HYDROLOGICAL AND ECOLOGICAL BALANCE OF URBAN LAKES

Anil Mehta
Joint Secretary - Jheel Sanrakshan Samiti
Lecturer - Vidhya Bhawan Polytechnic, Udaipur

ABSTRACT

Urban lakes are basically impounding of water against an embankment. As time passes after the formation, these lakes start to play an important role in sustaining the socio-economic, ecological and cultural fiber of that area. Increasing water demand, degradation of catchments, blockages and encroachment in inlet channels and lake beds along with disturbances in rainfall pattern, intensity and duration, have severely deteriorated the hydrological, ecological and limnological balances of almost all urban lakes. There are the years when one cannot find even a drop of water entering in to these lakes. Sedimentation is another problems, which has reduced the water storage capacities. Anthropogenic and cultural pollution along with sedimentation are the major factors of eutrophication. Many lakes are now extinct and others are on the verge of extinction. There is an urgent need of more rationalized scientific and engineering considerations, wholesome management policies, reforms in legal provisions and effective institutional building for the hydrological and ecological rejuvenation of urban lakes. The author has a long experience of conservation of urban lakes both as an activist and as water Engineer. The measures suggested are applicable to almost all urban lakes. There is an elaborative analysis of cost benefit aspect of desilting is furnished in the end of the paper.

WHY HYDROLOGICAL AND ECOLOGICAL REJUVENATION?

The urban lakes are center of all life supporting activities and sustainable development. Udaipur lakes not only provide drinking water and recharge ground water, they are the main source of livelihood of lakhs of citizens of Udaipur. Every year around 7 to 8 lac tourists visit this place and revenue generation is of the order of Rs. ten Thousand Millions per year. Lakes sustain important verities of flora and fauna. They play an important role in ecological balance of the whole area. There are many small lakes other than major lakes like Pichhola and Fatehsagar.

SOME FACTS ABOUT UDAIPUR LAKES

The gross storage capacities of Pichhola and Fatehsagar lakes are 13.68 mcm (483 mcft.) and 12.09 mcm (427 mcft.) respectively. While the estimated average annual yield for last 50 years for these two lakes are only 9.86 mcm and 3.06 mcm.

MAJOR PROBLEMS AND REMEDIAL MEASURES

Recording and Analysis of Hydrological Data

There are only three rain gauges in the 33 Thousand hectare catchments area of Pichhola and

Fatehsagar lakes. Though the numbers of rain gauges are broadly as per the norms (One rain gauge per 8 thousand ha.), but with the change in pattern of rainfall intensity, duration and distribution, the rainfall data and yield to the lakes do not provide any definite relationship. We need to change this provision and develop more rationalized provisions of installation of rain gauges. Similarly infiltration studies of the catchments, withdrawal, evaporation and seepage analysis of lakes should be done in order to maintain their hydrological balance.

Table 1. Rainfall v/s Max. Gauge

Year	Average Annual Rainfall in mm (Average Rainfall=660 mm)	Max. Gauge in feet attained		Remarks
		Pichhola FTL - 11 ft.	Fatehsagar FTL - 13 ft.	
1997	562	9.83	11.58	
1998	613	8.5	8.25	
1999	400	1.00	-1.08	Below sill level in Fatehsagar
2000	334	0.92	-3.58	Below sill level in Fatehsagar
2001	636	2.25	-4.5	Below sill level in Fatehsagar
2002	429	-16.3	-7.25	Below sill level in Fatehsagar & Pichhola

Table 2. Yield v/s Withdrawal (in terms of gauge feet)

Year	Pichhola		Fatehsagar	
	Yield	Withdrawal	Yield	Withdrawal
1998	9.58	7.5	10.00	9.33
1999	3.50	3.50	1.08	0.50
2000	0.92	4.17	3.08	8.22
2001	5.50	9.50	7.30	11.80
2002	2.08	1.67	2.22	6.00
Average	4.31	5.26	4.73	7.17

Catchment Area Protection and Conservation

(A.) Due to anthropogenic factors (human interference) catchment areas are deteriorating. Siltation in down stream water bodies has increased and deforestation is rampant. All these factors have caused desertification, change in rainfall pattern and decrease in yield. For proper and effective treatment of catchment areas, watershed boundaries should be demarcated on G.T. Sheets and by some simple provision on ground as well. There is need of satellite mapping of the area, demarcation and calculation of various land uses such as water body, forest areas, grasslands shrub cover and area encroached upon by habitation. The detection of aquifers present in the area and underground faults in rocks should be done to identification of ground water recharging sites.

(B.) Total number of intermediate water storage structures (like anicuts) constructed in the water shed boundary of particular water bodies should not intercept more than 40% of total Runoff generated from the area. Any intermediate structure should be designed on the basis of proper **Water Budgeting** and hydro geological investigations.

(C.) Massive soil and water conservation majors should be applied in the catchment.

Protection of Water Carrying Channels

Chocking and diversion of inlet and outlet channels/feeders of the lakes is common practice. This results in decrease in yield to the lakes. To avoid this identification and mapping of all water carrying channels is very necessary. The details should be marked on the revenue records and maps. The inlet and outlet channels should be restored to their original shape and size. A protection strip should be provided on both sides of the channels. The width of protection strip could be 50 meters, 10 meters, 5 meters for 1st order tributaries/main feeders (rivers) , 2nd order tributaries and 3rd order tributaries. In protection strips, plantation work should be done.

Mapping of Urban Lakes and Demarcation of Highest Flood Level (HFL)

This is the need of the hour to prevent and protect the urban lakes from encroachments and colonization. There are several cases all over the country where lakebeds are sold and land use is altered. Udaipur is foremost example. On the basis of past 50 years rainfall-runoff data and revenue records, the HFL should be marked on the ground and no construction activity be allowed in the area within the HFL. The activities like tube well drilling in this area should also be disallowed.

Identification Of Buffer Zones

Buffer zone beyond the periphery of HFL is required to protect the lakes from pollution and encroachments. The buffer zones could be of 200 meters width (as per National Lake Conservation Plan of MOEF) for major lakes and of 50 meters width for small lakes. The buffer zones should be used only for activities like afforestation, peripherial roads, landscaping, sewerage treatment plants etc. No residential or commercial construction activities should be permitted. The book on Lake Management authored by S. E Jorg and H. Loffler (volume 3,UNEP publication) elaborates the need and importance of buffer zones.

Conservation of Minimum Pool Level (MPL)

The increase in water demand and decrease in sufficient yield from the catchment basin are the major reasons for frequent drying of the urban lakes. This is imposing serious threats to the flora and fauna of the lake ecosystem. At many places the lakes are the major source of tourist attraction and revenue generation and their drying affect the livelihood of a large number of people. The urban lakes also maintain the local micro climate and recharging of ground water.

Therefore it is very necessary to keep the lakes up to a minimum level throughout the year. This requires skillful management of yield v/s withdrawal of lake water. There may be good rainfall in neighborhood basins so inter-basin transfer projects be implemented so as to maintain the lakes to a MPL.

A book on "Management of lakes and ponds", Authored by George W. Bennet clearly specify the need of MPL in order to maintain the ecological, limnological and hydrological balance of the lakes. It should be made mandatory to maintain the MPL of minimum 10% of the total storage capacity.

Protection of Embankments and Outlet Structures

These structures should be analysed for hydraulic and structural strength on the basis of highest possible yield, earthquake potential and transportation over the structures. Suitable majors be applied to repair, renovate and maintain them. In order to avoid piping, no tube-well drilling be allowed within at-least 200 meters distance downstream to the embankments.

Waste Water Treatment Plants

Every human settlement in the catchment area should have appropriate sewerage treatment plant and the treated wastewater can be poured into the downstream channel if the lake is under use as drinking water source, otherwise it can be poured into the lake after achieving the prescribed effluent water quality norms.

Reforms in Revenue and Land Use Laws

The land use of all petakasht (where agriculture is done) land, embankment, land up to Buffer Zone boundary, embankment, outlet structures should be registered in revenue records under one main title i.e WETLAND. Similarly land use of inlet and outlet watercourses should be defined in revenue records as Natural Nala/River. The landuse should not be changed for any other purpose at any cost of the aforesaid Wetlands and Natural Nalas. The peripherial control belt around the lakes i.e the Buffer Zones and protection strips along inlet and outlet water courses should be declared as "No Construction Zone".

Lake Development Authority

For effective management and conservation of urban lakes, there should be one nodal agency statutory formed by the government. This authority should be responsible and accountable for ecological, hydrological and limnological balance of the lakes concerned.

Desilting of Lakes as a Boon

Nutrient rich soil deposition in lakes not only affect their storage capacity but severely deteriorate the drinking water quality in particular and lake ecosystem in general. Increased nutrient deposition accelerates the process of eutrophication, and eventually the water body dies. Irrigation Engineers usually oppose the desilting of lakes on the basis of cost - benefit ratio. It is there general view that it is cheaper to build a new reservoir than to desilt the existing one. Such theories ignore the basic concepts of integrated lake management, and importance of the soil as an invaluable natural resource. As long as soil is treated as an inert material and lake body as mere water tank, such conservatism would continue.

According to a study conducted in the year 1983, every year about 5334 million tons of soil is eroded by water (Dhruvswamy & Rambabu),. Since only 20% of the erosion - affected land was treated (under water and soil conservation measures and waste land development programs) till the end of the 7th plan, the soil eroded in last 50 years is equivalent to the very fertile land of well over 70 million hectares having a depth of 9 inches i.e. around 21% of the total geographical area (329 Mha) of India. Moreover, the monetary value of these major plant nutrients is of the order of several hundred billions.. It is estimated that it takes about 700 years for formation of one inch of soil. Considering this fact it is evident how alarming the situation can be with regular soil erosion, as annual average loss of nutrients from land is 5.37 to 8.4 million ton annually. On the basis of fertiliser statistics reports,it can be derived that a kg. of nutrient costs at least Rs. 50.

The major content in lake soil is organic carbon. Organic carbon plays a vital role in productivity and conditioning of soils. Organic carbon is the main storehouse of nitrogen. Small amounts of all other plant nutrients are also supplied when organic matter decomposes. The organic matter content of most of the Indian soils is 1 to 2 percent. On an average, 50 million tons organic matter is lost every year by water erosion.

Dhruvanarayana & Rambabu (1983 - Estimation of soil erosion in India, journal of Irrigation drainage Engineering, ASCE) analyzed the existing soil loss data, and concluded that soil erosion was taking place at an average rate of 16.35 ton/ha/year. Nearly 29% of the total eroded soil was permanently lost to the sea, and nearly 10% was deposited in reservoirs, resulting in the reduction of their storage capacity by 1 to 2%.

Thus, life of most of the reservoirs has been drastically reduced. It has been found that the actual rate of sedimentation is always more than the assumed one because of massive deforestation in their catchment. In this context, lakes of urban areas are in most vulnerable condition because of faulty land use practice, and indiscriminate disposal of solid waste in their periphery and submergence area.

Sediment deposition (i.e deposition of productive soil) in lakes is of the order of app. 480 million tons per year. This indicates that other than losing top productive topsoil, we also lost 300 mcum of water storage per year which can otherwise fulfill the domestic water demand of millions of people @ 135 lpcd. To augment this much drinking water, we have to invest billions of rupees.

To get a clear picture of the loss of India's productive top-soil that is eroding each year into the reservoirs, journal of soil and water conservation in India (volume 5,no. 1, 1956) drew the following picture: If the 1982 acre-feet of silt deposited into Panchet hill reservoir were spread 6 inches deep over bare subsoil, it would cover 3964 acres of land and be more productive for field crops than the average land in India.(Murthy, B.N. and N.S. Iyengar)

DESILTING OF LAKES - COST BENEFIT ANALYSIS

It has been estimated that about 5.37 to 8.4 million ton nutrients are lost every year mainly due to water erosion. As stated earlier, out of total soil eroded annually, 10% get deposited into the lakes. On this basis, nutrient deposition can also be taken as 10% of the total nutrient lost, therefore, theoretically, nutrient content per unit weight of soil deposited into the lakes comes to around 0.1%, i.e per ton of the lake soil contains nearly one kg nutrients.

In the case of urban lakes, which seldom overflow and receive inflow of domestic sewage, municipal garbage, detergents generated by bathing & washing activities, nutrient rich backwash from water-filtration plants situated on the banks and deposition of residues of aquatic weeds and chemical fertilizers (excessive and unutilized, used by the farmers of the catchment areas); the nutrient content per ton is towards higher side than the theoretical value as evident from the case of Udaipur lakes .

CASE STUDY OF UDAIPUR LAKES

Over the last 25-30 years, massive deforestation and faulty land-use practices have severely degraded the Catchments of the lakes of Udaipur, resulting in increased inflow of sediments into this water bodies. The solid waste disposal around the periphery is further worsening the situation. The continuous sedimentation has not only reduced the water holding capacity but the quality of water is also being deteriorated severely. Siltation has reduced the original depths of lakes and thus a significant part of water (around 20%) gets evaporated due to increased water spread. It has been found that evaporation losses are more than percolation losses in the case of the lakes.

The Central Water Commission recommends provision of an average 715 cubic meter sediment inflow per square kilometer of the catchments area, but the actual rate of siltation i.e. reduction in the overall capacity is towards much higher side because of sediments input from the submergence area of lakes due to encroachments and dumping of highly infectious municipal garbage and constructional waste. It is estimated that around 50 tons of solid waste is disposed off around the lakes everyday. Considering this aspect, the sediment flow rate could be very safely assumed as 1000 cum/sq. kilometer (i.e. quite close to the all India average) of catchment per year.

On this basis, sediments depositions in Udaipur city lakes, which are having 171 sq. km free catchment area and 25.77 mcm gross storage capacity, are of the order of 10 mcm i.e. around 40% capacity has been already reduced.

It was found in the year 1987-88, that sediments deposits in the Udaipur city lakes were approximately 5.00 mcum. College of Technology & Agricultural Engineering (CTAE), Udaipur (Purohit et al 1988), conducted this study. One more study conducted by Hindustan Zinc Limited in the year 1986-1987, found that sediment deposition in Udaisagar lake, (lake body 15 km downstream from Udaipur city lakes) was 8.7 mcum (30 % of the gross capacity). On the basis of sedimentation survey, CTAE has calculated the useful life of Udaipur lakes as 97 years for Pichhola and 72 years for Fatehsagar.

DRINKING WATER QUALITY

The bacteriological analysis of sediments, conducted by Jheel Sanarakshan Samiti (JSS, 1995) revealed that the deposits have a very high content of Ova and Cysts of pathogenic helminthes and protozoa. It is found that Udaipur lakes, especially Pichhola, harbor citrobacter and strepto faecalis in addition to E. coil. The most concerning matter is the occurrence of ova of Ascaris, cysts of E. histolytica, Giardia and Trichuria trichuria in Udaipur lakes. This means that any amount of chlorination and treatment by other available chemicals will not make the water potable.

It is clear that Sediment deposit is having around 1% organic carbon, which is an indication of good fertility. The total quantity of various micro and macronutrient is also 1% i.e. per ton of lake sediments is having 10 kg nutrients costing worth 500 rupees.

Table 3. Nutrient Content Analysis of Udaipur lakes Sediments

S.N.	Factors (%)	Rang Sagar	Swarroop Sagar	Fateh Sagar	Pichhola	Average
1.	Organic Carbon	0.933	0.481	0.975	0.901	0.8225
2.	Calcium	0.517	0.485	0.502	0.525	0.5072
3.	Magnesium	0.0052	0.0070	0.0065	0.0062	0.0062
4.	Nitrogen	0.031	0.019	0.030	0.033	0.0280
5.	Phosphorus	0.005	0.0062	0.0061	0.0052	0.0056
6.	Sodium	0.078	0.076	0.083	0.082	0.0798
7.	Chlorides	0.430	0.443	0.390	0.372	0.408
8.	Zinc	0.1038	0.0769	0.2115	0.0577	0.1124

Details of Desilting Operation (January to June, 2000)

The desilting operation was performed jointly by Government agencies (Local Self Govt. Bodies), Public Sector Industrial Units Like RSMML and HZL, donations from industries and individuals, with active input from Jheel Sanrakshan Samiti, Chamber of Commerce and Industries and other like minded NGOs & citizens. The farmer community was motivated to carry excavated soil, free of cost, by Jheel Sanrakshan Satniti.

The operation was further accelerated after timely intervention of the State high Court who directed the Urban Improvement Trust (UIT) and Municipal Council, Udaipur to speed up the task while hearing PILs filed by Jheel Sanrakshan Samiti. Total 0.2204 mcm soil was removed from 20 ha. peripherial areas.

The total expenditure incurred was Rs 5.00 million, out of which app. Rs. 1.00 million came from donations (in the form of cash and Machinery), and Rs 1.00 million was saved by the UIT by using the coarser soil for road construction in their development areas. Therefore, the working cost of 1.00 cubic meter dredging is just Rs 18.00, which is 75 % less than the average estimated cost as per the governmental rates i.e. Rs. 70 per cubic meter.

Assessment of Economic Benefits

(a) Direct Economic Benefits

Soil used by Farmers	=	0.2062 mcum equivalent to 28,000 ton.
Nutrient content	=	28,000 kg. (@ 10 kg. per ton)
Nutrient Value @ Rs 50 per kg	=	Rs. 14.00 million
Soil used for road construction by the U I T	=	0.0 142 mcum
Amount Saved	=	Rs. 1.00 million

(b) Indirect Benefits

Revival of app. 1% water storage capacity and increase in soil productivity and food grain/ Vegetables productions.

Ecological Benefits

1. Highly infectious debris, organic waste and other garbage accumulated along the shoreline, and on the Ghats get removed .
2. The dredging of highly nutritious upper layers of silt deposition significantly arrest the phenomenon of eutrophication and quality of water get improved..
3. Large mass of seeds of aquatic weeds like water hyacinth, which remain viable for 20 years, get removed
4. The pits formed due to excavation along peripheries will work as silt traps and will retain the future inflow of sediments. The water collected in the excavated areas will eventually infiltrate and raise the under ground water table. The increased depth of water in such pits will reduce the rate of evaporation.

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