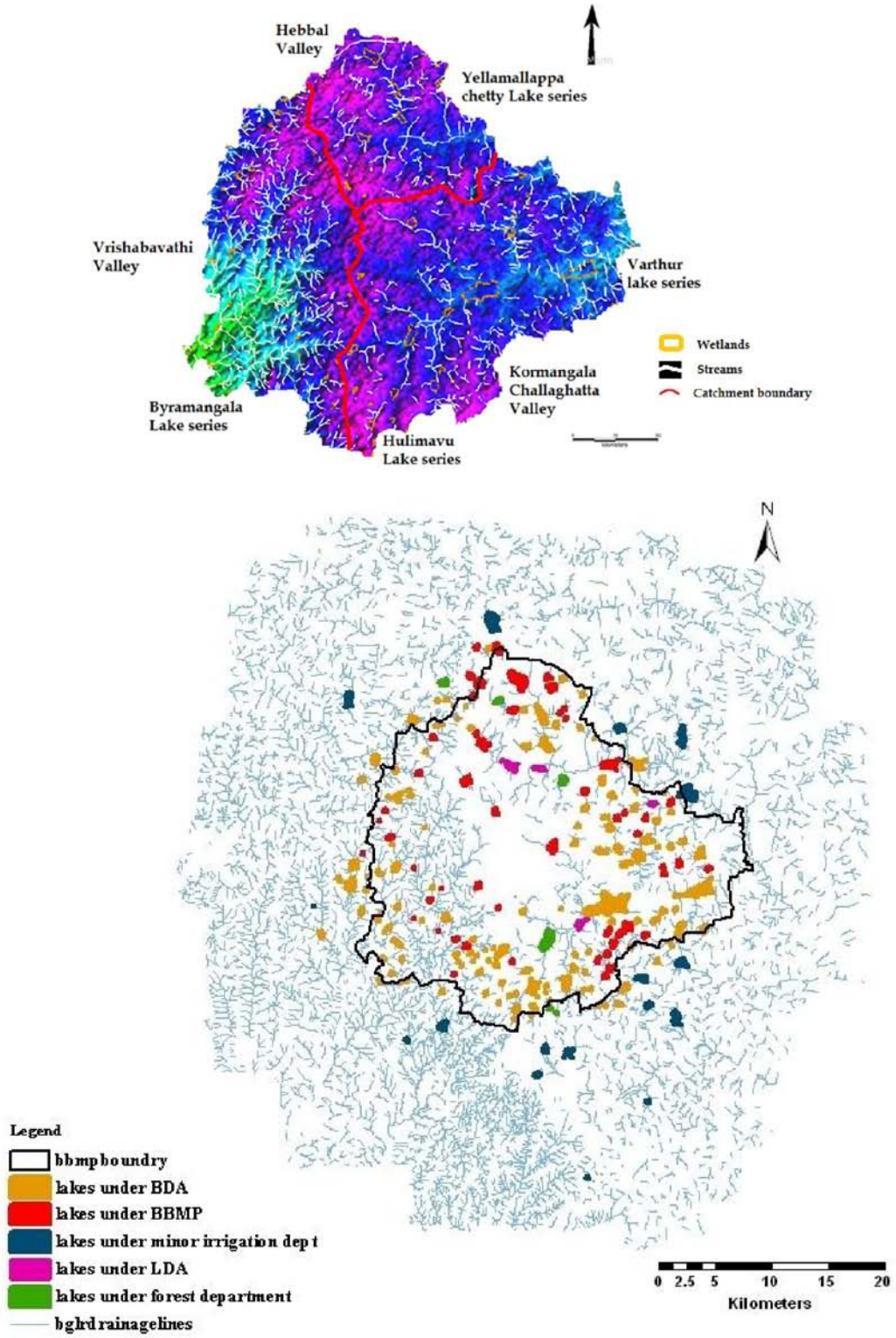


Figure 1.2: Watersheds (drainage with water bodies) of Bangalore

Land use analyses were carried out using supervised pattern classifier - Gaussian maximum likelihood classifier (GMLC) for Landsat and IRS data, and Bayesian Classifier (MODIS data). The method involved (Ramachandra *et al*., 2012): i) generation of False Colour Composite (FCC) of remote sensing data (bands – green, red and NIR). This helped in locating heterogeneous patches in the landscape ii) selection of training polygons (these correspond to heterogeneous patches in FCC) covering 15% of the study area and uniformly distributed over the entire study area, iii) loading these training polygons co-ordinates into pre-calibrated GPS, vi) collection of the corresponding attribute data (land use types) for these polygons from the field. GPS helped in locating respective training polygons in the field, iv) supplementing this information with Google Earth (latest as well as archived data), v) 60% of the training data has been used for classification, while the balance is used for validation or accuracy assessment.

Land use analysis carried out using GRASS - Geographic Resources Analysis Support System (http://wgbis.ces.iisc.ernet.in/ grass) for the period 1973 to 2013 and details are in table 1.1 and urban dynamics is illustrated in Figure 1.3. There has been a 925% increase in built up area from 1973 to 2013 leading to a sharp decline of 79% area in water bodies in Bangalore mostly attributing to intense urbanisation process. Analyses of the temporal data reveals an increase in urban built up area of 342.83% (during 1973 to 1992), 129.56% (during 1992 to 1999), 106.7% (1999 to 2002), 114.51% (2002 to 2006) and 126.19% (2006 to 2010). 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 (Ramachandra and Shwetmala, 2009). Vegetation has decreased by 32% (during 1973 to 1992), 38% (1992 to 2002) and 64% (2002 to 2013). Disappearance of water bodies or sharp decline in the number of water bodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Many lakes (54%) were encroached for illegal buildings. Field survey of all lakes (in 2007) shows that nearly 66% of lakes are sewage fed, 14% surrounded by slums and 72% showed loss of catchment area. In addition, lake catchments were used as dumping yards for either municipal solid waste or building debris (Ramachandra, 2009a). 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 water bodies. 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 water bodies. Some of the lakes have been restored by the city corporation and the concerned authorities in recent times.

Table 1.1: Land use changes in Bengaluru during 1973 to 2013

Class →	Urban		Vegetation		Water		Others	
Year ↓	Ha	%	Ha	%	Ha	%	Ha	%
1973	5448	7.97	46639	68.27	2324	3.40	13903	20.35
1992	18650	27.30	31579	46.22	1790	2.60	16303	23.86
1999	24163	35.37	31272	45.77	1542	2.26	11346	16.61
2002	25782	37.75	26453	38.72	1263	1.84	14825	21.69
2006	29535	43.23	19696	28.83	1073	1.57	18017	26.37
2010	37266	54.42	16031	23.41	617	0.90	14565	21.27
2013	50440	73.72	10050	14.69	445.95	0.65	7485	10.94

Urbanisation in Greater Bangalore

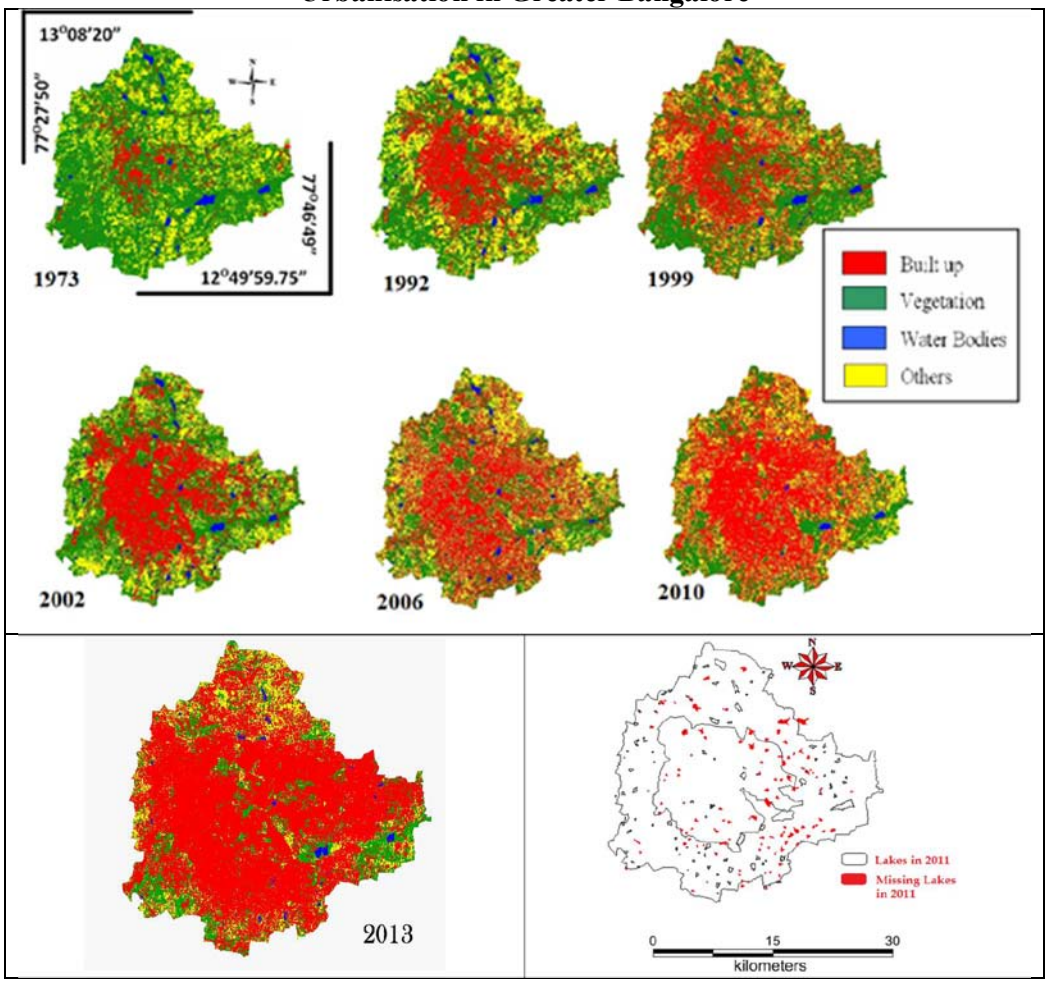


Figure 1.3: Land use dynamics since 1973

Increase in Built-up (concrete / paved surface): 925%

Loss of vegetation: 78%

Loss of water bodies: 79%

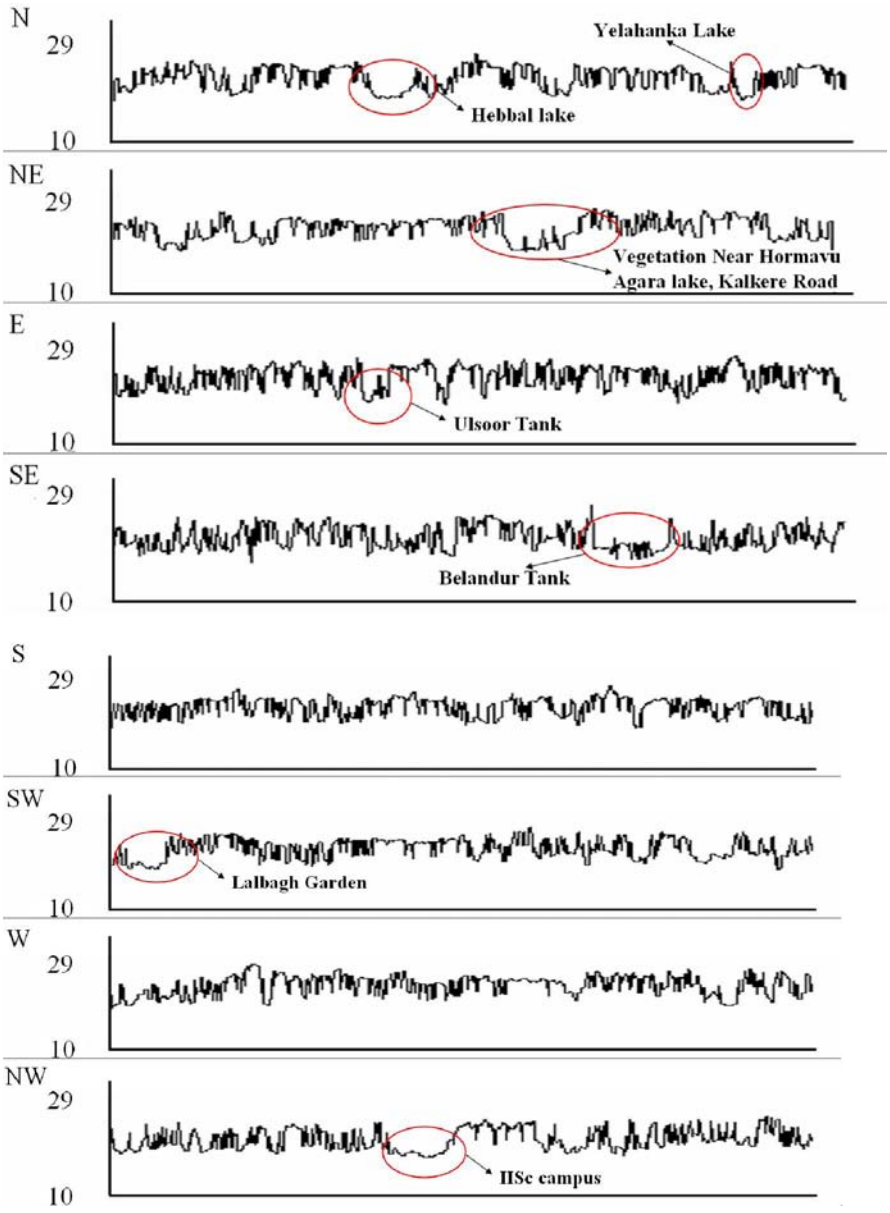


Figure 1.4: Temperature profile in various directions. X axis – Movement along the transacts from the city centre, Y-axis - Temperature (°C)

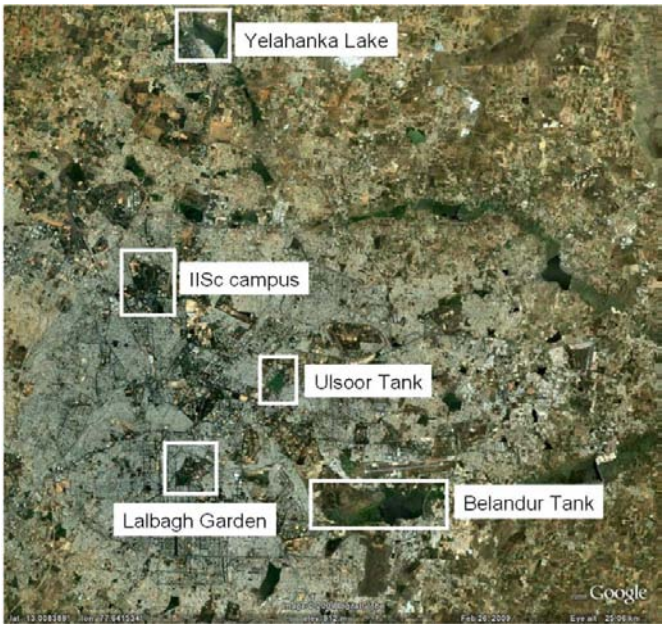


Figure 1.5: Google Earth image showing the low temperature areas [Source: http://earth.google.com/]

The temperature profile plot fell below the mean when a vegetation patch or water body was encountered on the transact beginning from the centre of the city and moving outwards eight directions along the transact as in figure 1.4 It is evident that major natural green area and water bodies act as microclimate moderators responsible for lower temperature (marked with circle in Figure 1.5). The spatial location of these green areas and water bodies are marked in figure 1.5.

Conclusion

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. Temporal land use analysis reveal that there has been a 925% increase in built up area from 1973 to 2013 leading to a sharp decline of 79% area in water bodies in Bangalore mostly attributing to intense urbanisation process. The increase in urban built up area ranges from 342.83% (during 1973 to 1992), 129.56% (during 1992 to 1999), 106.7% (1999 to 2002), 114.51% (2002 to 2006) to 126.19% (2006 to 2010). The gradient analysis showed that Bangalore grew radially from 1973 to 2010 indicating that the urbanization is intensifying from the city centre and has reached the periphery of the Bangalore. The temperature profile analysis by overlaying the LST on the land use reveal of higher temperatures in urban area while vegetation and water bodies aided in moderating temperature at local levels (evident from at least 2 to 2.5 °C lower temperature compared to urban pockets).

Frequent flooding in the city is a consequence of the drastic increase in impervious area (of 925% in 4 decades) and loss of wetlands (and interconnectivity of wetlands) with the high-density urban developments. The uncoordinated pattern of urban growth is attributed to a lack of good governance and decentralized administration, which was evident from the lack of coordination among many Para-state agencies. This has led to unsustainable use of the land and other resources. The mitigation of frequent floods and the associated loss of human life and properties entail the restoration of

interconnectivity among wetlands, restoration of wetlands (removal of encroachments), conservation, and sustainable management of wetlands.

References

1. Ramachandra, T.V. (2002). Restoration and management strategies of wetlands in developing countries. *Electronic Green Journal,* 15. http://egj.lib.uidaho.edu/index.php/egj/article/view/2839/2797
2. Ramachandra, T.V., Kiran, R., & Ahalya, N. (2002). *Status, conservation and management of wetlands.* New Delhi: Allied Publishers.
3. Ramachandra T V, Rajinikanth R and Ranjini V G, (2005), Economic valuation of wetlands, Journal of environment Biology, 26(2):439-447.
4. Kulkarni, V. and Ramachandra T.V. (2009), *Environmental Management*, Commonwealth Of Learning, Canada and Indian Institute of Science, Bangalore, Printed by TERI Press, New Delhi
5. Ramachandra T V, (2009a), Conservation and management of urban wetlands: Strategies and challenges, ENVIS Technical Report: 32, Environmental Information System, Centre for Ecological Sciences, Bangalore.
6. Ramachandra T V, (2009b). Essentials in urban lake monitoring and management, CiSTUP Technical report 1, Urban Ecology, Environment and Policy Research, Centre for Infrastructure, Sustainable Transportation and Urban Planning, IISc, Bangalore
7. Ramachandra T.V and Kumar U, (2008), Wetlands of Greater Bangalore, India: Automatic Delineation through Pattern Classifiers, *The Greendisk Environmental Journal*. Issue 26 (http://egj.lib.uidaho.edu/index.php/egj/article/view/3171).
8. Ramachandra T V and Mujumdar P M, (2009). Urban floods: case study of Bangalore, *Journal of Disaster Development*, 3(2):1-98
9. Ramachandra T.V. and Shwetmala (2009), Emissions from India's Transport sector: State wise Synthesis, *Atmospheric Environment*, 43 (2009) 5510–5517.
10. Ramachandra T.V., (2009c).Soil and Groundwater Pollution from Agricultural Activities, Commonwealth Of Learning, Canada and Indian Institute of Science, Bangalore, Printed by TERI Press, New Delhi.
11. Ramachandra. T.V., Bharath H. Aithal and Durgappa D. Sanna (2012) Insights to Urban Dynamics through Landscape Spatial Pattern Analysis., *International Journal of Applied Earth Observation and Geoinformation*, Vol. 18, Pp. 329-343.
12. Ramachandra T V and Uttam Kumar (2009), Land surface temperature with land cover dynamics: multi-resolution,spatio-temporal data analysis of Greater Bangalore, *International Journal of Geoinformatics*, *5* (3):43-53
13. Ramachandra T. V., Alakananda B, Ali Rani and Khan M A, (2011), Ecological and socio-economic assessment of Varthur wetland, Bengaluru (India), *J Environ Science & Engg*, Vol 53. No 1. p 101-108, January 2011.
14. Ramachandra. T.V., Bharath H. Aithal and Uttam Kumar., (2012). Conservation of Wetlands to Mitigate Urban Floods., Resources, Energy, and Development. 9(1), pp. 1-22.

2.0 Varthur – Bellandur – Yamalur Fiasco

Status	Contaminated water, sediment and air
Cause	1. Encroachment of lakebed, flood plains, and lake itself; 2. Loss in lake interconnectivity - Encroachment of rajakaluves / storm water drains and loss of interconnectivity; 3. Lake reclamation for infrastructure activities; 4. Topography alterations in lake catchment; 5. Unauthorised dumping of municipal solid waste and building debris; 6. Sustained inflow of untreated or partially treated sewage and industrial effluents; 7. Removal of shoreline riparian vegetation; and unabated construction activities in the valley zone has threatened these urban wetlands. 8. Pollution due to enhanced vehicular traffic; 9. Too many para-state agencies and lack of co-ordination among them. 10. Too many para-state agencies and too less governance
Solution	• Good governance (too many para-state agencies and lack of co-ordination) • Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance and action against polluters (encroachers as well as those contaminate through untreated sewage and effluents, dumping of solid wastes) • Digitation of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query based information system to public. • Removal of encroachment near to lakes after the survey based on reliable cadastral maps; • Effective judicial system for speedy disposal of conflicts related to encroachment; • Restriction of the entry of untreated sewage into lakes; • To make land grabbing cognizable non-bail offence; • Letting off only treated sewage into the lake (as in jakkur lake model); • Regular removal of macrophytes in the lakes; • Implementation of 'polluter pays' principle as per water act 1974; • Plant native species of macrophytes in open spaces of lake catchment area; • Stop solid wastes dumping into lakes • Ensure proper fencing of lakes • Restrictions on the diversion of lake for any other purposes; • Complete ban on construction activities in the valley zones.
The restoration and conservation strategies has to be implemented for maintaining the ecological health of aquatic ecosystems, aquatic biodiversity in the region, inter-connectivity among lakes, preserve its physical integrity (shorelines, banks and bottom configurations) and water quality to support healthy riparian, aquatic and wetland ecosystems. The regular monitoring of water bodies and public awareness will help in developing appropriate conservation and management strategies.	

Varthur – Bellandur – Yamalur Fiasco

Lakes in Bangalore are interconnected and there are three valleys and Kormangala-Challaghatta-Bellandur-Varthur Valley is one among them (Figure 2.1). Varthur Lake series belongs to Kormangala-Challaghatta Valley consisting of Byappanahalli, Harlur, Kasavanahalli, Kaikondanahalli, Doddanakundi, Vibuthipura, Kundalahalli, Chinnappanahalli, Bellandur, Agara and Varthur Lakes.

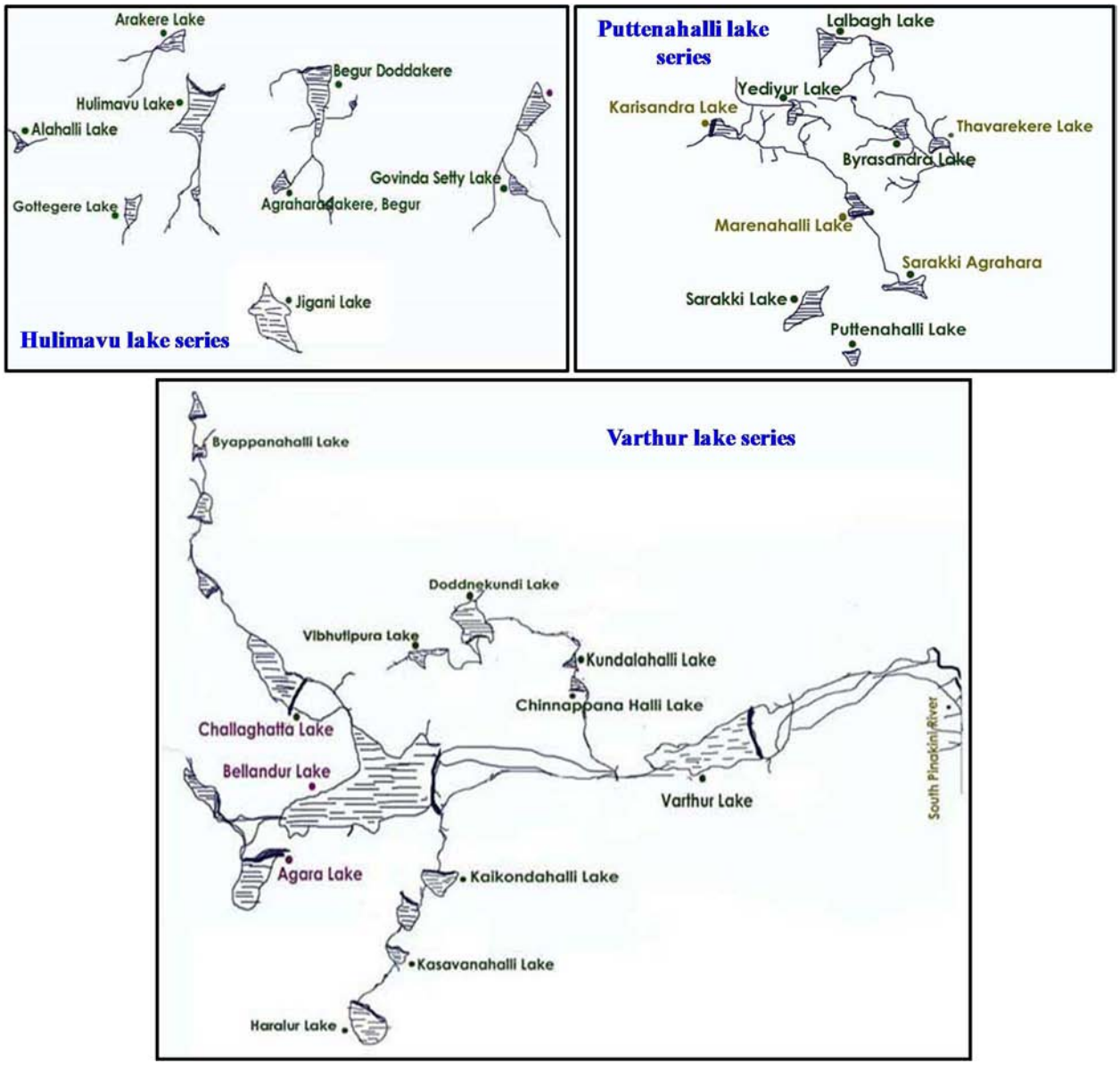


Figure 2.1: Lakes in Kormangala – Challaghatta Valley
(**Source:** http://parisaramahiti.kar.nic.in/vseries.html)

Varthur lake is the second largest lake in Bangalore. It is a part of a system of interconnected tanks and canals, i.e. three chain of lakes in the upstream joins Bellandur lake with a catchment area of about 148 square kilometres (14979 Hectares) and overflow of this lake gets into Varthur lake and from where it flows down the plateau and joins Pinakini river basin. Thus, Varthur lake receives all the surface runoff, wastewater and sewage from the Bangalore South taluk. The pollution levels had increased beyond the lake's assimilative capacity. Thus, nutrient enrichment and profuse growth of macrophytes and algae occurs, which leads to reduced oxygen levels and threats the aquatic life. A decline in ecosystem goods and services was also evident that affects economic growth and livelihood of local people. Thus, Varthur lake series has to be restored in order to maintain and improve the quality of life of local residents of the Varthur lake area.

The water quality analysis show that Varthur is heavily polluted/enriched with nutrients with high organic load, increased decomposition of organic matter, depletion of oxygen levels and macrophytes cover. The overgrowth of algae, bacteria and macrophytes had lowered nitrate level as it is required for their growth as well as reproduction, but orthophosphate levels were very high. The nutrients accumulated in Varthur lake due to sewage entry to the lake water daily (~500 million liters per day, MLD). Foam generated from Varthur lake (at Varthur Kodi junction) and spilled over to a road adjacent to the lake, causing hindrance to traffic movement and emanating a foul smell. It is normally sticky and white in colour. The physico-chemical characteristics of foam samples (collected from V2) of Varthur lake (Kodi junction) revealed that the foam had higher concentrations of ionic as well as organic components. Foams were enriched with particulate organic and inorganic compounds such as nutrients (Nitrogen, Phosphorus and Carbon) and cations (Sodium, Potassium, Calcium and Magnesium). These foams will cause an environmental problem. Varthur lake water has been contaminating groundwater sources. The nutrient enrichment in Varthur lake is evident from the overgrowth of macrophytes (85%) dominated mainly by *Eichhornia* sp., *Alternanthera* sp., *Typha* sp., and *Lemna* sp. The algae of Varthur lake was categorized mainly into four groups like Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae.

This series receives about 500 MLD (million liters per day) of untreated and partially treated sewage daily. ***Sustained inflow of untreated sewage (due to BWSSB) and effluents (from industries) has contaminated the lake as the inflow of pollutants has surpassed the lake's assimilative capacity. Froth formation at outlets, profuse growth and spread of marcrophytes are all the indicators of nutrient enrichment. Nutrients in the form of N (nitrogen), carbon (C) and P (phosphorous) enters the lake through untreated sewage. Major part of N is up-taken by plants and algae while phosphorous and carbon gets trapped in sediments. Due to high wind coupled with high intensity of rainfall leads to upwelling of sediments with the churning of water as it travels from higher elevation to lower elevation forming froth due to phosphorous. Discharge of untreated effluents (rich in hydro carbon) with accidental fire (like throwing cigarettes, beedi) has led to the fire in the lake.***

Rejuvenation of Bellandur -Varthur lake involves:

1. De-silting: Due to sustained inflow of sewage and effluents, lake sediments are contaminated (with heavy metal, etc.). Needs de-silting and technological advancements allow wet dredging in a lake. Removal of accumulated silt will help in the storage of rain water and also recharging of ground water resources in the vicinity. This is essential as the groundwater table in the vicinity is as high as 1000-1500 feet.
2. Treatment of wastewater through constructed wetlands and algal ponds (similar to Jakkur lake). Constructed wetlands with shallow algal ponds helps in the removal of nutrients
3. Allowing only treated wastewater (sewage and effluents) to the lake.
4. Re-establishing interconnectivity among lakes. Removal of all encroachments (of storm water drains and Raja Kaluves). Encroachments of storm water drains has led to stagnation of water and flooding in Yamalur region.
5. Ban on alterations in the topography. Due to large scale land use changes and filling of low lying area, some of the new localities are now vulnerable to floods.
6. Removal of all encroachments in the lake bed. We need to show mercy to our next generation (not to land grabbers) and evict all types of encroachers.
7. Re-establishing wetlands at the inlets of these lakes. Bellandur lake on either side (inlet as well as at outlets) had large spatial extent wetlands, which have been and are being encroached by land mafia. These encroachments have to be evicted immediately to ensure the successful lake restoration and ensuring water security in the region.
8. Maintaining 30 m buffer around the lake (with regulated activities)
9. Stoppage of dumping of solid waste (and building debris in the lake bed and in the lake) and disposal of liquid waste by tankers.
10. Constituting lake conservation committee consisting of all stakeholders for regular monitoring and management.
11. Threshold on high raise building in the region. Need to protect valley zones considering ecological function and these regions are 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015. No new projects in Bangalore unless carrying capacity assessment is done.
12. Rejuvenation is meaningful only when all interconnected lakes in the series are restored otherwise Bellandur and Varthur lake will continue to face contamination due to polluted lakes in the upstream.

INTRODUCTION

Wetlands constitute a transitional zone between terrestrial and aquatic habitats, which are influenced to varying degrees by both terrestrial and aquatic habitats. They differ widely in character due to regional and local differences in climate, soils, topography, hydrology, water chemistry, vegetation, and other factors (Ramachandra and Rajinikanth, 2005). Wetlands supports large biological diversity and provide a wide range of ecosystem services, such as food and fibre; waste assimilation; water purification; flood mitigation; erosion control; groundwater

recharge; microclimate regulation; support many significant recreational, social and cultural activities, besides being a part of our cultural heritage (Ramachandra, 2012). Lakes have vanished due to adhoc approaches in planning leading to intense urbanization and urban sprawl. Some lakes are reduced to small pools of water, some are unauthorized encroached for illegal buildings, some have undergone unauthorised encroachment by slums and private parties, some have dried up and are leased out by the Government, many are sewage fed and are also used as dumping yards for either municipal solid waste or building debris (Ramachandra, 2010). Lack of proper management strategies will eventually lead to loss of lakes around Bangalore and depletion of ground water resources (Shivakumar, 2008). The failure to restore these ecosystems will result in extinction of species or ecosystem types and cause permanent ecological damage (Ramachandra, 2008).

Greater Bangalore (77°37'19.54'' E and 12°59'09.76'' N) is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka with an area of 741 square kilometers and lies between the latitudes 12°39'00'' to 131°3'00''N and longitude 77°22'00'' to 77°52'00''E. Bangalore is located at an altitude of 920 metres above mean sea level, delineating three watersheds: Hebbal, Koramangala - Challaghatta and Vrishabhavathi watersheds. The undulating terrain in the region has facilitated creation of a large number of tanks for traditional uses such as irrigation, drinking, fishing, and washing (Ramachandra and Kumar, 2008). Bangalore has grown spatially more than ten times since 1949 (~69 square kilometers to 741) and is the fifth largest metropolis in India. The rapid urbanization process in Bangalore has led to the drastic changes in land use leading to imbalance in biological and social environment. There has been a % growth in built-up area during the last four decades with the decline of vegetation by 66% and water bodies by 74% (Ramachandra et al., 2012). The population has increased accounting for 45.68% growth in a decade. (Ramachandra et al., 2013).

Varthur lake is located in the south of Bangalore District in Karnataka. This lake is the second largest freshwater body in Bangalore built by the Ganga Kings over a thousand years ago for domestic and agricultural purposes. It covers a water-spread area of 190 ha (mean depth 1.1 m). It is a part of a system of interconnected tanks (figure 2.1, table 2.1) and canals that receive all the surface runoff, wastewater and sewage from the Bangalore South taluk and finally drains into the Dakshina Pinakini River (Mahapatra et al., 2011). The lake provides the local community with a pleasant microclimate and considerable aesthetic appeal. Varthur lake is surrounded by small farms that grow rice, ragi, coconut, flowers, and a variety of fruits and vegetables using the lake water (Ramachandra et al., 2006).

Lakes should maintain the physical, chemical and biological integrity for the survival, growth and reproduction of aquatic as well as riparian communities (Ramachandra, 2005). Most of the sewage and wastewater generated is discharged directly into storm water drains that are ultimately linked to water bodies which have contaminated the surface and ground waters. The

deterioration and degradation of lake water quality occurs due to inflow of untreated sewage, dumping of domestic and municipal solid waste, silt and nutrient accumulation that allow profuse growth of algae and aquatic plants leading to depletion of aquatic biodiversity and other anthropogenic activities (like encroachments etc.). These activities in the lake would lead to the extinction or permanent ecological damages, so proper restoration measures and conservation strategies should be taken immediately

Pollution of aquatic ecosystems causes a decline in ecosystem goods and services that affects economic growth and livelihood of local people (Ramachandra et al., 2011). Rapid development and population expansion within Bangalore and its surrounding towns and villages, have polluted tanks and lakes in the area. . The sewage brings in large quantities of C, N and P that enables massive algal and macrophyte (water hyacinth, covering about 85% lake area) growth and malodour generation (Mahapatra et al., 2011).

Table 2.1: Lakes in Varthur series and their area (**Source:** http://parisaramahiti.kar.nic.in/vseries.html)

Sl. No.	Name of the Lake	Area (Hectares)
1	Byappanahalli Lake	3.23
2	Haralur Lake	5.16
3	Kasavanahalli Lake	8.91
4	Kaikondanahalli Lake	27.09
5	Doddanakundi Lake	47.08
6	Vibhuthipura Lake	30.20
7	Kundalahalli Lake	10.48
8	Chinnappanahalli Lake	56.80
9	Varthur Lake	180.40

Foam from Varthur lake has spilled over to a road adjacent to the lake, causing hindrance to traffic movement on the busy road and a foul smell was emanating from it at Varthur Kodi junction on 29/04/2015, in the morning. Foams are formed in lakes due to sustained inflow of sewage (rich in phosphates). Decomposition of algae, fish and macrophytes, releasing a variety of organic compounds into the water body. These organic compounds act as surfactants (foaming agents) that has a hydrophilic (water attracting) end and hydrophobic hydrocarbon chain (water repelling) at the other end. Also, surface-active agents in wastewater include synthetic detergents, fats, oils, greases and biosurfactants. These agents rise to the surface of lakes and interact with water molecules thus, reducing the attraction of water molecules to each other (i.e. surface tension of the water). When the surface tension decreases, air mixes with the water molecules and foaming agents resulting in bubbles formation. These bubbles aggregate together and forms foam in lakes (figure 2.2). The foams formed in large quantities moves to shorelines by wind and water currents. Natural foams are usually linked to humic and fulvic acid substances, fine colloidal particles, lipids and proteins released from aquatic or terrestrial plants,

saponins (plant glycosides), the decomposition products of phytoplankton containing carbohydrates and proteins and the organic matter in sediments (Schilling and Zessner, 2011).

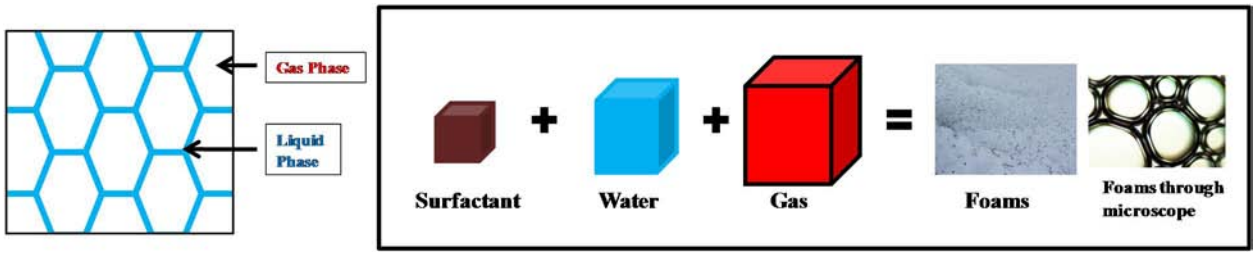


Figure 2.2: Structure and formation of foam in lakes

Foam accumulates compounds that are repelled by water (hydrophobic). Thus, foams are enriched with particulate organic and inorganic compounds such as nutrients (Nitrogen, Phosphorus, Carbon), cations (Sodium, Potassium, Calcium, Magnesium), heavy metals (Cadmium, Copper, Iron, Lead, Zinc) and chlorinated hydrocarbons. The organisms that inhabit the surface layer will be exposed to these contaminants and thus, affect the food web. These foams will cause an environmental problem, when it reaches drinking water supplies.

OBJECTIVE: The main objective of the study is to assess the present status of Varthur lake and to understand the causal factors of the foam emerging out of the lake and to suggest remedial measures for the protection of the lake.

MATERIALS AND METHODS

Study Area: Varthur lake (12°57 ′24.98″ to 12°56′31.24″ N, 77°43′03.02″ to 77°44′51.1″ E) is located in the Bangalore South taluk of the Bangalore District in Karnataka (figure 2.3). It covers a water-spread area of 190 ha and is the main irrigation source to the nearby agricultural fields and, supports a wide variety of flora and fauna. The average annual rainfall of Bangalore is 859 mm and temperatures vary from 14°C (December to January) to 33°C (maximum during March to May). There are two rainy periods, i.e. from June to September (south-west monsoon) and November to December (north-east monsoon).

Water Quality Analysis: The analysis of physico- chemical parameters like water temperature (WT); pH; total dissolved solids (TDS); electrical conductivity (EC); dissolved oxygen (DO); chemical oxygen demand (COD); total alkalinity (TA); chloride (Cl); total hardness (TH); calcium hardness (CaH); magnesium hardness (MgH); nitrate; orthophosphate (OP); sodium (Na) and potassium (K) of water and foam samples collected from Varthur lake were done according to the standard protocol (table 2.2; figure 2.4) as per APHA AWWA WEF (1998) and Trivedy Goel (1986).

Figure 2.3: Google Earth image of Varthur lake

Table 2.2: Standard methods followed for water quality analysis

Parameters	**Methods (with Reference)**
Onsite Measurements	
Water temperature (^{0}C)	Eutech: PCSTestr 35
pH	Eutech: PCSTestr 35
Total Dissolved Solids (TDS, mg/l)	Eutech: PCSTestr 35
Electrical conductivity (µS/cm)	Eutech: PCSTestr 35
Dissolved Oxygen (DO) (mg/l)	Winkler's Method (APHA, 1998: 4500-O)
Laboratory Measurements	
Hardness (mg/l)	EDTA titrimetric method (APHA, 1998: 2340-C)
Calcium hardness (mg/l)	EDTA titrimetric method (APHA, 1998: 3500-Ca B)
Magnesium hardness (mg/l)	Magnesium by calculation (APHA, 1998:3500-Mg)
Sodium (mg/l)	Flame emission photometric method (APHA, 1998:3500-Na B)
Potassium (mg/l)	Flame emission photometric method (APHA, 1998: 3500-K B)
Alkalinity (mg/l)	Titrimetric method (APHA, 1998: 2320 B)
Chloride (mg/l)	Argentometric method (APHA, 1998:4500-Cl^- B)
Biochemical Oxygen Demand (BOD) (mg/l)	5-Day BOD test (APHA, 5210 B, Trivedi&Goel, 1986, pp.53-55)
Chemical Oxygen Demand (COD) (mg/l)	Closed reflux, titrimetric method (APHA, 5220 C, Trivedi&Goel, 1986, pp.55-57)
Nitrates	Phenol Disulphonic acid method (Trivedy and Goel, 1986: pp 61)
Orthophosphates (mg/l)	Stannous chloride method (APHA, 4500-P)

Figure 2.4: Collection of water and foam from Varthur South (V1) and North (V2) outlets.

RESULTS AND DISCUSSIONS

The physico-chemical parameters of water (collected from V1 and V2) and foam samples (from V2) of Varthur lake (table 2.3) revealed that the foam had higher concentrations of all the parameters compared to that of water. Thus, foams are enriched with particulate organic and inorganic compounds such as nutrients (Nitrogen, Phosphorus and Carbon), cations (Sodium, Potassium, Calcium and Magnesium). Foam generated is normally sticky and white in color. Most surfactants originate from the detergents, oil and grease that are used in households or industry. Surfactant could stabilize the foaming and allow foam to accumulate. The organisms living at the surface layer of lake will be exposed to these contaminants and thus, these contaminants enter the food chain/web. These foams will cause an environmental problem. The use of Varthur lake water for domestic and irrigational purposes will be harmful and this is likely to contaminate groundwater.

Table 2.3: Physico-chemical parameters of water and foam samples from Varthur lake (01/05/2015)

Parameters	V1	V2	Foam
Water temperature (^{0}C)	27.1	26.9	27.2
TDS (mg/l)	448	454	7000
EC (µS)	749	764	17000
pH	7.46	7.35	6.98
DO (mg/l)	2.6	0	-
BOD (mg/l)	24.39	60.98	650.41
COD (mg/l)	40	88	1140
Alkalinity (mg/l)	336	336	12000
Chloride (mg/l)	117.86	122.12	3195
Total Hardness (mg/l)	206	224	13000
Ca Hardness (mg/l)	57.72	64.13	3607.2
Mg Hardness (mg/l)	36.03	38.85	2282.45
Phosphate (mg/l)	1.263	0.881	74.59
Nitrate (mg/l)	0.541	0.361	129.72
Sodium	169.5	161	770
Potassium	35	34	230

REVIEW OF VARTHUR LAKE WATER QUALITY (from 2001 – 2015)

The physico-chemical characteristics of Varthur lake from 2001 to 2015 (table 2.4, 2.5; figure 2.5) revealed that Varthur lake had received higher amounts of nutrients and ionic components over years. The presence of higher amount of different physico-chemical parameters like total dissolved solids (332-1246 mg/l); electrical conductivity (460-1470 µS); dissolved oxygen (0-8.16 mg/l); chemical oxygen demand (40-325.33 mg/l); biochemical oxygen demand (24.39-140.8 mg/l); alkalinity (56-520 mg/l); chloride (88.04-191.7 mg/l); total hardness (198-436 mg/l); calcium hardness (56.11-344.27 mg/l); magnesium hardness (18.08-124 mg/l); sodium (9-1046 mg/l) and potassium (0-130 mg/l), indicate pollution/sewage entry into the lake as per CPCB standards (table 2.6).

Table 2.4: Physico-chemical parameters of Varthur lake at South outlet (V1)

	2015	2014	2013	2013	2009	2008	2002	2001	2001
WT (^{0}C)	27.1	32	24	24.4	30	26.3	22	26	23
TDS (mg/l)	448	596	500	532	749	840	1204	335	358
EC (µS)	749	1027	1030	1084	1075	1057	1470	460	474
pH	7.46	7.57	7.5	7.2	7.5	8.06	-	8	-
DO (mg/l)	2.6	0.24	0	0	8.16	0.81	2.2	2.8	5.5
COD (mg/l)	40	69.29	168	44	124	229.33	-	-	-
TA (mg/l)	336	520	317.33	377.33	400	300	-	-	348
Chloride (mg/l)	117.86	176.79	132.06	142	173.24	88.04	170	-	96
TH (mg/l)	206	253	198	210	236	420	251.1	383.7	218.4
Ca H (mg/l)	57.72	158.15	62.52	70.01	128	344.27	-	-	-
Mg H (mg/l)	36.03	23.05	32.92	34.02	26.24	102.4	-	-	-
OP (mg/l)	1.263	0.527	0.084	0.664	4.22	1.8	15.06	-	1
Nitrate (mg/l)	0.541	0.112	0.466	0.487	0.47	0.04	1.3	0.21	0.3
Na (mg/l)	169.5	178	41.2	208	174	23.2	-	1046	18.9
K (mg/l)	35	35.6	5.6	43.6	19	4.3	1.8	115	21.4
BOD (mg/l)	24.39	-	-	-	119.5	40.78	74.2	-	-

Note: 2013 – twice sampling was done

Table 2.5: Physico-chemical parameters of Varthur lake at North outlet (V2)

	2015	2013	2013	2011	2010	2010	2010	2010	2009	2008	2003	2003	2003	2002	2001	2001
WT (^{0}C)	26.9	24.4	25	-	29.5	27.5	26.5	26	26	25.6	27	27	23	23	27	26
TDS (mg/l)	454	489	532	-	636	700	-	-	849	849	-	-	-	1246	332	371
EC (µS)	764	1014	1075	1054	798	890	-	-	1224	1068	460	474	1420	1420	460	474
pH	7.35	7.7	7.2	7.61	7.84	7.58	8	8	7.5	9.03	7.61	7.55	7.68	-	7.75	-
DO (mg/l)	0	0	0	1.56	4.07	7.15	1.63	4.06	0	4.22	2	3	2.9	2.9	2	3
COD (mg/l)	88	184	52	98.2	192	298.67	-	234.66	188	325.33	-	-	82.2	-	-	-
TA (mg/l)	336	308	372	-	260	56	-	120	420	420	-	-	-	-	-	332
Cl (mg/l)	122.12	130.64	142	-	119.28	142	-	142	191.7	144.84	-	100	170	170	-	100
TH (mg/l)	224	198	214	-	264	236	292	420	288	436	213.6	209.3	232.5	232.5	213.6	209.3
Ca H (mg/l)	64.13	56.11	70.01	-	132	112	200	188.17	135	176.14	132	124	158.1	-	-	-
Mg H (mg/l)	38.85	34.48	34.99	-	85.39	124	92	48.76	37.18	106.38	19.83	20.73	18.08	-	-	-
OP (mg/l)	0.881	0.18	0.596	0.98	0.05	1.73	4.175	0.718	5	1.7	-	1	15.54	1.5	-	1
Nitrate (mg/l)	0.361	0.418	0.364	0.3	0.03	0.28	0.162	0.24	0.55	0.04	-	-	-	1.4	-	1.07
Na (mg/l)	161	48	202	-	34.6	31.5	-	18.93	180	19.4	-	-	-	9	907	32.8
K (mg/l)	34	12	43.2	-	6.7	6.3	0	0	19	3.5	-	-	-	2.2	130	20.2
BOD (mg/l)	60.98	-	-	89.7	46.28	55.28	44.7	-	140.8	41.68	-	-	74.2	74.2	-	-

Note: 2013 and 2001 – twice sampling was done, quarterly sampling in 2010 and 2003

Higher values of chemical parameters in Varthur lake is due to the sustained inflow of untreated daily (~500 million liters per day, MLD). The BOD and COD values reflected high pollution at Varthur with heavy organic load, decomposition of organic matter, depletion of oxygen levels and macrophytes cover. Water temperature (22-32°C) showed seasonal variations, while pH was found to be alkaline (7.2- 9.03). The nutrient like nitrate (0.03-1.4 mg/l) was lower in the system due to the uptake of nutrients by algae, bacteria and macrophytes for growth as well as reproduction. The orthophosphate (0.05-15.54 mg/l) levels were high.

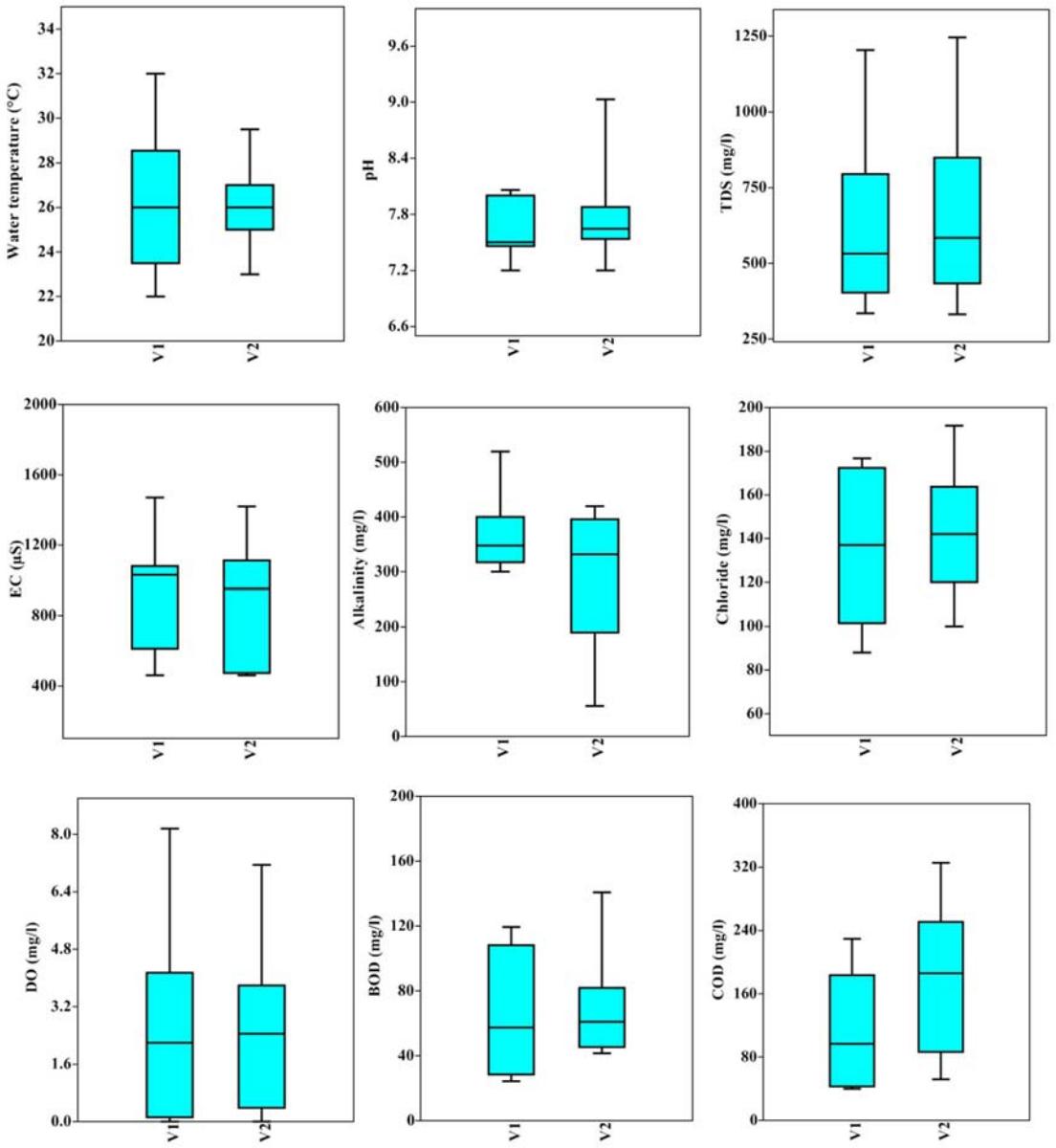
Table 2.6: Classification of Inland Surface Water (CPCB)

As per ISI-IS: 2296-1982	
Classification	**Type of use**
Class A	Drinking water source without conventional treatment but after disinfection
Class B	Outdoor bathing
Class C	Drinking water source with conventional treatment followed by disinfection.
Class D	Fish culture and wild life propagation
Class E	Irrigation, industrial cooling or controlled waste disposal

Characteristic	**A**	**B**	**C**	**D**	**E**
pH	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.0 - 8.5
DO (mg/L)	6	5	4	4	-
BOD (mg/L)	2	3	3	-	-
TDS, mg/l, Max	500	-	1500	-	2100
Electrical Conductance at 25 °C, µS, Max	-	-	-	1000	2250
Total Hardness (as $CaCO_3$), mg/l, Max	300	-	-	-	-
Calcium Hardness (as $CaCO_3$), mg/l, Max	200	-	-	-	-
Magnesium Hardness (as $CaCO_3$), mg/l, Max	100	-	-	-	-
Chlorides (as Cl), mg/l, Max	250	-	600	-	600
Nitrates (as NO_2), mg/1, Max	20	-	50	-	-

The continuous entry of sewage water and rainwater runoff to Varthur lake had reduced the depth of the lake (due to sedimentation with silt transport from the catchment due to large scale construction activities), reduction of ground water recharge (sedimentation has formed semi-paved surface, reducing the groundwater recharge potential) and contamination of ground water (due to sustained inflow of untreated sewage from household and untreated effluents from

industries). The solid waste dumping and discharge of municipal wastewater had caused nutrient enrichment in Varthur lake, which is evident from the overgrowth of macrophytes (85%) dominated mainly by *Eichhornia* sp., *Alternanthera* sp., *Typha* sp., and *Lemna* sp. The algae of Varthur lake was categorized mainly into 4 groups: Chlorophyceae (*Chlamydomonas* sp., *Chlorogonium* sp., *Scenedesmus* sp., *Ankistrodesmus* sp., *Chlorella* sp., *Oedogonium* sp.); Cyanophyceae (*Cylindrospermopsis* sp., *Arthrospira* sp., *Microcystis* sp., *Oscillatoria* sp., *Anabaena* sp., *Merismopedia* sp., *Lyngbya* sp.); Bacillariophyceae (*Gomphonema* sp., *Cymbella* sp., *Navicula* sp., *Pinnularia* sp., *Nitzschia* sp., *Synedra* sp., *Fragilaria* sp., *Cocconeis* sp., *Melosira* sp.); Euglenophyceae (*Phacus* sp., *Euglena* sp., *Trachelomonas* sp., *Lepocinclis* sp.).



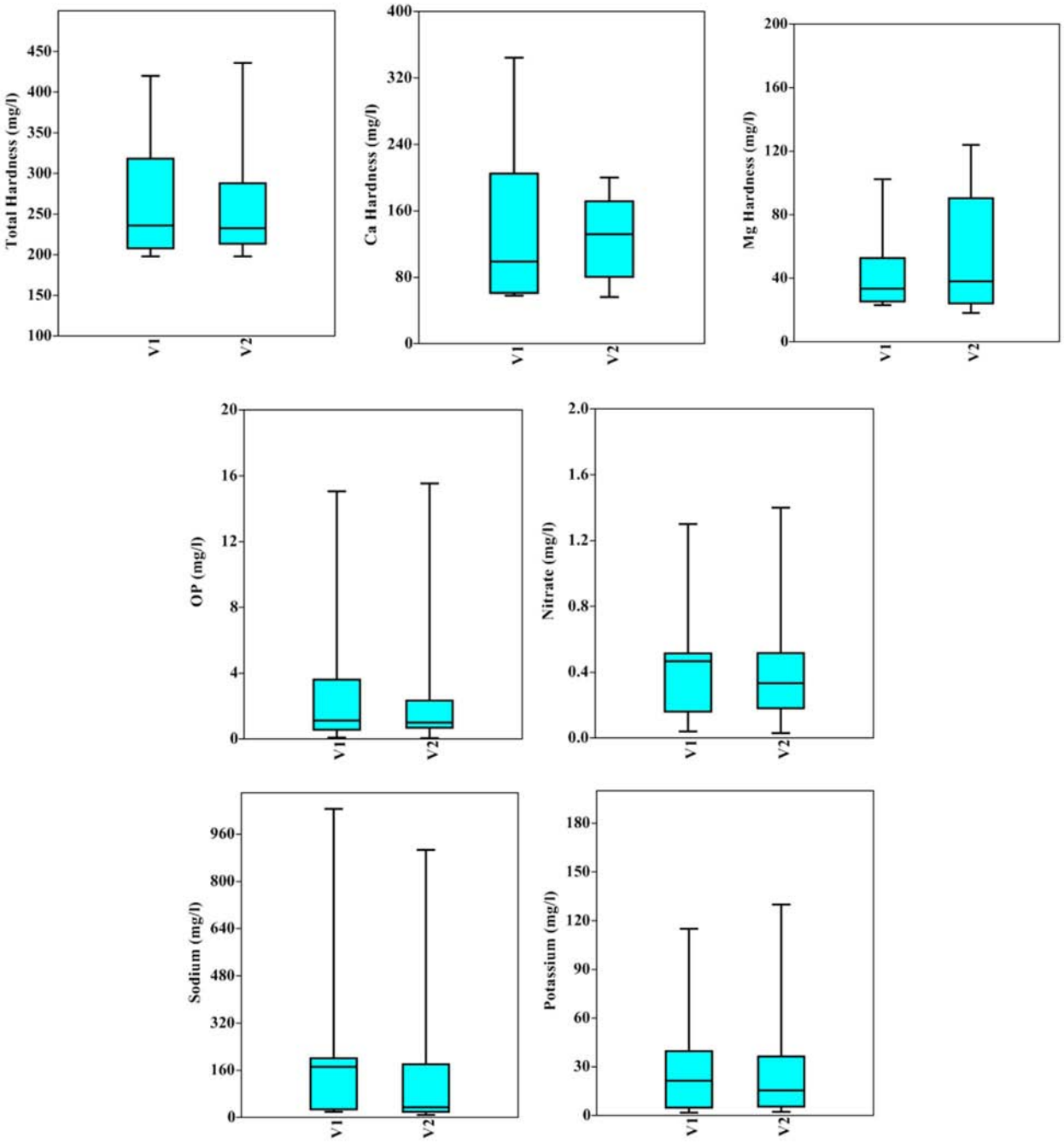


Figure 2.5: Temporal variation of physico-chemical parameters in Varthur lake water samples (2001 to 2015).

WATER QUALITY AND PHYTOPLANKTON STUDIES ON VARTHUR LAKE

Table 2.7: Water quality studies on Varthur lake (2001 – 2013)

Influence of Catchment Land Cover Dynamics on the Physical, Chemical and Biological Integrity of Wetlands LULC changes in the wetland catchment that alters the physical and chemical integrity of the system are the direct and indirect consequence of anthropogenic activities leading to loss of biodiversity, water and soil pollution and climatic changes. Varthur wetland with high percent of built-up and being densely populated is in stressed condition with high pollution due to inflow of sewage and industrial wastes. During the study, hypoxic and even anoxic condition prevailed due to low dissolved oxygen levels that attributed to the presence of water hyacinth covering the water surface, with heavy domestic organic load and decomposition of organic matter. Thus, the concentration of both BOD and COD exceeded the permissible limits at all sampling sites and across months. Total hardness (236-420 mg/l), alkalinity (55-440 mg/l) and chlorides (119.28-153.36 mg/l) were recorded very high due to sewage inflow. Thus, the plans for conservation of wetlands should be done at catchment scale. Diatom community comprised of pollution tolerant species reflecting trophic status. Pollution tolerant diatoms dominated the wetlands with eutrophic water quality condition. The species such as *Gomphonema parvulum, Cyclotella meneghiniana, Nitzschia palea* and *Nitzschia umbonata* are tolerant to high electrolyte and organic rich condition inhabited Varthur wetland. This clearly signifies that the wetland is polluted and eutrophic in condition. Thus, catchment characteristics are critical in determining biota of freshwater bodies, thus plans for conservation of wetlands should also be seen at catchment scale, rather than looking wetlands as isolated ecosystem. **Recommendation**: The restoration and conservation measures should be taken based on the LULC changes in the catchment area of wetlands. **Reference**: Ramachandra T.V, Meera D.S. and Alakananda B., 2013, Influence of Catchment Land Cover Dynamics on the Physical, Chemical and Biological Integrity of Wetlands, *Environment & We -International Journal of Science & Technology - (EWIJST)*, 8(1): 37-54.	**Annexure 1** **2013**
Biomonitoring to Assess the Efficacy of Restoration and Management of Urban Water Bodies The Varthur lake categorized under polluted wetlands was characterized by high ionic contents with high EC (1245.5 µS), BOD (34.27 mg/l) and COD (81.3 mg/l) but low DO levels (2.96 mg/l), indicating the presence of high organic matter. Varthur lake had about 91.7% of eutrophic algal species with a Shannon diversity of 1.28 and Dominance index of 0.37. The abundance of *Cyclotella meneghiniana*, *Nitzschia palea*, *Fallacia pygmaea* and *Staurosirella pinnata* were evident. **Reference**: Alakananda B., Mahesh M.K and Ramachandra T.V., 2013, Biomonitoring to assess the efficacy of restoration and management of urban water bodies, *International Journal of Environmental Sciences*, Vol 2 (3), pp: 165-178.	**Annexure 2** **2013**

Role of Macrophytes in a Sewage Fed Urban Lake Macrophytes help in maintaining the nutrient levels in urban lakes. The analysis of seasonal data of Varthur lake reveals that dissolved oxygen concentration and redox condition is dependent on the extent of macrophyte spread. The increase in nutrient content (32 t N/d) due to sustained inflow of sewage has resulted in the prolific growth of invasive species like water hyacinth (*Eichhornia crassipes*). This hinders aerobic functioning of the lake by restricting sunlight penetration and hence, reducing algal photosynthesis. This in turn, results in anoxic environment due to blockage of air-water interface, influencing oxygen diffusion. The roots of these floating macrophytes provide a good substratum for the attachment of bacteria, increasing bacterial activity in the system that leads to reduced DO levels. The increased amount of plant litter decomposition also contributes to higher autochthonous organic load and hence higher BOD levels. In Varthur lake (with 85% macrophytes cover), highly anaerobic conditions (-235 mV), low DO level (0 mg/l) and high BOD load (180 mg/l) persisted during summer. Varthur lake behaves as an aerobic lagoon in monsoon, aerobic-anaerobic lagoon in pre-monsoon and as anaerobic–aerobic system in post-monsoon. The overgrowth, ageing, and subsequent decay of macrophytes creates anoxic conditions and devours the lake from oxygen, which in turn, affects the food chain and interferes with the ecological integrity of the system. This necessitates the regular removal of macrophytes from the lake, which allows the growth of primary producers and other aquatic organisms. **Recommendation**: Regular removal of macrophytes from the lake. **Reference**: Durga Madhab Mahapatra, Chanakya H.N., Ramachandra. T.V., 2011, Role of macrophytes in a sewage fed urban lake. *Institute of Integrative Omics and Applied Biotechnology Journal (IIOABJ)*, Vol. 2, Issue 8, pp. 1-9.	**Annexure 3** **2011**
Ecological and Socio-Economic Assessment of Varthur Wetland, Bengaluru (India) The socio-economic survey and water quality analysis showed a decline of ecosystem goods and services with the decline in water quality affecting the livelihood of dependent population and local economy. Varthur had a total economic value of only Rs 118.9/ha/d, which is lower than unpolluted lakes. The main effects of pollutants entering Varthur lake are disappearance of native species, dominance of invasive exotic species (African catfish), in addition to profuse breeding of disease vectors and pathogens. This necessitates the implementation of sustainable management strategies to recover the lost wetland benefits or to enhance the use-value of Varthur lake. The strategies include restoration of wetlands, letting of treated sewage into the wetlands, letting treated water through series of wetlands for further improvement of water quality, removal of excess growth of macrophytes and exotic fish species, regular monitoring of wetlands, public awareness and enhanced co-operation among government agencies. Also, water treatment plant for Varthur wetland will improve the water quality and the massive sludge can be used for agricultural fields as fertilizers.	**Annexure 4** **2011**

Reference: Ramachandra T. V., Alakananda B, Ali Rani and Khan M. A, 2011, Ecological and socio-economic assessment of Varthur wetland, Bengaluru (India), *Journal of Environment Science & Engineering*, Vol 53. No 1. p 101-108, January 2011.	
C:N Ratio of Sediments in a Sewage Fed Urban Lake The analysis of C:N ratio of surficial sediments collected from Varthur lake was done as the sludge/sediments act as a major sink for C and N. The C and N values were found to be significantly higher in the deeper areas than the shallow inlet regions due to the accumulation of autochthonous organic material. About 60% of the nutrients were terrestrial in origin. The quantity of C and N stored on the sediments in a daily basis was large which accounts to 9 t C and 2.9 t N. The north side of the lake had higher C content compared to the other regions, which attributed to higher anthropogenic effects and terrestrial C sources like sewage from the urbanized pocket. A lower C value in the southern side is attributable to suburb type habitations with more agricultural fields in the immediate vicinity. The lake has a higher organic matter at the centre and near the outlets, due to rapid decay and settling of the autochthonous organic matter. The N content was very low (below 5% of the dry wt.) in the sediment/sludge sample of Varthur lake, indicating an N deficient system. The N limitation is due to uptake by micro and macro-biota or rapid volatilization, denitrification and leaching in water. The organic N in the sediments will be transformed to various inorganic forms as nitrites, ammonia, nitrous oxide or molecular nitrogen. The source of organic matter (OM) in sediments of Varthur lake is essentially autochthonous macrophytes near the outlets and terrestrial N near the inlet zones, whereas the middle part OM is phycogenic in origin. The C/N ratios indicate that run-off water from the catchment can increase the terrestrial OM component. This lake surrounded by agricultural and horticultural lands (67%) can increase OM content. Therefore, proper wastewater management strategies have to be taken to minimize sewage inflow and prevent agricultural run-off into the lake systems. **Reference**: Durga Madhab Mahapatra, Chanakya H. N. and T. V. Ramachandra, 2011, C:N ratio of Sediments in a sewage fed Urban Lake. *International Journal of Geology*, Issue 3, Vol. 5, pp. 86 - 92.	**Annexure 5** **2011**
Assessment of Treatment Capabilities of Varthur Lake, Bangalore, India This study includes the physico-chemical and biological analysis of sewage-fed Varthur lake and assessment of its treatment capabilities in terms of BOD removal, nutrient assimilation and self-remediation. Varthur lake with an average water depth of 1.1m, water spread area of 220 ha, and receiving about 500 MLD of wastewater per day has a water retention time of 4.84d. Anaerobic conditions (0 mg/L) prevailed at the inlet but at the middle and outlets DO were higher due to algal photosynthetic activities. About >50% BOD removal was achieved in the monsoon season but the extensive coverage of macrophytes during February - May lowered the organic decomposition, and BOD removal. Alkalinity, TDS, conductivity and hardness values were higher than earlier studies due to continuous influx of untreated sewage.	**Annexure 6** **2011**

The lake behaved as an anaerobic - aerobic lagoon. The primary producers (phytoplankton) treated the water to nearly standard water quality levels. The macrophytes and the algae together with wetland vegetation have an important role in regulating the amount of nutrients. The role of macrophytes and phytoplankton in removing nutrients in sewage-enriched systems varies with the nature of the effluent and age of the wetland, in addition to other environmental factors like sunlight. **Reference**: Mahapatra, D.M., Chanakya, H.N. and Ramachandra, T.V. 2011, Assessment of Treatment capabilities of Varthur Lake, Bangalore, India. *International Journal of Environment, Technology and Management*, Vol. 14, Nos. 1/2/3/4, pp. 84-102.	
Biofuel Prospects of Microalgal Community in Urban Wetlands Varthur lake showed moderate water quality. The class Bacillariophyta (diatoms) and Chlorophyta dominated at Varthur lake as well as agricultural sample with *Achnanthidium* sp., *Gomphonema* sp., *Nitzschia* sp., *Navicula* sp., *Chlamydomonas* sp., *Scenedesmus* sp. and *Anabaena* sp. accounting more in number (occurrence number in microscopic field). The Varthur lake and agriculture field samples had diatoms that are lipid-rich were suggested as an important source for biodiesel. **Reference**: Ramachandra, T.V., Alakananda, B. and Supriya G., 2011, Biofuel prospects of microalgal community in urban wetlands. *International Journal of Environmental Protection (IJEP)*, Vol.1 No. 2, PP.54-61.	**Annexure 7** **2011**
Algal Photosynthetic Dynamics in Urban Lakes Under Stress Conditions Varthur lake is undergoing a high nutrient stress resulting in anaerobic conditions with prolonged sewage inflow. Thus, deprivation of oxygen (hypoxic conditions at the inflow region and 4.22 mg/l at the outlets of Varthur lake) is an indicator of the present trophic status of the lake, which is rich in inorganic and organic matter making the conditions increasingly eutrophied. The biochemical oxygen demand levels in Varthur lake (BOD level: 40.78 - 99.95 mg/l) indicate higher levels of biodegradable organic matter, high oxygen consumption by heterotrophic organisms and a high rate of organic matter remineralization. The phosphate content in Varthur lake (1.3-2.1 mg/l) was well beyond the eutrophic levels due the inflow of sewage, sediment resuspension during high turbulence period, anaerobic conditions at the lake bottom and agricultural runoff from the cultivated lands nearby. The nitrate content in Varthur (0.03 – 0.05 mg/l) was very low due to the growth of aquatic weeds, persistence of anaerobic conditions and scant oxidation. The Day net productivity values indicates lower productivities in Varthur lake which can be attributed to decreased transparency and hence, lesser sunlight penetration due to microalgal bloom (*Chlorella* sp.). The productivity of the lake directly linked to the type and the abundance of the algal community. In Varthur lake, the algal community dominated by *Chlorella* sp. (member of Chlorophyceae) that comprised of *C. vulgaris*, *C. pyrenoidosa* and *C.minutissima*, followed by members of Bacillariophyceae (18%) as *Nitzschia palea* and *Gomphonema parvulum*. *Microcystis aeruginosa* (Cyanophyceae) occured in minor proportions (1%). The abundance of Chlorophyceae and Cyanophyceae	**Annexure 8** **2010**

members in Varthur lake is an indicator of organic pollution and nutrient accumulation. The turbidity values shows very high algal abundance in Varthur lake, which is attributing to algal bloom, coincides with the high inorganic nutrients and high BOD values. Chlorophyceae growth depends upon the nutrient load and is an indicator of trophic status of the lake. **Reference**: Durga Madhab Mahapatra, Supriya Guruprasad, Chanakya H. N. and Ramachandra T. V., 2010, Algal Photosynthetic Dynamics in Urban Lakes under Stress Conditions. Proceedings of the Conference on Infrastructure, Sustainable Transportation and Urban Planning CiSTUP@CiSTUP 2010, 18th - 20th October 2010, C*i*STUP, IISc, Bangalore.	
Status of Varthur Lake: Opportunities for Restoration and Sustainable Management This study focuses on restoration aspects of Varthur lake based on hydrological, morphometric, physical-chemical and socio-economic aspects. The results of the water quality analysis showed that the lake is eutrophic with high concentrations of phosphorous and organic matter. The results of the morphometric analysis reveal that Varthur is a shallow lake, with a very large surface area in relation to its depth. The total area of the lake was estimated 1,478,000 m^2. The bathymetric map of Varthur lake shows that the lake has an estimated maximum depth of approximately 2.0 meters with the mean depth of 1.05 m. The lake bottom exhibits a very gradual downward slope from west to east, with maximum observed depth occurring near the dam wall. The presence of bacterium *Escherichia coli* in Varthur indicates faecal contamination. The water quality analysis of groundwater revealed that the parameters (ammonia, chloride, electrical conductivity, fluoride, nitrate, and pH) were within the limits set by Indian Standards Specification for Drinking Water. The lake water has not contaminated the groundwater in the vicinity. The socio-economic aspects of Varthur lake showed that local residents relied heavily on the lake for cattle fodder and irrigation. The total land area irrigated using Varthur lake water was 622.27 hectares and the total number of farmers dependent on the lake water for irrigational purposes was1159. The crops grown in Varthur village include paddy, coconut, banana, beetle leaf, arecanut and floriculture. Thus, the lake has to be restored in order to maintain and improve the quality of life of local residents of the Varthur lake area. **Recommendations:** Pollution impediment, harvesting of macrophytes, desiltation, rain water harvesting, watershed management and the adoption of restoration programmes with an ecosystem approach through Best Management Practices (BMPs) which will help in correcting point and non-point sources of pollution. **Reference**: Ramachandra T .V., Ahalya N. and Payne, M., 2006, Status of Varthur Lake: Opportunities for Restoration and Sustainable Management. Technical Report: 102, Centre for Ecological Sciences, Bangalore.	**Annexure 9** **2003**
Conservation of Bellandur Wetlands: Obligation of Decision Makers to Ensure Intergenerational Equity The Mixed Use Development Project - SEZ is proposed by Karnataka	**Annexure 10** **2013**

Industrial Areas Development Board (KIADB) along Sarjapur Road in a wetland between Bellandur and Agara Lake, with an area of 33 hectare. The proposal of the project is to construct residential areas, offices, and retail and hotel buildings in this area, which is contrary to sustainable development as the natural resources (lakes, wetlands) will be affected. This violates Hon'ble High Court of Karnataka's verdict to protect, conserve, rehabilitate and wisely use lakes and their watersheds in Bangalore, all lakes in Karnataka and their canal networks, and also violates CDP 2015 as the valley zone is supposed to be protected as the region is "No Development Zone". The SEZ will affect the ecological functioning, enhances flooding in the vicinity (due to encroachment of drains/rajakaluves; alterations in topography; encroachment of lakebed and encroachment of lake itself by dumping debris and land filling), traffic congestion due to additional vehicle movement (SEZ has a capacity of over 14000 Car units); enhances levels of vehicular pollutants that causes health problems (increase in respiratory diseases) and brings shortage in drinking water in Bangalore (SEZ requires 4587 Kilo Liters per day (4.58 MLD – Million liters per day)). **Reference:** Ramachandra, T. V., Aithal, B. H., Vinay, S., and Lone, A. A., Conservation of Bellandur wetlands: Obligation of decision makers to ensure intergenerational equity. ENVIS Technical Report: 55, Environmental Information System, Centre for Ecological Sciences, Bangalore, 2013.	

DISCUSSIONS: The major problems faced by Varthur lake (table 2.8) are (i) encroachment, (ii) sustained inflow of untreated sewage and industrial effluents and (iii) dumping of municipal solid wastes and building debris.

Table 2.8: Threats to lakes and its effects

Sl.No	Problems faced by lakes	Effects on lakes
1.	Discharge of untreated domestic sewage and industrial effluents	▪ Degradation of water quality ▪ Odour problems ▪ Dissolved oxygen depletion ▪ Nutrient accumulation ▪ Heavy metal contamination ▪ Over growth of algae and aquatic macrophytes ▪ Accumulation of silt and organic matter ▪ Reduction in depth of lake ▪ Contamination of ground water. ▪ Loss of aesthetic value
2.	Encroachment of lake and construction activities in the lake catchment	▪ Reduction of catchment area of lakes ▪ Reduction of ground water table as water recharge capacity goes down ▪ Increased discharge of domestic sewage

		▪ Generation of building debris and solid wastes ▪ Soil erosion, sedminentation ▪ Cutting down of trees in that location ▪ Affects fauna population ▪ Loss of interconnectivity among lakes
3.	Land use change	▪ Reduction of catchment area ▪ Affected the hydrological regime ▪ Affected micro climatic conditions
4.	Unplanned urbanization	▪ Loss of wetlands and green spaces ▪ Increased frequency of floods ▪ Decline in groundwater table ▪ Heat island ▪ Increased carbon footprint
5.	Threat to ecological balance	▪ Aquatic biodiversity is affected (fish, birds, flora and fauna that are dependent on lake system)
6.	Decline of Ecosystem goods and services	▪ Affects economic growth and livelihood of local people
7.	Removal of shoreline riparian vegetation	▪ Causes soil erosion ▪ Effests the habitat of aquatic organisms
8.	Dumping of municipal solid waste and building debris	▪ Affects human health ▪ Breeding of disease vectors and pathogens

SOLUTIONS:

1) Mapping of water body (identification of flood plain and buffer zone)
2) Remove encroachments near to lakes after surveying the lake area
3) Apply 'polluter pays principle' in true spirit - Restrict the entry of untreated sewage into lakes
4) Let only treated sewage through constructed wetlands and shallow algae pond into the lake (as in Jakkur lake)
5) Regular maintenance of floating macrophytes
6) Planting of native species of macrophytes in open spaces of lake catchment area (for retaining water in the lake)
7) Avoid dumping of solid wastes into lakes
8) Ensure proper fencing of lakes
9) Lake area cannot be diverted for any other purpose
10) Make local residents environmentally literate

SUGGESTIONS

Table 2.9: Suggestions to be implemented in lakes

Desilting of lakes	Silt has accumulated during last 50 years and with sustained inflow of sewage, the accumulated silt had contaminated which has to be removed on priority. Lake has become a shallow lake with a maximum depth of 2m. Desilting of the lake was done by local people in mid 70's. Removal of silt also helps in ground water recharge in the region as the accumulated silt in the lake over a period has become non-permeable, which had prevented the vertical and lateral flow of water. Bangalore is facing a severe water crisis and removal of silt will help in harvesting of rain water efficiently.
Letting only treated sewage into lake	Model similar to Jakkur lake with constructed wetland and algal pond will help in removal of nutrients **(Annexure 11).**
Restoration and treatment of lake in the entire basin	Varthur lake, being located in the downstream of Agaram and Madivala lake series, will get rejuvenated only when the connected and interconnected lakes are restored and treated in similar way.
Protection of riparian and buffer zone vegetation	Any clearances of riparian vegetation and buffer zone vegetation (around lakes) have to be prohibited.
Management of polluted lakes	• The highly polluted lakes should be fenced off to prevent fishing, cattle grazing, washing, bathing and collection of edible or medicinal plants to prevent health hazards • Warning boards should be displayed around water bodies • Implementation of bioremediation method for detoxification of polluted water bodies • Based on the concept of **polluter pays,** a mechanism be evolved to set up efficient effluent treatment plants [ETP], individual or collective, to reduce the pollution load
Environment Education	• Public education and outreach should include all components of aquatic ecosystem restoration, management and conservation • Lake associations and citizen monitoring groups have proved helpful in educating the general public • Environmental education program should be more proactive, field oriented and experimental (with real time examples) for effective learning • Environmental education should be made mandatory at all levels – schools, colleges, universities, professional courses, teachers and teacher educators at the teachers' training institutes (Tch, B Ed, D Ed)

The important recommendations suggested through Lakshman Rau committee report, emphasizing the preservation and restoration of existing tanks in Bangalore in 1988 are applicable for Varthur lake also.

This includes:

- Efforts should be made to ensure that these tanks are not polluted by discharge of wastes.
- Off shore development by large scale planting of trees and also removal of encroachments to prevent silting
- Existing tanks should be deweeded and aquatic life must be developed
- The Bangalore Development Authority / Bangalore City Corporation / Minor Irrigation Department must remove encroachments in the tank areas
- The Forest Department, Bangalore Development Authority, Bruhat Bengaluru Mahanagara Palike, Minor Irrigation Department, Bangalore Water Supply and Sewerage Board, and Town Planning Department should play an active role in the implementation of recommendations and these recommendations should be reviewed periodically
- Mosquito control measures are to be entrusted to BBMP or any other suitable agency
- The responsibility of maintenance of water bodies in a clean and safe condition should be with Bangalore Water Supply and Sewerage Board

The aquatic conservation strategy (Ramachandra et al., 2005) focuses on conservation and maintainence of ecological health of aquatic ecosystems so as to maintain the aquatic biodiversity in the region, maintain inter-connectivity among lakes, preserve its physical integrity (shorelines, banks and bottom configurations) and water quality to support healthy riparian, aquatic and wetland ecosystems. The regular monitoring of waterbodies involving students at school, college and research institutions, and also public awareness will help in developing appropriate conservation and management strategies.

REFERENCES

1. Alakananda, B., Mahesh, M. K., and Ramachandra, T. V., 2013, Biomonitoring to assess the efficacy of restoration and management of urban water bodies. *International Journal of Environmental Sciences*, Vol 2(3), pp: 165-178.
2. APHA, Standard Methods (20 Ed.) for the examination of water and waste water, APHA, AWWA, WPCE, Washington DC, 1998.
3. Mahapatra, D. M., Chanakya, H. N., and Ramachandra, T. V., 2011, C:N ratio of sediments in a sewage fed urban lake. *International Journal of Geology*, Vol. 5(3), pp. 86 - 92.
4. Mahapatra, D. M., Chanakya, H. N., and Ramachandra, T. V., 2011, Role of macrophytes in a sewage fed urban lake. *Institute of Integrative Omics and Applied Biotechnology Journal (IIOABJ)*, Vol. 2(8), pp. 1-9.
5. Mahapatra, D. M., Chanakya, H. N., and Ramachandra, T. V., 2011, Assessment of treatment capabilities of Varthur Lake, Bangalore, India. *International Journal of Environmental Technology and Management*, Vol. 14, pp. 84-102.
6. Mahapatra, D. M., Supriya, G., Chanakya, H. N., and Ramachandra, T. V., 2010, Algal photosynthetic dynamics in urban lakes under stress conditions. Proceedings of the Conference on

Infrastructure, Sustainable Transportation and Urban Planning CiSTUP@CiSTUP 2010. 18th - 20th October 2010, C*i*STUP, IISc, Bangalore.

7. Ramachandra, T. V., 2012, Conservation and Management of Wetlands: Requisite Strategies. LAKE 2012**:**National Conference on Conservation and Management of Wetland Ecosystems.
8. Ramachandra, T. V., Conservation and management of urban wetlands: Strategies and challenges, ENVIS Technical Report: 32, Environmental Information System, Centre for Ecological Sciences, Bangalore, 2009.
9. Ramachandra, T. V., Conservation, restoration and management of aquatic ecosystems, In *Aquatic Ecosystems - Conservation, Restoration and Management*, Ramachandra, Ahalya N. and Rajasekara Murthy (ed.), Capital Publishing Company, New Delhi, 2005.
10. Ramachandra, T. V., Ahalya N., and Payne, M., Status of Varthur Lake: opportunities for restoration and sustainable management. Technical report 102, Centre for Ecological Sciences, Indian Institute of Science, Bangalore, 2003.
11. Ramachandra, T. V., Aithal, B. H., and Durgappa, D. S., 2012, Insights to urban dynamics through landscape spatial pattern analysis. *International Journal of Applied Earth Observation and Geoinformation*, Vol.18, pp. 329-343.
12. Ramachandra, T. V., Aithal, B. H., and Kumar, U., 2012, Conservation of wetlands to mitigate urban floods. *Resources, Energy, and Development*. Vol. 9(1), pp. 1-22.
13. Ramachandra, T. V., Aithal, B. H., Vinay, S., Setturu, B., Asulabha, K. S., Sincy, V., and Bhat, S. P., Vanishing lakes interconnectivity and violations in valley zone: Lack of co-ordination among para-state agencies, ENVIS Technical Report 85, CES, Indian Institute of Science, Bangalore, 2015.
14. Ramachandra, T. V., Aithal, B. H., Vinay, S., and Lone, A. A., Conservation of Bellandur wetlands: Obligation of decision makers to ensure intergenerational equity. ENVIS Technical Report: 55, Environmental Information System, Centre for Ecological Sciences, Bangalore, 2013.
15. Ramachandra, T. V., Alakananda, B., Ali Rani and Khan, M. A., 2011, Ecological and socio-economic assessment of Varthur wetland, Bengaluru (India). *Journal of Environmental Science and Engineering*, Vol. 53(1), pp. 101-108.
16. Ramachandra, T. V., Alakananda, B., and Supriya, G., 2011, Biofuel prospects of microalgal community in urban wetlands. *International Journal of Environmental Protection (IJEP),* Vol.1(2), pp. 54-61.
17. Ramachandra, T. V., and Ahalya, N., Essentials of Limnology and Geographical Information System (GIS). Energy and Wetlands Research Group, Center for Ecological Sciences, Indian Institute of Science, Bangalore, 2001.
18. Ramachandra, T. V., and Kumar, U., 2008, Wetlands of Greater Bangalore, India: Automatic delineation through pattern classifiers, *The Greendisk Environmental Journal*. Issue 26 (http://egj.lib.uidaho.edu/index.php/egj/article/view/3171).
19. Ramachandra, T. V., Mahapatra, D. M., Bhat, S. P., Asulabha, K. S., Sincy, V., and Aithal, B. H., Integrated wetlands ecosystem: Sustainable model to mitigate water crisis in Bangalore. ENVIS Technical Report 76, Environmental Information System, CES, Indian Institute of Science, Bangalore, 2014.
20. Ramachandra, T. V, Meera, D. S., and Alakananda, B., 2013, Influence of catchment land cover dynamics on the physical, chemical and biological integrity of wetlands. *Environment and We - International Journal of Science and Technology - (EWIJST)*, Vol. 8(1), pp. 37-54.

21. Ramachandra, T. V., and Rajinikanth, R., 2005, Economic valuation of wetlands. *Journal of Environmental Biology*, Vol. 26(3), pp. 439-447.
22. Rau, L., 1988, Report of the expert committee for preservation, restoration or otherwise of the existing tanks in Bangalore metropolitan area.
23. Schilling, K., and Zessner, M., 2011, Foam in the aquatic environment, *Water Research*, Vol. 45, pp. 4355 – 4366.
24. Shivakumar, K. V., 2008, Water quality monitoring of lakes in Bangalore-Laborattory Central Laborattory KSPCB. Proceedings of Taal 2007: The 12th World Lake Conference, pp. 1908 – 1915.
25. Trivedi, R. K., and Goel, P. K., Chemical and biological methods for water pollution studies. Published by Environmental Publications, Post Box 60, Karad, 1986.
26. http://esrd.alberta.ca/water/programs-and-services/surface-water-quality-program/documents/FoamSurfaceWaters
27. http://nhlakes.mylaketown.com/uploads/tinymce/nhlakes/NewsArticles/LakeConcerns/5-3 Lake Foam
28. http://www.deccanchronicle.com/150430/nation-current-affairs/article/filthy-foam-varthur-lake-spills-bengaluru-road
29. http://www.in.gov/idem/files/wqsurvey_025surfacefoam
30. http://parisaramahiti.kar.nic.in/vseries.html
31 http://wgbis.ces.iisc.ernet.in/energy/water/paper/researchpaper2.html

Foam and Fire: Indicator of contaminants in Varthur & Yamalur - Bellandur Lakes

Cause	Sustained inflow of untreated sewage (due to BWSSB) and effluents (from industries) due to dereliction of duties by regulatory agencies (KSPCB, CPCB) has contaminated the lake as the inflow of pollutants has surpassed the lake's assimilative capacity. Froth formation at outlets, profuse growth and spread of marcrophytes are all the indicators of nutrient enrichment. Nutrients in the form of N (nitrogen), carbon (C) and P (phosphorous) enters the lake through untreated sewage. Major part of N is up-taken by plants and algae while phosphorous and carbon gets trapped in sediments. Due to high wind coupled with high intensity of rainfall leads to upwelling of sediments with the churning of water as it travels from higher elevation to lower elevation forming froth due to phosphorous. Discharge of untreated effluents (rich in hydro carbon) with accidental fire (like throwing cigarettes, beedi) has led to the fire in the lake.
Solution	1) Decentralised treatment of municipality waste water preferably at ward levels (similar to Jakkur lake) 2) Apply 'polluter pays principle' in true spirit - Restrict the entry of untreated sewage and industrial effluents into lakes. Agency responsible for sustained inflow of untreated sewage need to restore the lake. Similarly industries responsible for polluting water bodies should be made to pay (this also entails penalising regulatory agency for dereliction of duties by not applying 'polluter pays' principle as per Water Act, 1974) 3) Let only treated sewage through constructed wetlands and shallow algae pond into the lake (as in Jakkur lake) 4) Regular maintenance of floating macrophytes 5) Mapping of water body (identification of flood plain and buffer zone) 6) Remove encroachments near to lakes after surveying the lake area 7) Re-establish interconnectivity among lakes (by removing all encroachers of storm water drains/raja kaluves without any humanity considerations – encroacher or polluter needs to pay for arrogance of encrachments) 8) Planting of native species of macrophytes in open spaces of lake catchment area (for retaining water in the lake) 9) Avoid dumping of solid wastes into lakes 10) Ensure proper fencing of lakes 11) Lake area should not be diverted for any other purposes 12) Make local residents environmentally literate 13) Restrictions / product ban – detergents using phosphorous (which is a limited, non-renewable resource)

Foam and Fire: Varthur - Yamalur - Bellandur Lakes

Cause: Sustained inflow of sewage (500 MLD) into Bellandur and Varthur lakes comprises of many natural and synthetic dissolved organic compounds, such as soaps and detergents. These are surface-active agents or surfactants that reduce the surface tension of water, allowing air bubbles to persist at the water's surface. These detergents essentially consists of phosphates, and a portion of which is up-taken by aquatic plants while the balance gets trapped in the sediments.

Figure 3.1: Foam formation in the outfalls of Bellandur lake a) Initiation of foam formation by entrapment of air at the fall levels of the lake b) Foam piling up due to high flow and mixing c) Foam occupying the entire surface of the channel

Pre-monsoon showers coupled with gusty winds leads to the churning of lake water with upwelling of sediments. Vigorous mixing of surface water coupled with high flow across narrow channels, leading to bubble formation that persist and build up as foam (Figure 3.1 a-c). In the lakes, foam /froth gets accumulated along windward shores. Continuous sewage fed in Bellandur and Varthur lakes, has been witnessing foam at downstream in chocked channels or below fall/discharge point since one decade (Mahapatra et al., 2013a).

Sources of these surfactants: Also, macrophytes and algae inhabiting the lake waters produce many organic compounds (Ramachandra et al., 2009; Mahapatra and Ramachandra, 2013, Mahapatra et al., 2013a,b,c, Ramachandra et al., 2013; Mahapatra et al., 2014), which have surfactant properties. Natural surfactants include carboxylic fatty acids derived from lipids from macrophytes/weeds etc. These are released into water and contribute to a large variety of soluble organic material known as dissolved organic carbon (DOC). Though DOC is produced within lake waters, the major source is the sustained inflow of sewage from the vicinity of the lakes and the watershed. Higher DOC concentrations in lakes, generally impart a brown colour to the water. This highlights that the foam is caused by synthetically produced surfactants released through sewage to surface waters. Synthetic surfactants are widely used in household cleaning products (detergents/soaps), cosmetics and personal care products (shampoo, toothpaste etc.). Common detergents also contains branch-chained alkyl benzene sulfonate surfactants, which are non-biodegradable and results in extremely persistent foam accumulating below the fall levels in the lake and other wastewater outfalls.

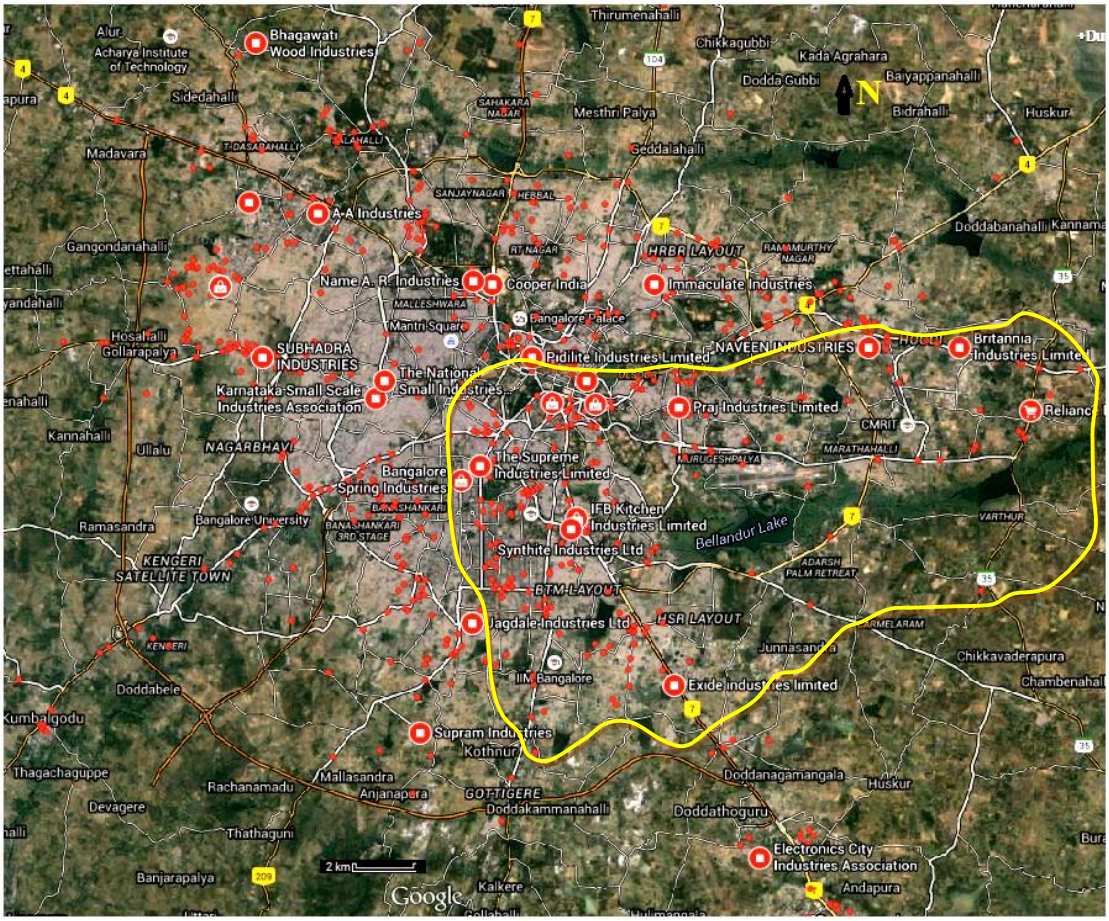


Figure 3.2: Distribution of industries in the vicinity of Bellandur and Varthur lake and also industries scattered in the city (overlaid on Google earth image http://earth.google.com)

Detergents and soaps mostly contain phosphate (P) softeners to enhance the effectiveness of surfactants through the reduction of water hardness. P loading in lakes has contributed to nutrient enrichment with the proliferation of cyano-bacterial blooms and macrophytes (aquatic plants). There are set of advanced detergents that exclude phosphates but contain biodegradable linear alkyl benzene sulfonate surfactants, such as sodium or ammonium lauret or lauryl sulfate. Surfactants are also used by many industries (Figure 3.2 and 3.3) as wetting agents, dispersants, defoamers, de-inkers, antistatic agents, and in paint and protective coatings, pesticides, leather processing, plastics and elastomer manufacturing, and oil extraction and production.

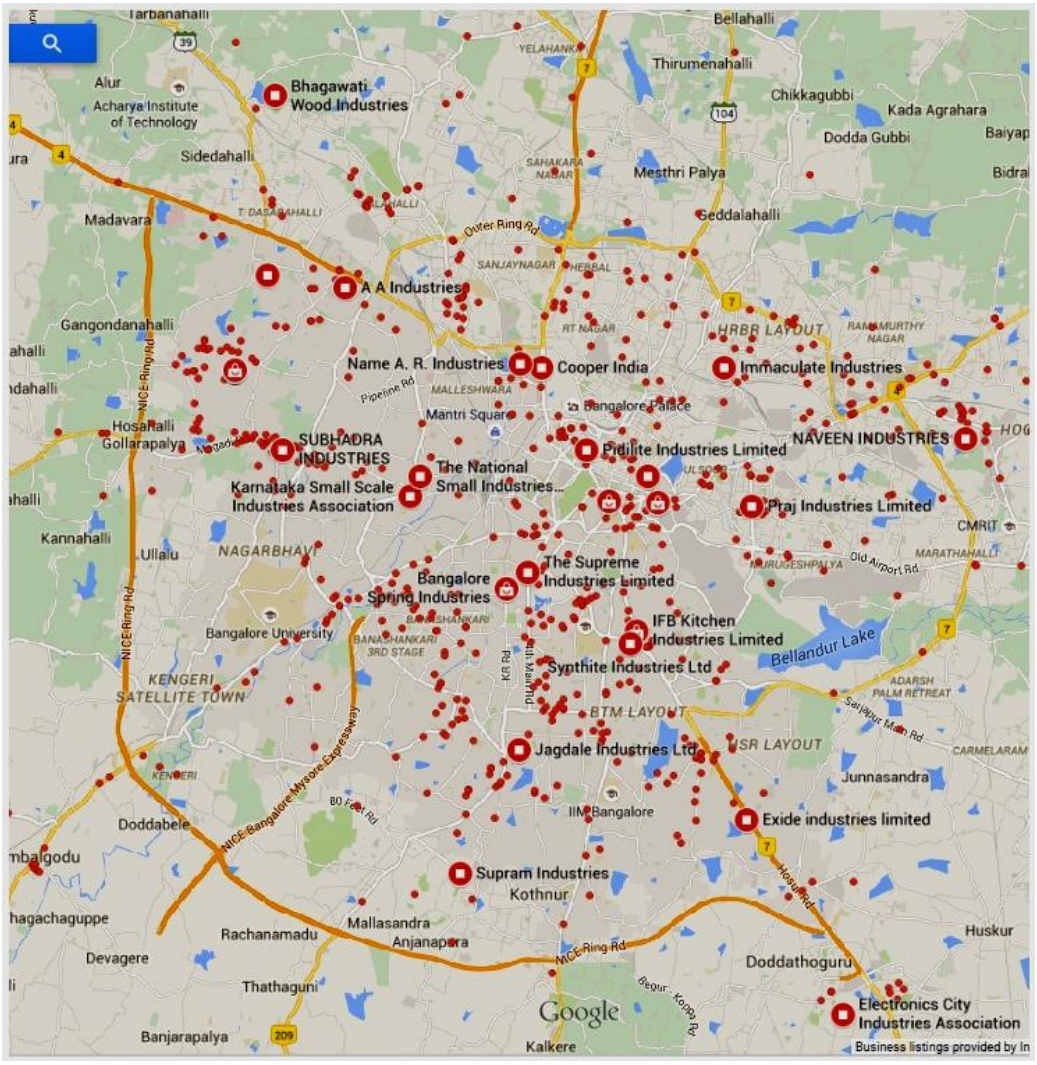
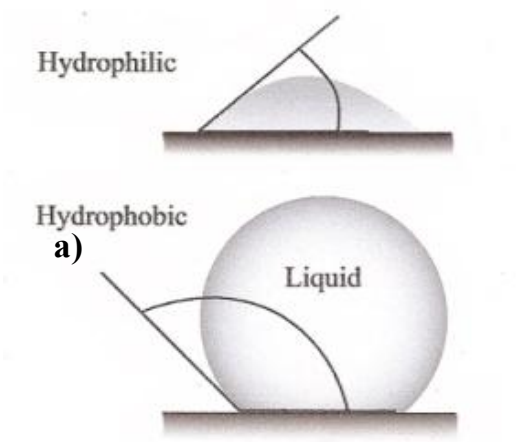


Figure 3.3: City map showing the distribution of various industries scattered in the city

Many industries that are present (Figures 3.2 and 3.3) in the upstream of Bellandur and Varthur lakes (Ramachandra and Solanki, 2007) have also contributed to high levels of surfactants in the waters due to the release of untreated effluents in addition to the domestic sewage. These surfactants are very persistent in the environment, bio accumulate in organisms and humans with various biological consequences. Alkyl phenol ethoxylates for example, which continue to be widely used by industry, have been shown to have estrogenic properties eliciting reproductive effects in fish and other organisms. Similarly, per-fluoro octanoic acid and per-fluoro octane sulfonate, which were commonly used in the production of stain resistant and non stick coatings including Scotch guard and Teflon, also have estrogenic and carcinogenic properties. In contrast to natural foam, fresh detergent based foam is of white colour with noticeable odour. Bellandur and Varthur lake have been receiving a mix of untreated and partially treated wastewaters (~500 million litres per day, MLD), from major residential areas and some industries, both synthetic and natural compounds that are present have contributed to the formation of foam.

Surfactants influence on the surface tension of water: Surface tension is an important property of water. It results from cohesion – the attraction of water molecules for one another. Cohesion gives water the ability to form droplets and contributes to the formation of waves and currents, which play an important role in the distribution of temperature, dissolved gases, nutrients, micro-organisms and plankton. At the surface of the lake (i.e. the air-water interface), cohesion creates a thin 'film' or tension. This allows insects like water striders to 'walk' on water and forms a special habitat for some aquatic organisms adapted to living on this surface film (mosquito larvae for example). Surfactants are amphipathic molecules, that is, they contain both hydrophilic (water-attracting) and hydrophobic (water-repelling) components. The hydrophilic component can form bonds with water and competes with other water molecules as they attract one another (Figure 3.4 a). In this manner, surfactants reduce the overall attraction between water molecules, thus diminishing surface tension (Figure 3.4b). Lower surface tension causes water to become more 'fluid' or elastic, and when air gets in the resulting bubbles can persist for some time.



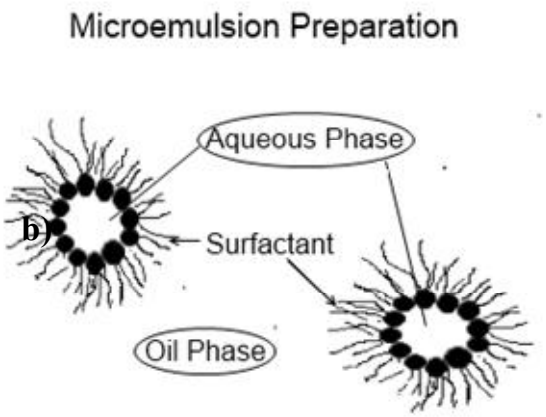


Figure 3.4a) Surface tension in case of hydrophobic and hydrophilic molecules

Figure 3.4b) Action of a surfactant in reducing the surface tension with polar heads binding to aqueous phase and hydrophobic tails that binds to oil/dirt phase

Figure 3.5: Foam formation at the a) Varthur North (Kodi) outfalls, b) South outfalls

Foam / Froth formation: Surfactants have contributed to 50% of foaming due to a reduced surface tension and balance is due to the intrusion of air into these waters to form the foam bubbles. In the studied lakes wind-induced currents and incipient waves cause turbulent mixing of air and water. Foaming often increases during runoff and rainstorms that transport the surfactants. Figure 3.6 illustrates hydrophobic oil and aqueous phases.

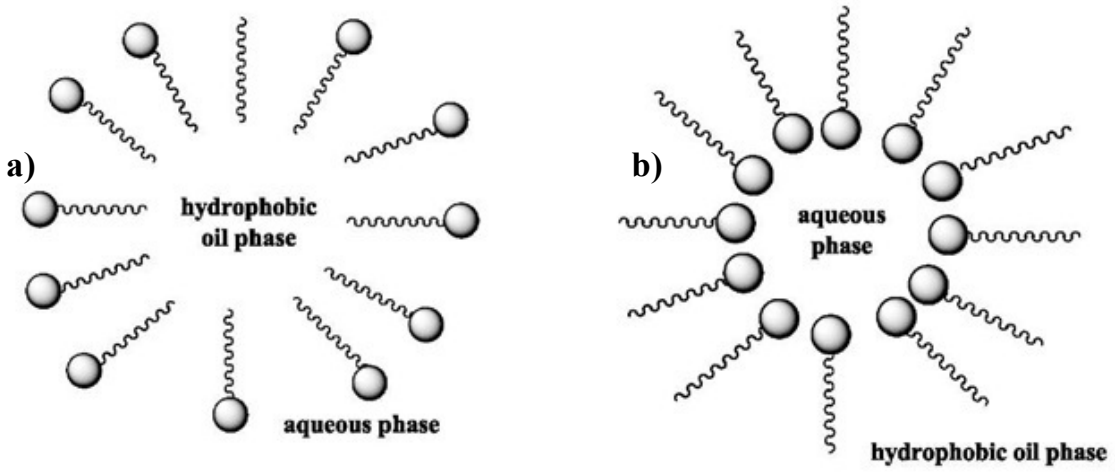


Figure 3.6 a) Hydrophobic oil phase (non polar tails towards the centre) b) Aqueous phase (polar heads to wards the centre)

Characteristics of foam: The foam collected from the Varthur outfalls were white in colour with a greasy/oily dark materials sticking on the surface of the foam bubbles (Figure 3.7). The foam had a pungent odour with sulphide smell unlike the natural foam that has an earthy or fishy aroma. These white foams progressively turn off-white and then settle as dark grey residue over time. Experiments conducted in laboratory shows, the persistent nature of the foam that lasts up to 6 days (Figure 3.8).

Figure 3.7: Foam sample collection from Varthur north outfalls

The analysis conducted on foaming abilities showed, mean bubble size decrease with time, and finally ends up in sizes < 2 mm in diameter. The initial bubble sizes range from 2-4 cm (Figure 3.9). Moreover, the foam volumes were observed to be higher during the 2nd and 3rd day that correlated with the mean bubble size. The foam diminishes after the 6th day due to low stability. Earlier reports on wastewater systems have indicated onset of foaming is because of surfactants and bio-surfactants, abundant in wastewater and sludge. They have both hydrophobic and hydrophilic properties and tend to accumulate at air–liquid interfaces increasing surface activity. When air/gas is introduced into solution, a thin liquid film is formed around the gas bubbles as they reach the air–liquid interface preventing them from bursting (Hug, 2006 and Ganidi et al., 2009). The foaming persistence tests carried out in the laboratory by stirring showed the presence of surfactants indicating highest foaming abilities. The liquid phase of the foam samples contained significant amounts of surface active groups during the analysis period. However the foaming potential decreased after 4 days this can be attributed to the decrease in the interactions between solid particles and the surfactants and hence the stability of the foam. Studies on wastewater systems highlights that sludge, (Mahapatra et al., 2013a) containing surfactants and the foaming potential is enhanced or reduced depending on the surfactant–surfactant and particle–surfactant interactions (Glaser et al., 2007 and Eisner et al., 2007). More importantly increase of temperature in liquids containing surfactants result in increased surface activity (lower surface tension) enhancing the foaming potential (Barber, 2005) which was also observed in the present study as the foaming events are periodic and are often noticed during the summer at lake outfalls. In order to gain a better understanding of foam creation and stabilization, the liquid phase of foams generated at the outfalls of Varthur lake was analysed for carbon assays as COD, BOD and solids. The BOD and COD values were ~0.6 g/l and 1.14 g/l respectively. High total solids (TS) of ~110 g/l were observed in the liquid phase of the foam sample out of which ~92 g/l were total volatile solids (TVS). The ash content was ~16.2 g/l and the total dissolved solids (TDS) were ~7 g/l.

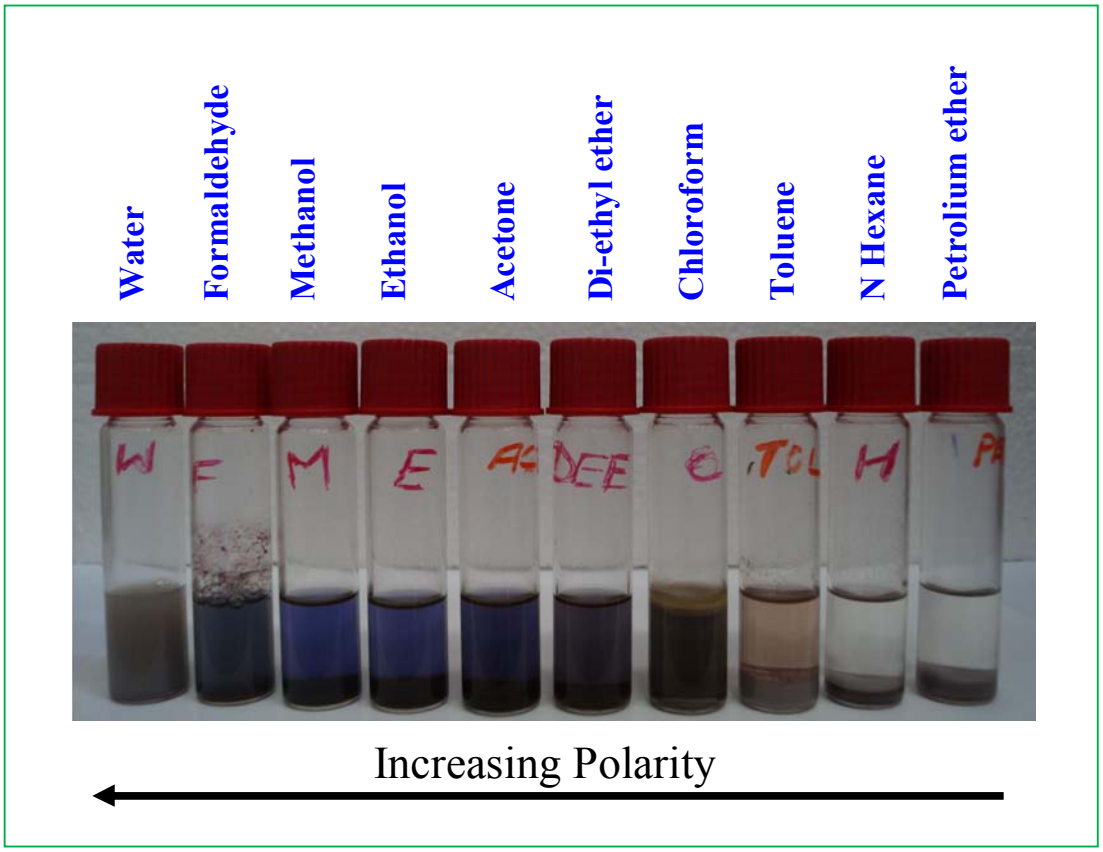


Figure 3.8: Analysis of Elution of the liquid phase of the foam in different solvents in the order of increasing polarity

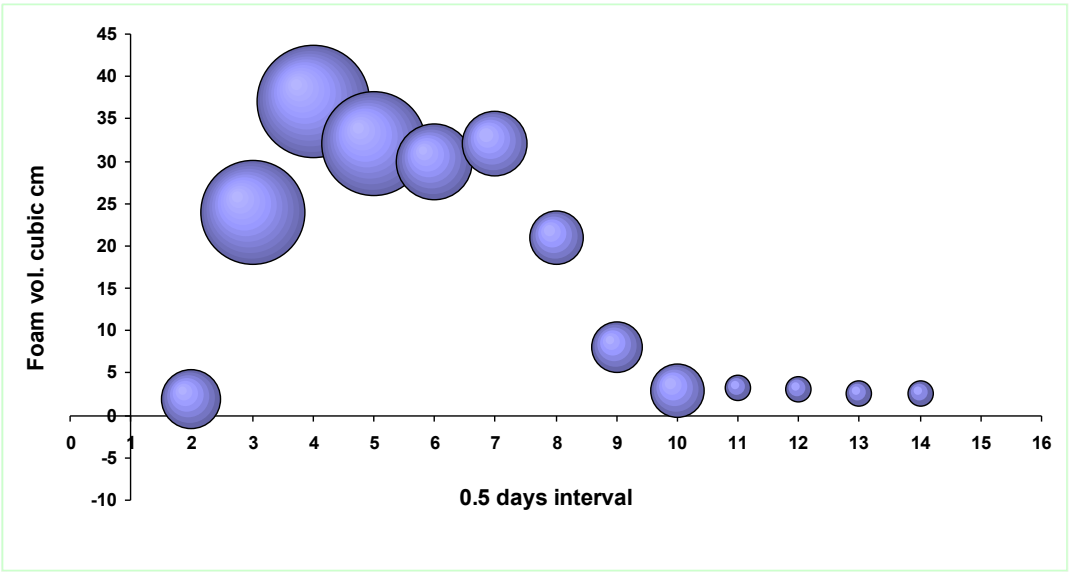


Figure 3.9: Foaming coefficients– foam volume and mean bubble size variation with time (note 1-12 indicates 6 days' interval)

Hydrophobic compounds present in the DOC foam were confirmed by eluting the foam in non-polar and polar solvents (Mahapatra et al., 2013a-c; Mahapatra et al., 2014a,b). The solvents comprised of water, formaldehyde, methanol, ethanol, acetone, di-ethyl ether, chloroform, toluene, n-Hexane and petroleum ether that were arranged in order of decreasing polarity. The results showed the presence of amphipathic molecules as shown in Fig. 8. The analysis showed presence of both polar and non polar compounds in the liquid phase of the froth. The froth analysis showed higher values of TP >2 g/l with orthophosphate values >75 mg/l indicating higher P content in waters owing detergents and also P up-welling due to anaerobic conditions in the sediment layer of the lakes, aided my macrophyte cover over the lake surface. Laboratory analysis of the commonly used detergents as Surf Excel, Ariel, Rin etc. showed higher presence of poly phosphates (27-34 %) and TP (~20-25 %) indicating detergents rich in P. Earlier studies on sludge sediments in Varthur lake indicated greater P influx from sediments during anaerobic conditions mostly during summer. The organic matter settled in the bottom of the lake resuspends owing to change in redox environment, that up-wells large quantities of immature sludge which imparts the dark grey colour to the lake water. Consequently, the water at the outfalls were grey in colour with higher particulate matter arising from sludge.

Influence of water hardness on foaming: Water hardness influences the amount of foam that results from water turbulence. Water hardness is a result of the presence of certain minerals in water, principally calcium and magnesium (and iron and manganese, to a lesser extent). Dissolved in water, calcium and magnesium exist as positively charged ions. These out-compete water molecules for binding to negatively charged surfactants (carboxylic fatty acids for example). The harder the water, the more likely the surfactant will be bound up by calcium or magnesium and, consequently, the less likely surface tension will be reduced. The Bellandur and Varthur lake waters are moderately hard waters (~215 mg/l of total hardness), with high Ca and Mg concentrations. As a result, foaming is not usually excessive in these waters. The incidence of high foam is also associated with high Na content in the lake in comparison to Ca and Mg. When the water is soft foam may occur more frequently.

Foam is usually harmless if they are only from vegetative origin where the foaming agents are primarily proteinaceous or carbonaceous matter. In this case only a small amount of fatty acids or other foaming agents are required to produce foam. Only about 1% of the foam is made up of the foaming agent, the remaining 99 % being air and water. The foams originating from the wastewaters, detergents and other industrial origin surfactants will have significant impacts to the aquatic ecosystem and human health. These foam can accumulate compounds that are repelled by water (hydrophobic), so foam can be enriched significantly with particulate organic and inorganic compounds such as nutrients (N, P, C), cations (K, Na, Ca, Mg), heavy metals (Cd, Cu, Fe, Pb, Zn) and chlorinated hydrocarbons. Therefore when these foams get in direct contact with human beings, depending on the specificity, they can cause many stimulatory effects that can trigger the immune response in the body. Moreover, the organisms that inhabit the surface layer would be more exposed to these contaminants and this could form a pathway to introduce contaminants into the food web.

Fire associated with foam in Yamalur- Bellandur lake

Flammability is the ability of a substance to burn or ignite, causing fire or combustion. Incidence of foam catching fire (Fig ure 3.10a and b) are due to compounds with high flammability i.e. mostly hydrocarbons and organic polymers from nearby industries in the vicinity of Bellandur lake. High wind coupled with high intensity of rainfall leads to upwelling of sediments with the churning of water as it travels from higher elevation to lower elevation forming froth due to phosphorous. Discharge of untreated effluents (rich in hydro carbon) with accidental fire (like throwing cigarettes, beedi) has led to the fire in the lake.

Figure 3.10 a) Flames over the surface of the froth during the night observed at the Yamalur-Bellandur lake outfalls b) Flames due to the residual black (oily/greasy materials – heterogenous phase) on the surface of the foam

The foam is a very periodic event (annual) which happens mostly in the pre-monsoon period at the outfalls of Bellandur and Varthur lake (Mahapatra et al., 2013a). The foam built up at the dry periods can be attributed to churning and associated sediment re-suspension from the lake bottom. This phenomena is also triggered due to anaerobic environments in the sediments that leads to a reducing environment (-340 to -280 mv – oxidation reduction potential; ORP; Mahapatra et al., 2013a-c) where the sludge/sediment bound P along with the decomposed plant parts, oil and greasy materials gets resuspended in the water (Mahapatra et al., 2013a,b). This produces a solid black layer on the surface of water that comprise of macrophyte/plant derived organic acids. With high wind velocities and water flow, this black particle that is mostly soluble in oil phase (hydrophobic in nature) gets deposited on the surface of the foam or bubbles. Frequent aeration of the lake waters falling off from the outfalls via splashing, forms gas bubbles that increase the liquid interfacial area a here at times charging occurs. Apart from charge generation at the surface, continuous aeration aids in formation of persistent froth that lasts from hours – days. This foam is also the source of very fine mist as it bursts. The rate at which the bubble bursts is dependent on the static spark that helps in disruption of the foam.

References:

1. Barber, W.P. (2005). Anaerobic digester foaming: causes and solutions. Water 21, 45–49. Available from: http://www-uk1.csa.com/ids70/results.php?SID=4oo9hnkld4c223a8lr72q3vbb1&id=2
2. Ganidi, N., Tyrrel, S., Cartmell, E. (2009). Anaerobic digestion foaming causes – a review. Bioresource Technol. 100, 5546–5554.
3. Hug, T. (2006). Characterisation and controlling of foam and scum in activated sludge systems. Swiss Federal Institute of Technology, Zurich.

4. Mahapatra D.M., Chanakya H.N., Ramachandra T.V. (2011c). C:N ratio of Sediments in a sewage fed Urban Lake. International Journal of Geology. 5,3:86-92.
5. Mahapatra D.M., Chanakya H.N., Ramachandra T.V. (2011a). Assessment of Treatment capabilities of Varthur Lake, Bangalore. International Journal for Environment, Technology & Management. 14, 1-4:84-102.
6. Mahapatra D.M., Chanakya H.N., Ramachandra T.V. (2013a), Bioenergy generation from components of a Continuous Algal Bioreactor: Analysis of Lipids, Spectroscopic and Thermal properties. Proceedings of 10th IEEE INDICON Conference on Impact of Engineering on Global Sustainability, pp. 183-184, IIT Bombay, India 12th – 15th Dec, 2013.
7. Mahapatra D.M., Chanakya H.N., Ramachandra T.V. (2014a), Bioremediation and Lipid Synthesis of Myxotrophic Algal Consortia in municipal wastewater. Bioresource Technology. 168: 142-150.
8. Mahapatra D.M., Chanakya H.N., Ramachandra T.V. (2014b), Novel Algal Bioreactor for Wastewater Treatment and Biofuel (lipid) Production. GYTI Technological Innovations, SRISTI pp. 60, GYTI Exhibition, IIM Ahmedabad. India 29th March, 2014.
9. Mahapatra D.M., Chanakya H.N., Ramachandra T.V., (2011b). Role of Macrophytes in urban sewage fed lakes. Institute of Integrative Omics and Applied Biotechnology. 2, 7: 1-9.
10. Mahapatra, D.M., Chanakya, H.N, Ramachandra, T.V. (2013b). *Euglena* sp. as a Suitable Source of Lipids for Potential use as Biofuel and Sustainable Wastewater Treatment. Journal of Applied Phycology. 25:855-865.
11. Mahapatra, D.M., Chanakya, H.N., Ramachandra, T.V. (2013c). Treatment efficacy of Algae based sewage treatment plants. Environmental Monitoring and Assessment. 185:7145-7164.
12. Mahapatra, D.M., Ramachandra, T.V. (2013). Algal Biofuel: Bountiful Lipid from *Chlorococcum* sp. proliferating in Municipal Wastewater. Current Science. 105:47-55.
13. Ramachandra T.V., Solanki, M. (2007). Ecological assessment of Lentic Waterbodies of Bangalore, ENVIS Technical Report 25, Environmental Information System, Centre for Ecological Sciences, Bangalore.
14. Ramachandra T.V. and Murthy R. (2000). Restoration and management strategies for wetlands, Lake Symposium 2000.
15. Ramachandra, T.V., Mahapatra, D.M., Karthick B., Gordon, R. (2009). Milking diatoms for sustainable energy: biochemical engineering vs. gasoline secreting diatom solar panels. Industrial & Engineering Chemistry Research. 48, 19:8769-8788.
16. Ramachandra, T.V., Mahapatra, D.M., Samantray, S., Joshi, N.V. (2013). Biofuel from Urban Wastewater: Scope and Challenges. Renewable and Sustainable Energy Reviews. 21:767-777.

Foam and Fire in Varthur & Yamalur - Bellandur Lakes: Highlights the level of irresponsibility of para-state agency responsible for handling sewage in the city.

4.0 Tragedy of encroachments in Varthur-Bellandur Valley

Status	**Disappearing water-bodies and interconnectivities among lakes**
Cause:	**Encroachment of lake bed and raja kaluves (storm water drains)**
Norms	1. "Preservation of Lakes in the City of Bangalore" Report of the Committee constituted by the **Hon'ble High Court of Karnataka** to examine the ground realities and prepare an action plan for preservation of lakes in the City of Bangalore. (Hon'ble High Court of Karnataka's Order dated 26/11/2010 in WP NO.817/2008 & others), • Lake area should not be diverted for any other purpose as lakes have an increased and important role to play vis–a-vis lakes in rural areas, like **ground water recharge, climate moderation, act as lung spaces, water for various purposes, urban recreation** etc • Currently **30m** buffer space needs to be maintained as per the **BDA** from the legal lake boundary (wetland) and any developmental activity. • **Lake preservation has to be integral to Layout Development by BDA** and Layout approvals by development and planning authorities like BIAPA, MICAPA, Nelamangala Planning Authority, Hosakote Planning Authority etc.,as eventually these areas will be part of Bangalore city. • **BDA should not acquire lake area at the time of notifying the area for development** and allot sites in the lake area as was done in many a layout development previously. Instead they have to properly get all the **lakes, raja kaluves, drains surveyed and marked on the ground as per village records with boundary stones and make provisions for buffers** as laid out in their norms. • Lake preservation is not limited to lake area itself, but very much dependent on catchment area and the drains that bring rainwater in to the lake. **Raja kaluves, branch kaluves are to be surveyed and encroachment therein evicted**. • **Effective Lake area should not be reduced by converting lake area into parks, children play grounds, widened bunds** etc. The desilting has to be minimized to remove only sludge portion with minimum depth near

	foreshore reaching maximum depth at the bund. **2. Violation as per BDA, RMP 2015; Section 17 of KTCP Act** In case of water bodies, a 30.0 m buffer of 'no development zone' is to be maintained around the lake (as per revenue records) • As per BDA, RMP 2015 • Section 17 of KTCP Act, 1961 and sec 32 of BDA Act, 1976 • Wetlands (Conservation and Management) Rules 2010, Government of India; Wetlands Regulatory Framework, 2008. **3. Construction activities in the valley zone:** This is contrary to sustainable development as the natural resources (lake, wetlands) get affected, eventually leading to the degradation/extinction of lakes. This reflects the ignorance of the administrative machinery on the importance of ecosystems and the need to protect valley zones considering ecological function and these regions are 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015 **4. Violations of National Water Policy, 2002** Water is a scarce and precious national resource and requires conservation and management. Watershed management through extensive soil conservation, catchment-area treatment, preservation of forests and increasing the forest cover and the construction of check-dams should be promoted The water resources should be conserved by retention practices such as rain water harvesting and prevention of pollution **5. Wetlands (Conservation and Management) Rules 2010, Government of India; Wetlands Regulatory Framework, 2008.** **Prohibited Activities** • Conversion of wetland to non-wetland use. • Reclamation of wetlands • Solid waste dumping and discharge of untreated effluents. **Regulated activities** • Withdrawal of water/impoundment /diversion/interruption of sources • Harvesting (including grazing) of living/non-living resources (may be permitted to the level that the basic nature and character of the biotic community is not adversely affected.)

	• Treated effluent discharges – industrial / domestic/agro-chemical. • Plying of motorized boats • Dredging (need for dredging may be considered, on merit on case to case basis, only in cases of wetlands impacted by siltation) • Constructions of permanent nature within **50 m** of periphery except boat jetties. • **Activity which interferes with the normal run-off and related ecological processes – upto 200 m** (Facilities required for temporary use such as pontoon bridges and approach roads, will be exempted) **6. Water (Prevention and Control of Pollution) Act, 1974** • It is based on the **"**Polluter pays**"** principle
Action Plan	• Good governance (too many para-state agencies and lack of co-ordination) - Single agency with the statutory and financial autonomy to be the custodian of natural resources (ownership, regular maintenance and action against polluters (encroachers as well as those let untreated sewage and effluents, dumping of solid wastes). • De-congest Bangalore: Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity (insufficient water, clean air and water, electricity, traffic bottlenecks, etc.) and assimilative capacity (polluted water and sediments in water bodies, enhanced GHG – Greenhouse gases, etc.) • Disband BDA – creation of Bangalore Development Agency has given impetus to inefficient governance evident from Bangalore, the garden city turning into 'dead city' during the functional life of BDA. • Digitation of land records (especially common lands – lakes, open spaces, parks, etc.) and availability of this geo-referenced data with query option (Spatial Decision Support System) to public. • Threshold on high raise building in the region. Need to protect valley zones considering ecological function and these regions are 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015 • Evict all encroachments from lake bed and raja kaluves • Reestablish interconnectivity among lakes • Restoration of lakes

Unplanned rapid urbanisation during post 2000 witnessed large scale conversion of watershed area of the lake to residential and commercial layouts. This has altered the hydrological regime and enhanced the silt movement in the catchment. Declining vegetation cover has lowered water yield in the catchment, affecting the groundwater recharge. Alterations in ecological integrity is evident from reduced water yield, flash floods, contaminated water, obnoxious odour, copious growth of invasive floating macrophytes, disappearance of native fish species, breeding ground for mosquito and other disease vectors, etc. A major portion of untreated city sewage (500+ million liters per day) is let into the lake, beyond the neutralizing ability of the lake, which has hampered the ecological functioning of the lake.

Ecological and Environmental Implications:

- Land use change: Conversion of watershed area especially valley regions of the lake to paved surfaces would alter the hydrological regime.
- Loss of Drainage Network: *Removal of drain (Rajakaluve) and reducing the width of the drain would flood the surrounding residential as* the interconnectivities among lakes are lost and there are no mechanisms for the excessive storm water to drain and thus the water stagnates flooding in the surroundings.
- Alteration in landscape topography: This activity alters the integrity of the region affecting the lake catchment. This would also have serious implications on the storm water flow in the catchment.
  The dumping of construction waste along the lakebed and lake has altered the natural topography thus rendering the storm water runoff to take a new course that might get into the existing residential areas. Such alteration of topography would not be geologically stable apart from causing soil erosion and lead to siltation in the lake.
- *Loss of Shoreline:* The loss of shoreline along the lakebed results in the habitat destruction for most of the shoreline birds that wade in this region. Some of the shoreline wading birds like the Stilts, Sandpipers; etc will be devoid of their habitat forcing them to move out such disturbed habitats. It was also apparent from the field investigations that with the illogical land filling and dumping taking place in the Bellandur lakebed, the shoreline are gobbled up by these activities.
- *Loss of livelihood:* Local people are dependent on the wetlands for fodder, fish etc. estimate shows that wetlands provide goods and services worth Rs 10500 per hectare per day (Ramachandra et al., 2005). Contamination of lake brings down goods and services value to Rs 20 per hectare per day.

Varthur Lake: Area of the lake 190 Hectares (471.43 acre) – Figure 4.1: cadastral map of the study region, Area of Lake as per BDA 180.3 Hectares (445.35 acre)

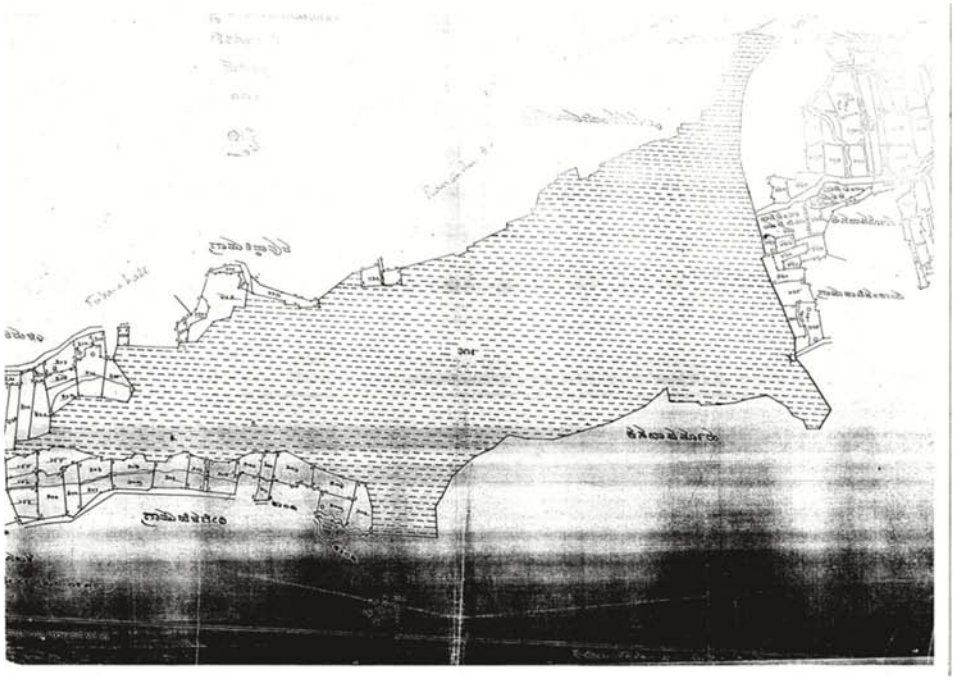


Figure 4.1: Varthur Lake Cadastral Map

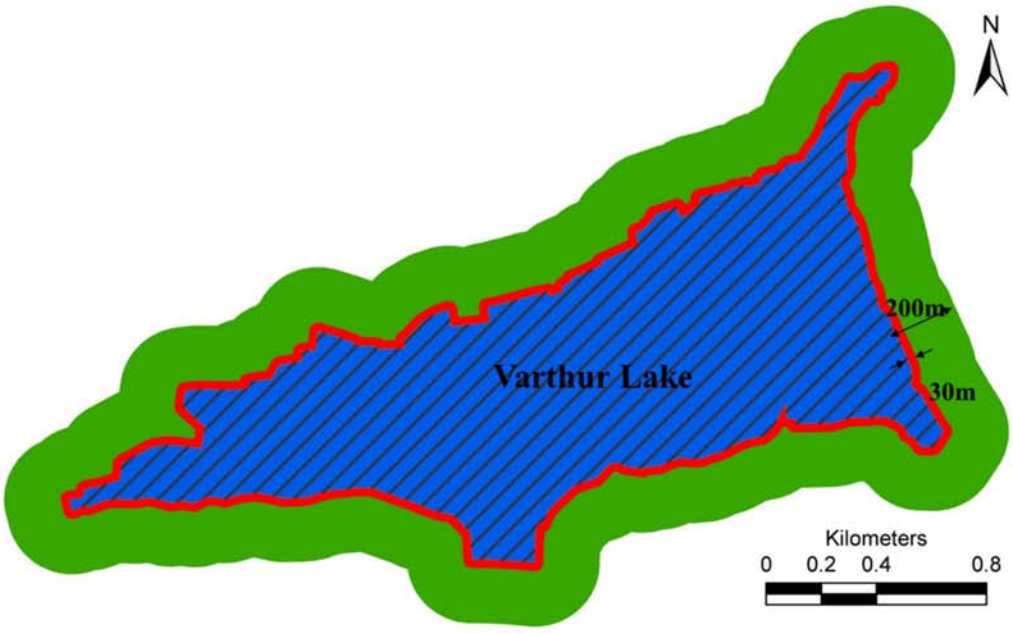


Figure 4.2: Varthur Lake and Buffer zones (30 m as per BDA and 200m as per MoEF, 2010-Wetlands regulatory framework)

City Development Plan: 'NO DEVELOPMENT ZONES' as per CDP 2005, 2015 include lakes, valleys, tanks and national parks and forests is proposed to preserve natural areas. Figure 4.3 depicts CDP for Bangalore indicating zones for conservation as well as for development. Figure 4.4 delineates valley zone in Bellandur-Varthur Valley.

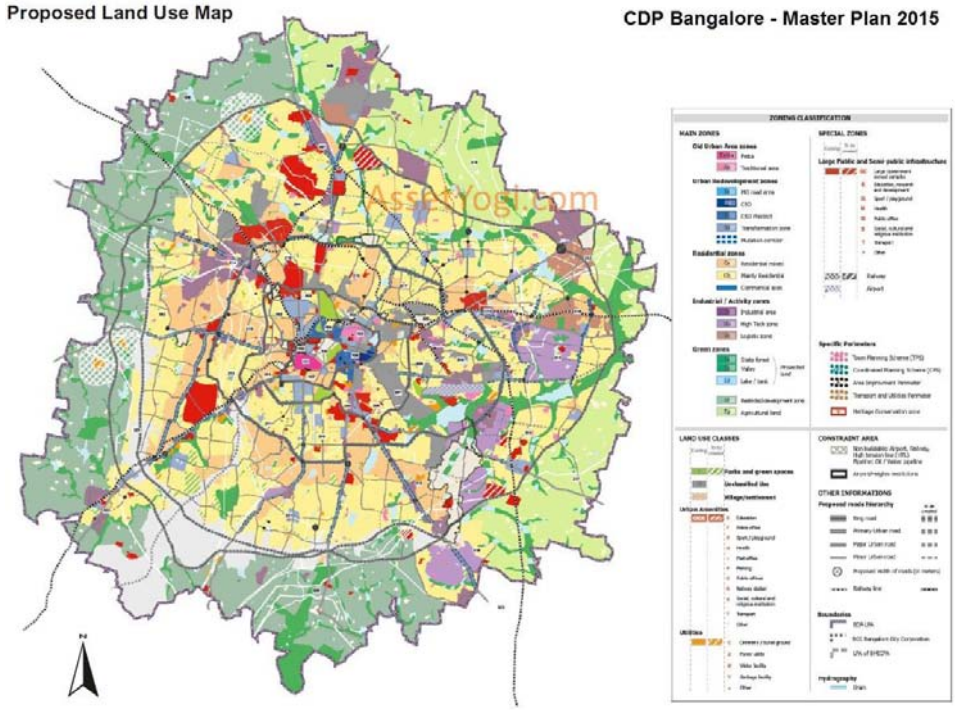


Figure 4.3: CDP 2015 Bangalore

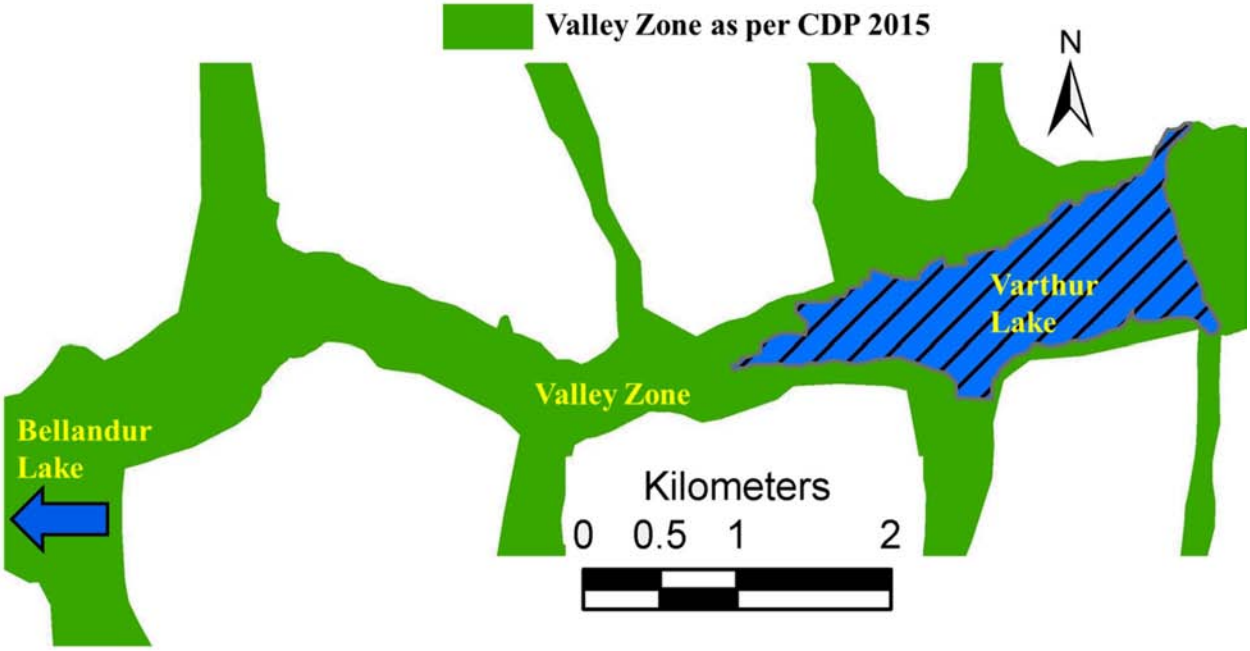
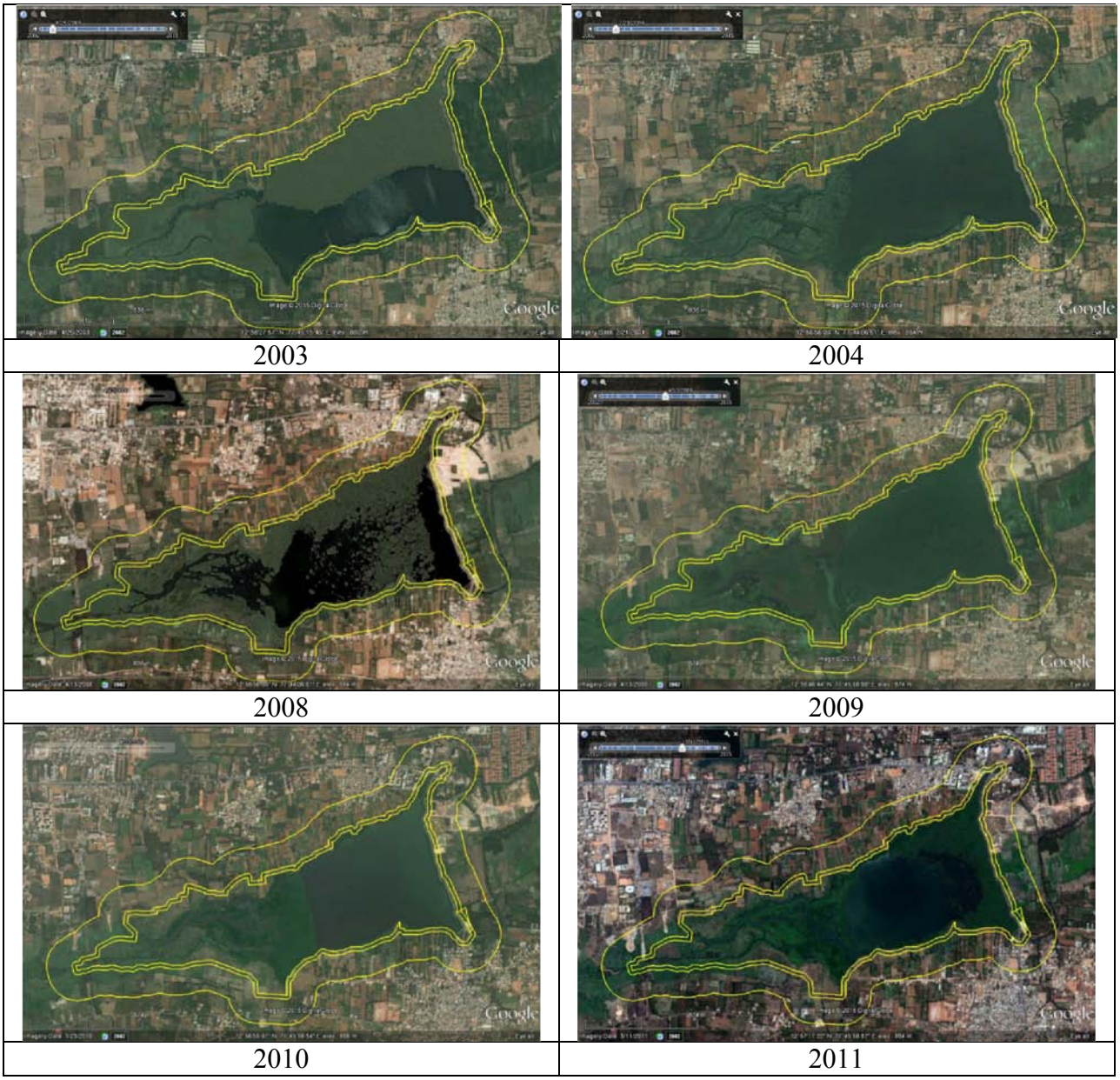


Figure 4.4: Valley Zone as per the City Development Plan 2015

Landscape dynamics in the Lake and buffer zone

Drainage network and Land cover of the wetland region were mapped using temporal Google earth (http://www.googleearth.com) for the period 2003 to 2015, and the changes in landuse and drainages (network as well as width of the channel/drain). Figure 4.5 depicts drastic land use changes evident from the conversion of wetland to other land uses during 2003 to 2015 in the valley and buffer zone.



2003	2004
2008	2009
2010	2011

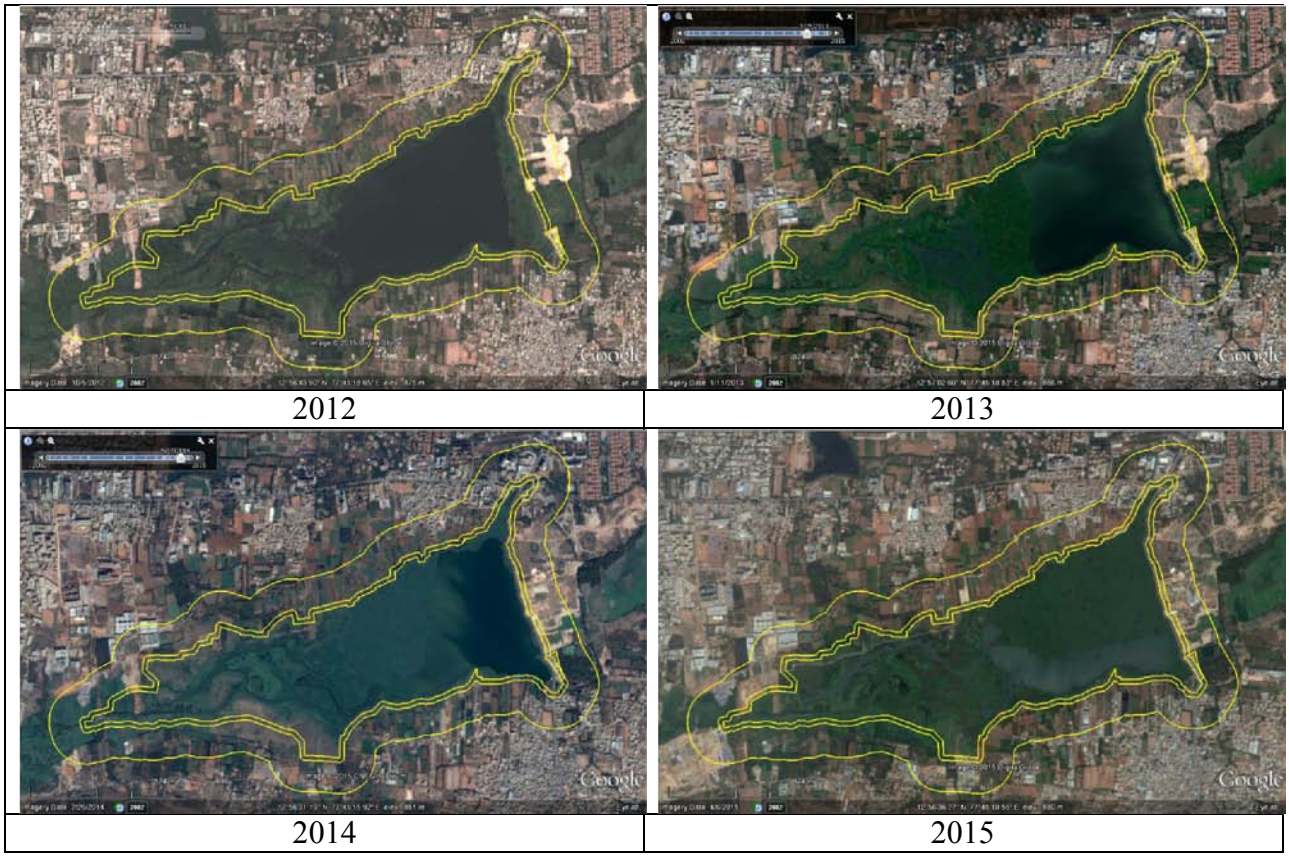


Figure 4.5: Landscape dynamics in the valley and buffer zone

Encroachment of Lake bed: Lake has an area of 190 Hectares as per cadastral map (180 hectares as per BDA). Figure 4.6 maps prohibited activities in the lake bed -construction of roads, buildings, agricultural and horticulture activities. Total area under encroachment is 12.4 Hectares (30.64 Acres).

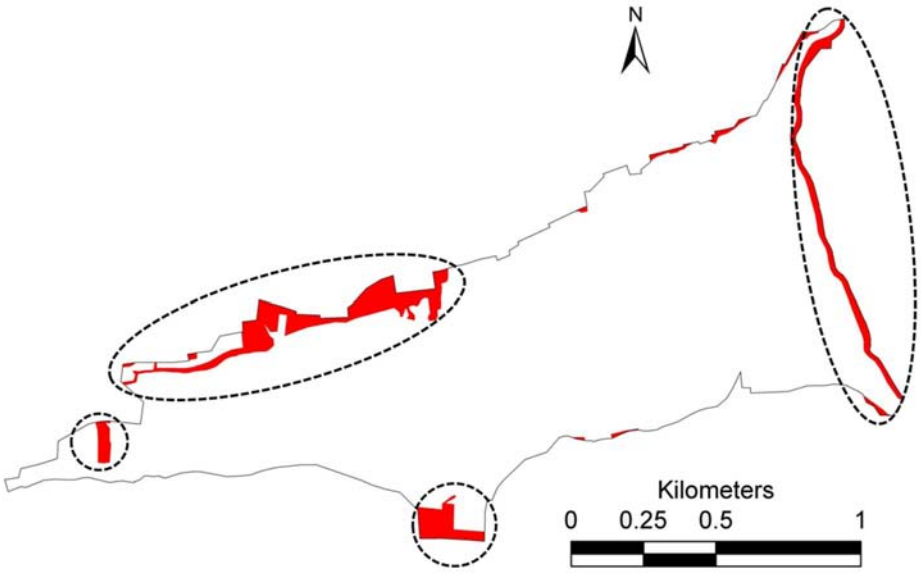


Figure 4.6: Encroachment of Lake

Construction activities in 30 m buffer: Area under Construction activities and Buildings 4.46 Hectares (11.09 Acre)

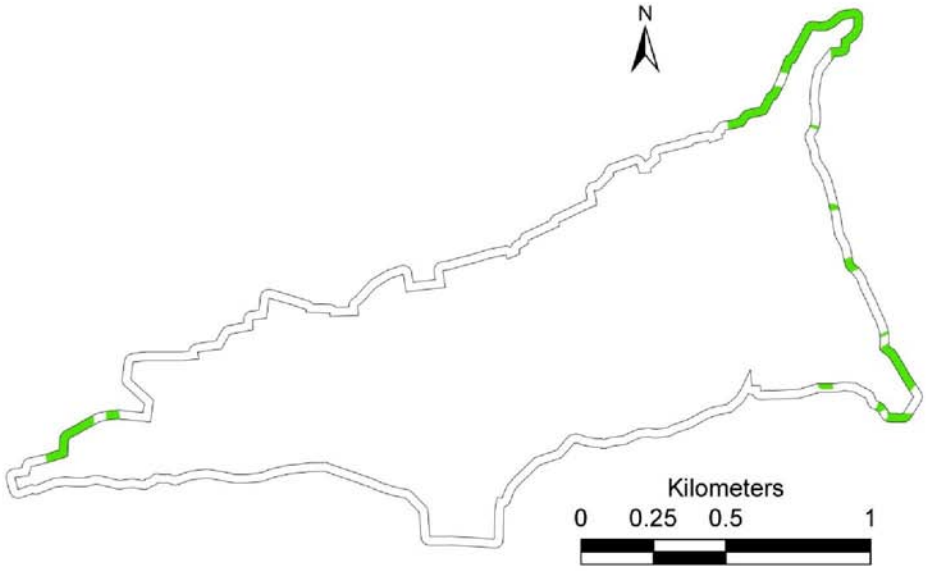


Figure 4.7: Construction activities 30 m buffer as per BDA

Construction activities in 200 m buffer: Figure 4.8 maps area under construction and buildings 49.53 Hectares (1122.40 Acre) in 200 m buffer zone (no building activities as per wetlands regulatory framework 2010). Figure 4.9a summaries violations in lake bed as well as in buffer zones. Figures 4.9b to 4.9f depicts section wise land use violations in the region.

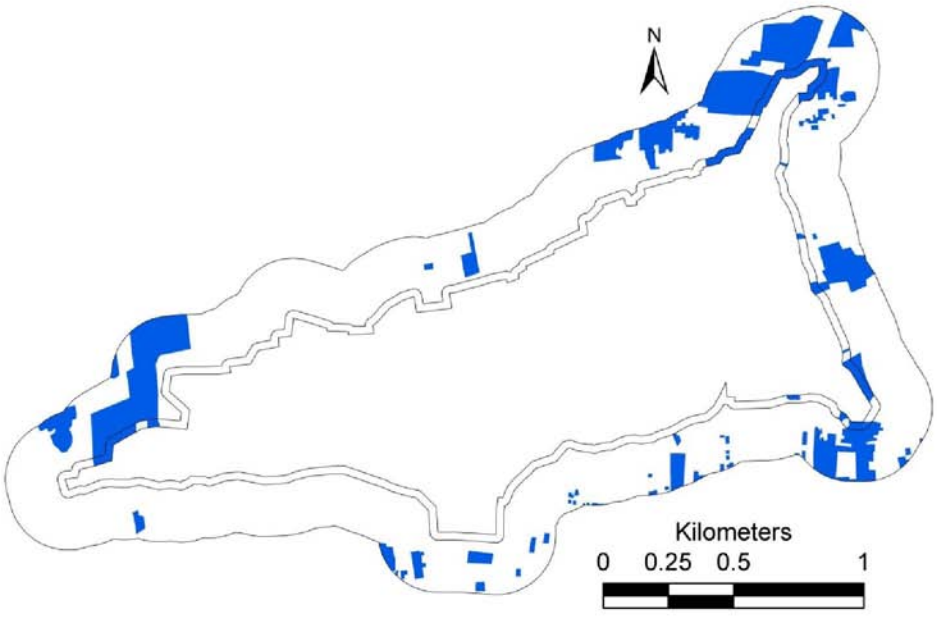


Figure 4.8 Construction activities 200m buffer as per MoEF

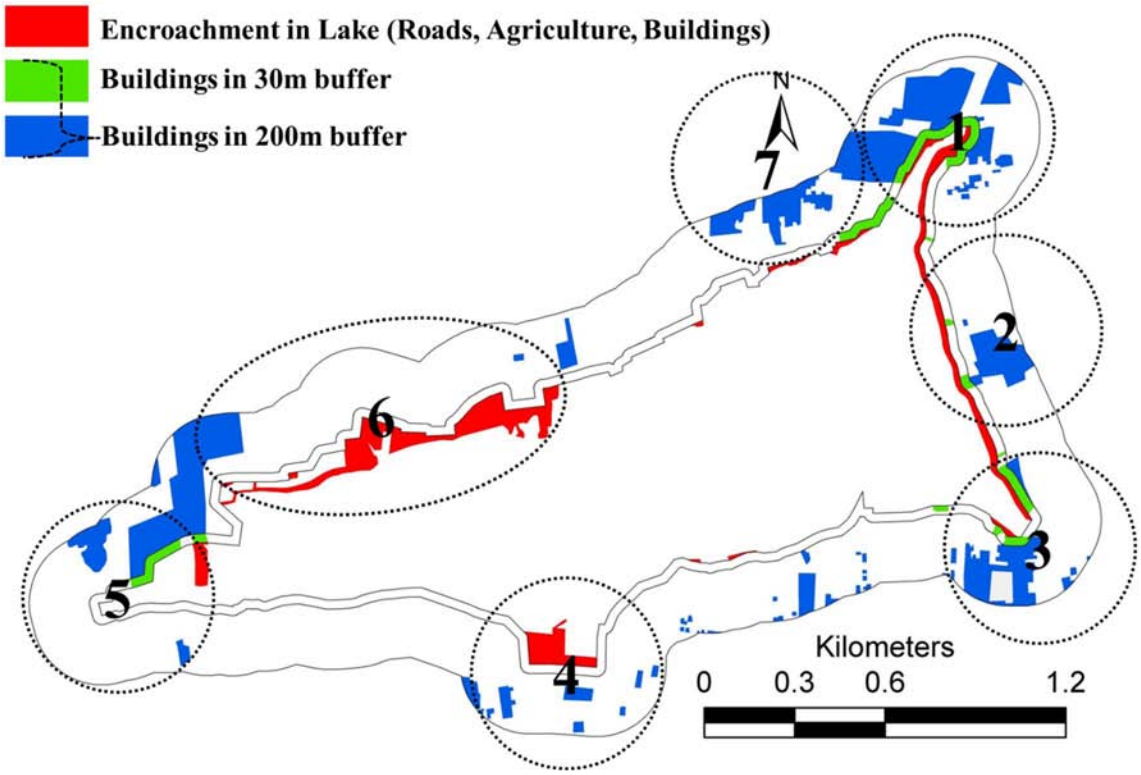


Figure 4.9a: Encroachments and Law violations in the lake and buffer zones

Figure 4.9b: Encroachments and Law violations at Section 1

Figure 4.9c: Encroachments and Law violations at Section 2

Figure 4.9c: Encroachments and Law violations at Section 3

Figure 4.9d: Encroachments and Law violations at Section 4

Figure 4.9e: Encroachments and Law violations at Section 5

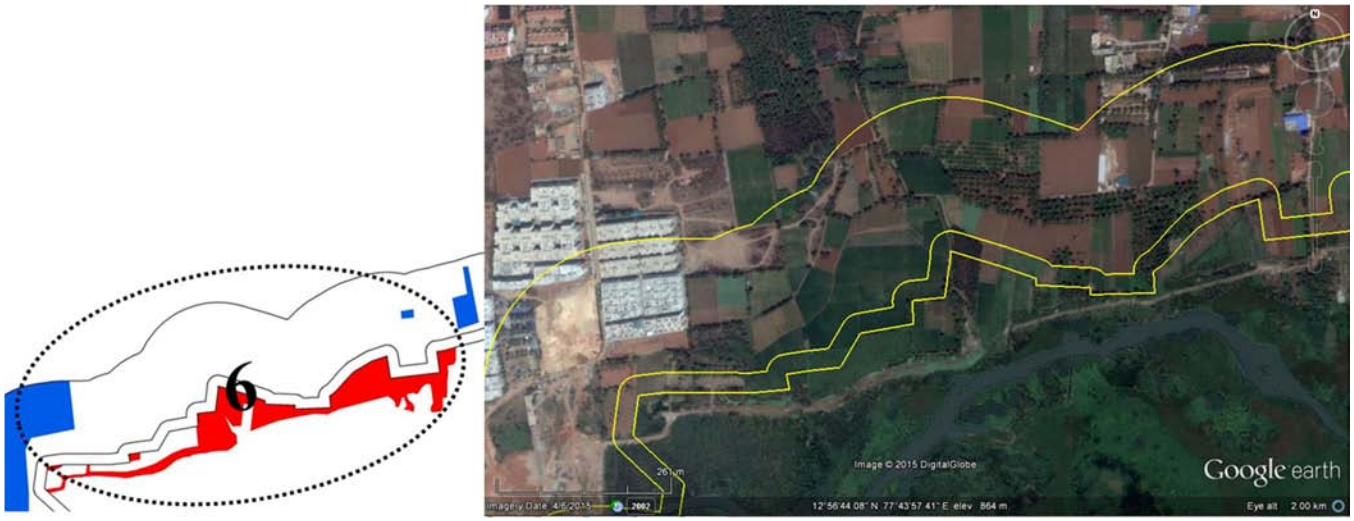


Figure 4.9f: Encroachments and Law violations at Section 6

Figure 4.9g: Encroachments and Law violations at Section 7

City Development Plan: As per the CDP, valley zones and the lakes need to be completely protected (Figure 4.10a), whereas large scale construction activities have degradation of valley zone. Area under altered valley zone (including STP) is 559.25Hectares (1381.93 acres). Figure 4.10b to 4.10e depicts temporal increase in violations / illegal construction activities in the valley zone during 2003 to 2015.

Loss of storm water drains: figures 4.11 to 4.13 depicts encroachment of stormwater drains in Varthur lake downstream.

Figure 4.10a: CDP indicating protected zones

Figure 4.10b: Valley Zone 2003

Figure 4.10c: Valley Zone 2009

Figure 4.10d: Valley Zone 2012

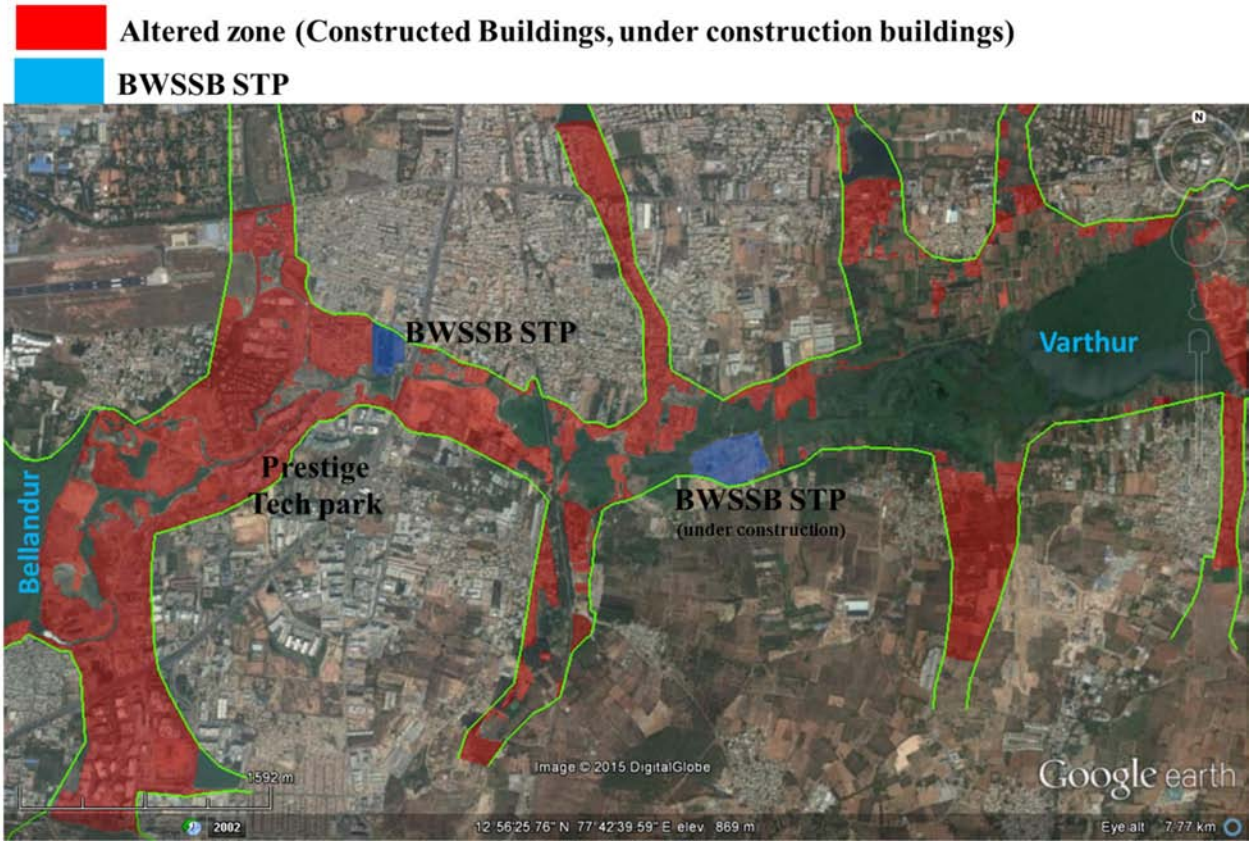


Figure 4.10e: Valley Zone 2015

Major violations:

- Development in the wetland - Violation of CDP 2015 as valley zone is supposed to be protected as the region is "No Development Zone";
- Encroachment of wetlands in the valley region: Wetlands removal affects the ecological functioning. Wetlands with numerous aquatic plants in the valley of Bellandur-Varthur were treating water through uptake of nutrient and heavy metals (bioremediation);
- These violations or construction activities activity enchases flooding in the vicinity due to
  i. Encroachment of drains / rajakaluves;
  ii. Alterations in topography;
  iii. Encroachment of lakebed; and
  iv. Encroaching of lake itself by dumping debris and filling up of same
- Construction activity in the lake floodplain;
- Violation of 30 m buffer (lake floodplain);
- Encroachment of a drains and lake bed;
- Filling of a portion of lake with building debris
- Removal of fence and systematic encroachment of lake bed through dumping of building debris.

Citizens of Bangalore allowed the development in the region with "utmost good faith". But, numerous para-state agencies with un-coordinated actions, inefficient regulatory agency and negligent industries have converted the garden city to unlivable city.

- Contaminated air, land and water are the penalty citizens have to pay for exercising tolerance with good faith.
- Growth in Bangalore has surpassed the threshold evident from stress on supportive capacity (insufficient water, clean air and water, inadequate electricity, traffic bottlenecks, etc.) and assimilative capacity (polluted water and sediments in water bodies, enhanced GHG – Greenhouse gases, etc.)
- There has been a 925% increase in built up area (concretisation, paved surfaces) in Bangalore from 1973 to 2013 with a sharp decline of 79% area in water bodies affecting the micro-climate, water availability, etc..
- Higher level of GHGs (Greenhouse gases) in the air environment, nutrient and heavy metal rich water bodies and land, highlight the penalty to be paid for allowing unplanned urbanisation.

Solution is "**Decongest and decontaminate Bangalore**"

so that at least next generation enjoys better environment in Bangalore

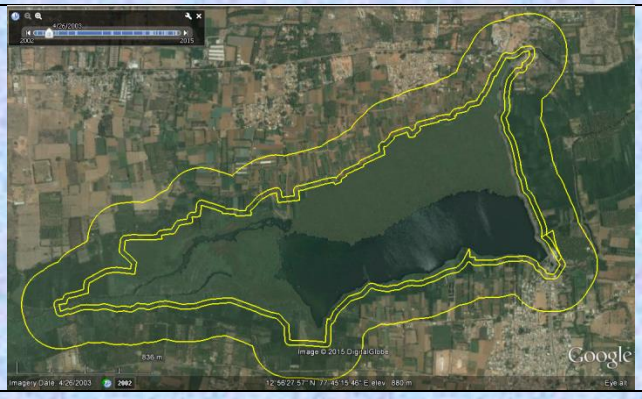
- Need to ensure the ecosystem integrity to sustain goods and services for maintaining inter-generation equity.

Clean air, water and environment are the fundamental rights of citizens as per the Constitution of India (Article-21 of the *Indian Constitution*)

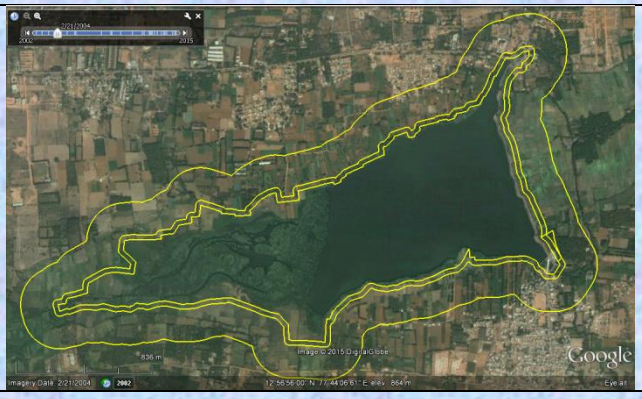
Figure 4.11: Encroached drains at downstream of Varthur Lake

Figure 4.12: Encroached canal and altered land use downstream of Varthur Lake

Figure 4.13: Encroached canal and altered land use upstream of Varthur Lake

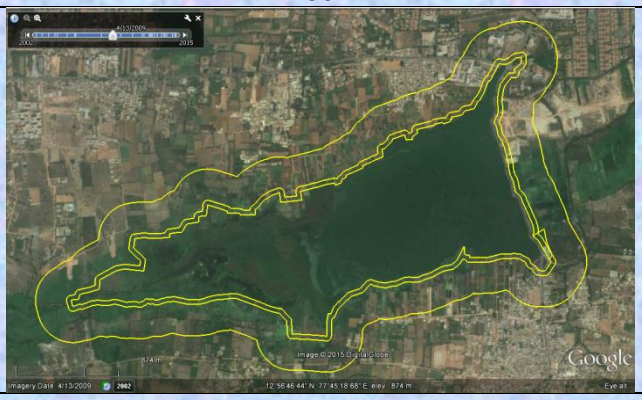


2003



2004

2008



2009

2014

2015

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