LARGE RESERVOIRS: ARE THEY THE LAST OASIS FOR THE SURVIVAL OF CITIES IN INDIA?

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Abstract

Urban water demand is rapidly growing in India due to high growth in urban population and rapid industrialization. Meeting this growing demand is a big challenge for the urban planners in India. Incidentally, urban areas in arid and semi arid regions of India are experiencing rapid growth. As a result, the supplies from local water resources including aquifers are far less than the high and concentrated water demands in most urban areas. Under such situations, the cities have to rely on large reservoirs. The paper argues that urban growth would be jeopardized in absence of water supplies from large reservoirs. The analysis of 302 urban centres shows that as population of cities grow, their reliance on surface water sources also grows. Also, greater the share of surface water in the city water supplies, better the level of water supply. A multiple regression analysis of 190 class I cities and 240 class II towns further supports this finding. In Class I cities, with every unit increase in population, there is a 1.12 unit increase in quantum of water supplies. Whereas in Class II towns, with every increase in population, there is only a 0.40 unit increase in quantum of water supply. This shows greater capacities of large cities to respond to the growing water demands, induced by population growth and urbanization. The future projections of population growth, economic development and future water demands clearly means that the role of large reservoirs in meeting the demand of urban water supply is going to be more critical.

1. INTRODUCTION

The traditional engineering approach to water management in India largely centered upon building storages and diversions in places which provided hydrological opportunities and taking water to regions that face shortages with the aim of reducing the imbalances in demand and supplies. But, large water resources projects began to face fierce resistance from environmental groups for the potential negative social and environmental consequences they could create (Shah and Kumar, 2008). Though they propose alternative approaches, these alternatives were quite general, and had looked at options for augmenting the aggregate water supplies against the aggregate demands. They missed two important factors that determine the nature of treatments that would be effective in a given situation. The first one is the source of growth in water demands, and thus the nature of water scarcity. The second one is the type of regions which are likely to experience rapid growth in water demands.

To elaborate, most of the solutions to India's water problems have been agriculture centric. The solutions advocated overlook the magnitude of water demands in urban areas; ignore that a significant chunk of the growth in water demand comes from urban areas. Urban water demands are different from agricultural water demands. They are more or less uniform over the year, and are highly concentrated. These characteristic features of urban water problems make it mandatory to have unique approaches and treatments.

Secondly, several of the suggestions on urban water management alternatives advocated[1] are based on the inherent assumption that the regions which are likely to experience water scarcity would have extra water resources availability for harnessing. In contrast to this, most of the regions experiencing urban growth in India are naturally water-scarce regions. These regions have limited water resources endowment. As a result, the

[1] They include local runoff water harvesting and groundwater recharging, urban storm water harvesting; roof water harvesting. Largely, these interventions would be effective only in high rainfall areas (Kumar et al., 2006).

amount of water that could be managed from small geographical areas in such regions is often too inadequate to cater to the high demands resulting from the population crossing a threshold.

The key propositions in this paper are as follows - i) in semi arid and arid areas, the urban water supply is dependent on local water sources such as wells, ponds and tanks; ii) the rapid growth in urban population and fast industrialization in and around urban centres, which is characteristic of these resource-scarce regions, is threatening the sustainability of local sources; ii) these urban centres will have to depend on exogenous water resources based on large reservoirs for ensuring sustainable water supplies, and as a result, as the city grows, the dependence on surface water resources from large reservoirs is likely to increase consistently; and iv) cities depending on exogenous sources for urban water supplies, particularly large reservoirs, maintain much better supplies as compared to those dependent on local sources.

The next section deals with the objective, hypothesis, methodology and data sets. The third section describes the trend of urbanisation in India and how that changes the pattern of water supply in urban areas. The subsequent sections analyse empirical data on urban population, pattern of water supply, and per capita water supplies in Class I cities and Class II towns, to identify the major determinants of the quality of water supply existing in urban areas. The last two sections offer policy suggestions and concluding remarks.

2. OBJECTIVES AND HYPOTHESIS

The objectives of the study are to: analyze the changing trend in urban water supplies vis-à-vis the dependence of towns and cities on local resources and large reservoirs in accordance with changing size of urban population; and identify the major determinants of water supply condition existing in urban areas.

The main hypothesis being tested in this paper is that beyond a threshold point, the population and economic growth of the city drive the water utilities to shift from groundwater to surface water, in semi arid hard rock regions of India resulting in improved water supplies. The sub-hypotheses to test are: 1] with increase in population, the dependence of cities on surface reservoirs for water supply would increase in both aggregate and percentage terms; and 2] with increase in dependence of cities on large surface reservoirs, the access to water supply would improve.

3. URBANIZATION AND GROWTH IN URBAN WATER DEMAND

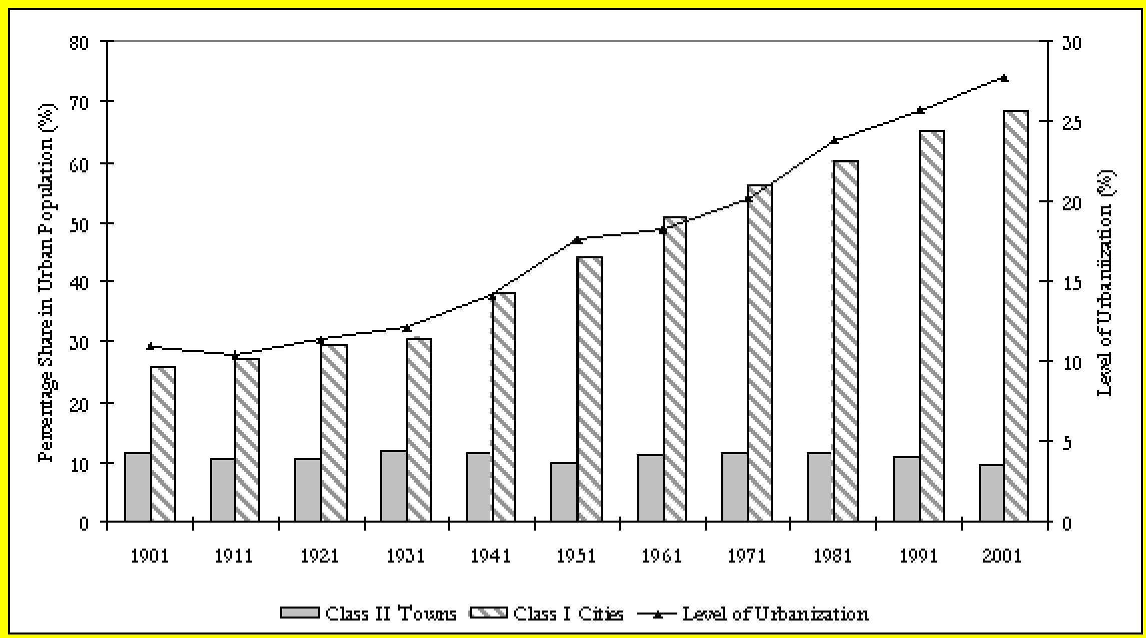
Since independence, the urban population of India has grown exponentially. Total urban population in India increased more than ten times surpassing India's overall population growth, which increased less than five times during 1901 to 2001 (Maiti and Agrawal, 2005). Currently around 27.8 % (285 million in absolute terms) of India's population is living in urban areas (Census of India, 2001), which, as per an estimate will continue to increase up to 40% or 550 million in 2021(Lundquist et al., 2003). The Census of India divides urban agglomerations between Class I and Class VI, based on their population size[2]. Figure 1 describes the share of Class I cities and Class II towns in total urban population and the level of urbanisation (urban population as a percentage of total population).

The magnitude of challenge to India's future water resources planning and management would be largely determined not so much by its population growth, but by the source of this growth, i.e., whether rural or urban, and where this growth is likely to take place, i.e., whether in water-scarce regions, or water-rich regions. The average annual exponential urban population growth rate for last 5 decades is 1.4 times higher than total population growth rate (Census of India, 2001).

Unlike in many developed countries, India's urbanisation is rapid, exponential and uncontrolled. While urbanisation in developed countries accompanied the country's economic growth, which financially supported the infrastructure development in the cities (see Biswas, 2006a). In India, sustaining high urban growth rate

[2] Metropolitan: with a population of more than one million people; the Class I cities are those with a population between one lac and one million. The Class II towns are those having population between 50,000 and one lac people; class III towns have population in the range of 20,000 and 49,999; Class IV towns have population in the range of 10,000 and 19,999; Class V towns: between 5000 and 9,999; and Class VI towns: with population of less than 5000.

Figure 1: Growing Population Pressure on Class I Cities and Class II Towns in India: 1901-2001



Source: Census of India (2001)

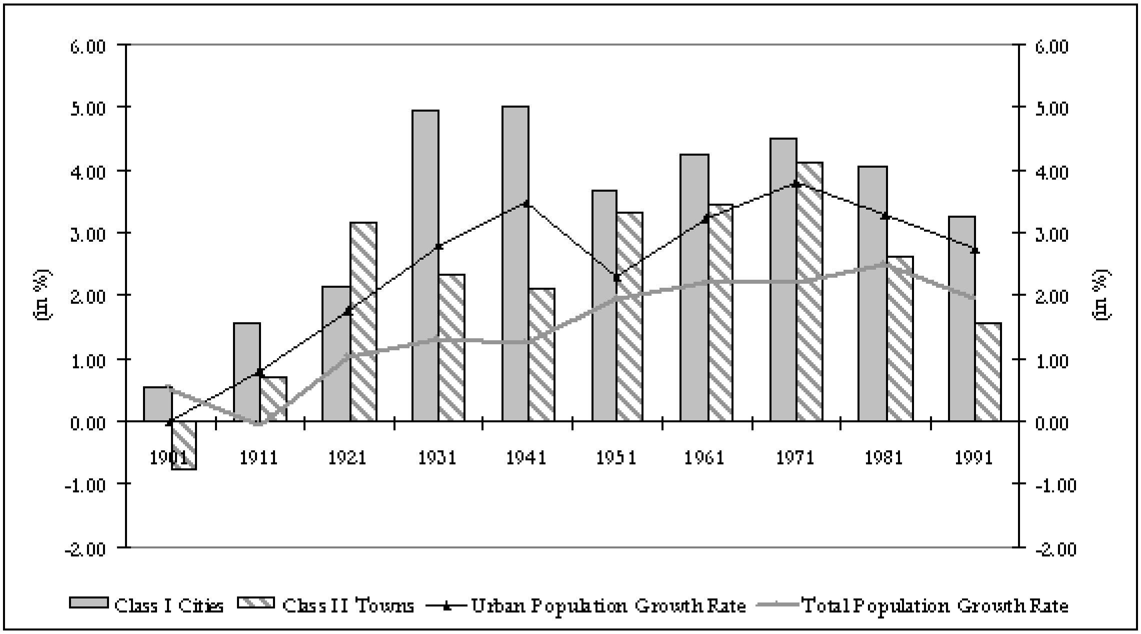
would be crucial for utilizing the future growth potential in the country's economy, which has been experiencing a two-digit growth for the past one decade. Cities are the engines of economic growth. It is estimated that the urban areas of the developing world, which have about 47.2% of the total population in 2000, contribute nearly two-thirds of their total gross national products, and also play an equally important role in terms of social development and cultural enhancement (Biswas, 2006). In case of India the urban population consists of one-third of the country's total population and contributes to more than 50% of the country's total Gross Domestic Product (GDP) (Planning Commission, GoI, 2002). Sustaining high urban growth rate is critical to sustaining the country's overall GDP growth.

Improving urban utilities, including water supply services is the key to sustaining high urban growth rates. As a recent study involving 145 nations around the world shows that the improvement in water security drives economic growth of a nation through the human development route (Kumar et al., 2008). Unlike other infrastructure, water supply needs continuous inputs to ensure high quality of services in terms of the maintaining the daily per capita supplies to the minimum standard, equity in access to water supplies, maintenance of water quality standards, and safe disposal of wastewater. If a city's own sources fall short in meeting the increasing demand for water supply beyond a point, and then it has to look out of its municipal limits to sustain its living condition and economic growth (see McGranahan et al., 2001).

The Nation Water Policy, 2002 (GoI, 2002) prioritised drinking water over agriculture and industrial water demands, and since then a large part of the total water harnessed by reservoirs is kept reserved for supplying to urban and rural households. However, despite the catalytic impact that dam projects have on the formation of modern urban landscapes, these projects have received very little attention in the emerging field of geographical enquiry on the urbanization of nature (Kaika 2006). Sardar Sarovar Project constructed on the Narmada River in Western India, for example, is expected to make a major dent in the rural and urban drinking water needs of 9,663 villages and 137 urban centres (Hirway and Goswami, 2008). Without the Sardar Sarovar project, the drinking water situation in these drought-prone areas would have been precarious to meet even the basic requirements (Talati and Kumar, 2005). As many cities and towns are running short of water, due to permanent depletion of local groundwater, many dams originally meant for irrigation are now supplying water for domestic consumption (Shah and Kumar, 2008).

Figure 2 explains India's exponential urban growth rate. Even now India's urbanisation is more or less uncontrolled and unplanned. The large population base and limited availability of finances for infrastructure development and up-gradation are the further limiting factors of promoting Indian cities at world class level.

Figure 2: Annual Exponential Growth Rate of Population across Urban Agglomeration in India



Source: Census of India (2001)

4. CHANGING URBAN WATER DEMAND AND SUPPLY SCENARIOS

Urban water demand comes both from (a) the concentration of people in cities, who need water to survive; and (b) urban economic activity (Meinzen-Dick and Appasamy 2002). The cities are characterised by concentration of population as well as various kinds of economic activities including industrial units. Against this, the factors that determine its sources of water supply and level of scarcity (physical, financial, political or qualitative) can be classified based on: geo-hydrology; rainfall; technology and management; economic growth potential; and, political influence. At initial stage of expansion the water requirement of a city is met through development of local groundwater resources, and diversion of water from lakes, ponds and tanks. This prove to be limited against the increase in demand, which is an outcome of increasing population pressure (vertical expansion) and expanding city's boundaries (horizontal expansion), growth of its economic activities, and improved standard of living. In this context long-distance transfer of water to the growing urban system is already necessary in many countries (Lundquist et al., 2003). Mexico City, Cairo and Beijing in the developing world and San Diego, Los Angeles, El Paso in USA are some of the examples where the city's water demands have been met through large reservoirs. In India Yamuna River is the major source of water supply for Delhi. Its future panning includes drawing water from Tehri dam. Delhi's hydro-geological characteristics and rainfall pattern cannot sustain its economic and population growth without the external support from far away places. Similarly, the growth of Jodhpur city in the arid regions of Rajasthan can be duly acknowledged to the water supplied through Yamuna canal. The vastly growing city of Hyderabad gets water supply from reservoir on Krishna river and structures built on Godavari river.

4.1 Economics of Urban Water Supply

The investment decisions in the water sector are largely taken on economic and political grounds. The water transfer from large reservoirs to cities is criticized on the grounds that - i) cities take away water from farms (see Lundqvist et al., 2003); ii) the cost of water transfer from far away places is very high (see SANDRP 1999); and iii) the environmental impacts of dam construction and water transfer are always negative and irreversible (see D'Souza 2002; McCully, 1996; Fitzhugh and Richter, 2004). On the other hand, all social, economic and political considerations favour transfer of water from agriculture to domestic sector. Meeting drinking water requirements is the first and foremost priority according to India's Water Policy-2002 (GoI, 2002). In spite of the fact that domestic sector (urban and rural) takes only 3% and less than 5% by industry (Bansil, 2004), this seems to be a daunting challenge, particularly when the domestic water supplies are dependent on groundwater based schemes. The reason is the de jure rights to access groundwater are not clear, whereas de facto, it is attached to land ownership rights.

The direct and indirect social and economic impacts generated by regular water supply in urban areas would justify a city's decisions to obtain supplies often at costs higher than what is necessary, but without significantly compromising their ability to expand and prosper even in the most unhelpful locations (Molle and Berkoff, 2006). When urban areas become large and house large manufacturing units, the opportunity cost of not providing adequate amount of water to maintain minimum supply levels would become prohibitively high in terms of negative consequences for the economic activities that urban areas support, and survival of the communities there, which are often more influential than the farming communities in rural areas. The political economy of growth based on urbanization and industrialization would continue to justify the huge investments in urban water supply infrastructure.

Also from a pure economic perspective, the contribution from agricultural sector to the overall GDP has been decreasing over the years (from 38% in 1980 to 22.7% in 2001), while the contribution from domestic and industrial sectors to the same has been increasing (Ministry of Agriculture 2002, as cited in Amarasinghe et al., 2005). This had forced water resource bureaucracies to reallocate water from agriculture to non-agricultural uses including urban and industrial uses in the past. But, growing water scarcity in rural areas including that for drinking and domestic uses, these agencies would be increasingly under pressure to look for new sources of water. This can lead to planning of new schemes that involve transfer of water from abundant regions to water-scarce regions where urban centres are located[3]. The underlying premise in this new approach is that while the negative environmental impacts of construction of large dams and water transfer can be controlled with good science and technology, the opportunity cost of delaying or stopping dam construction could often be severe (see UNDP 2006, Shah and Kumar, 2008).

5. HOW DOES WATER SUPPLY SCENARIO CHANGE WITH URBAN GROWTH?

In most cases cities exploit their groundwater resource, which is easily accessible since it is within the boundaries of urban centres, and cost effective in terms of initial investment. For a long time since Independence, Chennai city depended on the tanks which are located in the periphery of the city for municipal water supplies. Similarly, Ahmedabad city depended on water from Sabarmati River and the groundwater resources for meeting water supply needs of the city. But urban growth changes it's water demand patterns altogether. The reason for this is that rise in population and growth of economic activities increase the water demands of urban areas exponentially. The cumulative effect of urban economic growth and growth in urban population on urban water demand can be explained this way. The population itself increase per capita water supply needs. Further, economic growth increases the per capita water demand for domestic uses (Rosegrant et al., 1999). Also, urban growth, which comes with heavy industrialization, would increase the water supply needs for commercial activities and manufacturing units. Amarasinghe et al., (2006) shows that economic growth and urbanization influence the per capita water demand in urban centres. Their analysis shows that a 1% increase in per capita gross domestic product would have a 0.17% increase in the per capita domestic water demand. A similar increase in urbanization would result in a 0.68% increase in per capita domestic water demand.

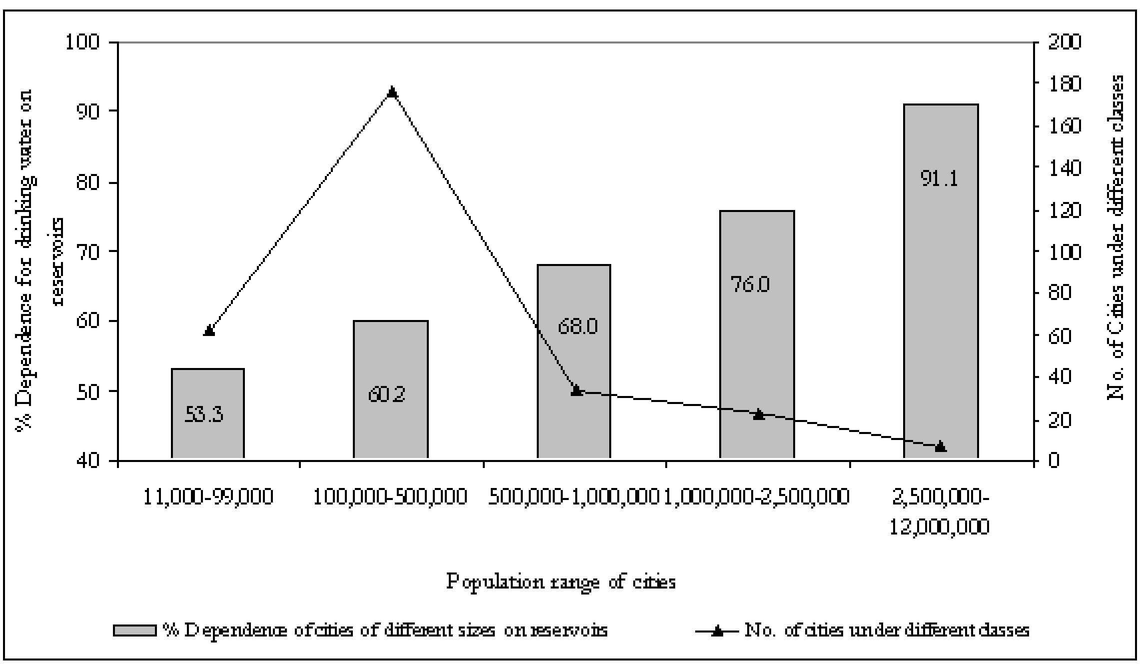
[3] The drinking water supply schemes in large number of cities in Gujarat including Ahmedabad, based on water from Sardar Sarovar reservoir is one of the most recent examples of such an approach. While earlier, Ahmedabad city depended on water from Dharoi reservoir, the increasing pressure on this scheme to get water for rural drinking had reduced its ability to meet Ahmedabad’s annual demands.

Thus when the cities grow, the dependability of local resources would become too low for water utilities to provide adequate supplies to the municipal users on a sustainable basis. More importantly, the fast growing urban centres in India are located in semi arid and arid areas experience high variability in rainfall conditions, making the supplies from local water bodies such as tanks, and ponds and wells unreliable. Examples are Pune, Ahmedabad, Hyderabad, Chennai, Delhi, Rajkot, Hyderabad and Bangalore. There are very few urban areas that are located in water-abundant regions. In a semi arid or arid area, if the urban centre taps water for municipal uses from underground sources, the chances of aquifers getting depleted due to excessive pumping are very high as the pumping takes place within small geographical areas creating "cones of depression". This is a phenomenon found in many urban areas around the world including those located in humid climates. Examples are Beijing, Bangkok and Ahmedabad. On the other hand, the tanks and ponds get dried up fast due to heavy diversions. More over, increasing urbanization leads to encroachment of tank catchments for building activities and peri urban agriculture, adversely affecting the inflows from the catchments.

As on today, when the supplies from the tanks around Chennai are compared against that city's water demands, these sources are not dependable for urban water supplies. Hence, Chennai now depends on water from Nagarjunasagar reservoir in Andhra Pradesh. Over-draft of groundwater for municipal uses had led to mining of aquifers underlying Ahmedabad city; with serious water quality problems in terms of high levels of salinity (as indicated by Total Dissolved Solids) and fluoride in groundwater beyond permissible levels. Whereas, Sabarmati river as a source of water for municipal uses ceased to exist due to excessive diversion of water from the upstream reservoir in Dharoi for rural drinking water supply and irrigation. Hence, Ahmedabad city depends on water from Sardar Sarovar reservoir. A similar phenomenon was found in Hyderabad. Earlier, the city depended on the lakes for its water supply needs. Today, with a population of nearly 4 million people, the Municipal Corporation heavily depends on water from Krishna river to ensure good quality supplies.

An analysis of the water supply sources of 302 urban centres representing various classes of cities shows that the dependence on surface reservoirs for water supplies increases with increase in size of the city (Figure 3).

Figure 3: Percentage Dependence (in Volumetric Terms) of Cities of Different Sizes on Reservoirs



Source: NIUA (2005)

5.1 Urban Water Supply from River Basin perspective

Water availability varies drastically in different parts of the country, and so an analysis based on aggregate number of cities would be highly misleading. To get overcome this limitation, we have analysed the basin wise urban water supply data. Rivers have played a significant role in the history of civilisation, and their role in the social, cultural, economic and spiritual lives of Indian population is equally unquestionable. The total land on India can be largely divided in 19 drainage basins. These basins are the home of millions of Indians and the sources of their basic and economic water requirements. Table 1 describes the area and population served by the river basins.

Table 1: Area and Population Served by the River Basins in India, 1999

	River Basin	Catchment Area (km^2)	Population		
			Total (millions)	Density (No./m.^{2})	Urban (% of total)
Basins of the Westerly Flowing Rivers	Indus	321	48.8	140	29
	Mahi	35	6.7	324	23
	Narmada	99	17.9	160	21
	Sabarmati	22	6	521	46
	Tapi	65	17.9	245	37
	WFR1	56	58.9	425	28
	WFR2	378	51.9	166	43
Basins of the Easterly Flowing Rivers	Brahmani and Baitarani	52	16.7	204	13
	Cauvery	81	32.6	389	30
	EFR1	87	19.2	293	26
	EFR2	100	39	484	40
	Ganga	861	370.2	449	25
	Godavari	313	76.7	186	15
	Krishna	259	68.9	253	32
	Mahanadi	142	27.2	202	20
	Pennar	55	14.3	189	22
	Subarnarekha	29	15	347	24
	Brahmaputra	194	33.2	161	14
	Meghna	42	10	160	18
	All Basins	3191	932	282	26

Source: Figures derived based on data available in table 1, Amarasinghe et al., (2005) originally compiled from various sources.

Notes:

- WFR1 = Westerly flowing rivers-Group 1: the westerly flowing rivers in the Kutch and Saurashtra regions of the state of Gujarat, and the Luni river.
- WFR2 = Westerly flowing rivers-Group 2: the westerly flowing rivers south of the Tapi basin.
- EFR1 = Easterly flowing rivers-Group 1: the easterly flowing small and medium-sized rivers between the Mahanadi and Pennar basins.
- EFR2 = Easterly flowing rivers-Group 2: the easterly flowing small and medium-sized rivers between the Pennar basin and Kanyakumari at the southern tip of India.

The Ganga basin has the largest catchment area, and it is also the most populated basin in absolute terms. However, if we compare the rural-urban composition and density ratio, Sabarmati basin surpasses all other basins in the country. 46% population in the basin is concentrated in its urban areas with a density as high as 521 persons/km^2. Its density ratio is almost one and half times more than the average of the all river basins. No wonder that a large chunk of total water harvested in Dharoi dam on Sabarmati River was supplied to cities including Ahmedabad (which is the largest urban centre in Sabarmati basin) until they started receiving the benefits of Narmada water through SSP. Incidentally, all river basins with high population densities such as Sabarmati, Mahi, WFR2, Cauvery, and EFR2 are also characterised by arid or semi-arid atmosphere, and so their environmental characteristics cannot support their urbanization unless water is drawn from other sources. Tables 2 and Table 3 show basin-wise water supply to Class I cities and Class II towns respectively.

The data shows that Class I cities rely more on surface water sources to meet their demand for water. The trend in Class II towns shows that these urban centres still rely on their groundwater sources to an extent. Meeting some part of the total water requirement in Class II towns can be attributed to its smaller population base, and limited economic and political power to draw water from surface sources located outside their municipal boundaries.

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Table 2: Basin-wise Water Supply in Class I Cities: 1999-00

Major River Basin	No.of Cities	Population	Surface Source (mld)		Ground Source (mld)		Combined Source (ml)		Total Water Supply (mld)	Per Capita Water Supply (Ipcd)
Brahmani	1	398,864	21.56	(100)					21.56	72
Brahmaputra	7	1,415,601	30.37	(20.9)	10.68	(7.3)	104.42	(71.8)	145.47	222
Cauvery	16	8,212,863	231.96	(25.2)	12.9	(1.4)	675.54	(73.4)	920.4	133
Ganga	103	49,478,976	1343.98	(15.1)	732.93	(8.2)	6809.94	(76.6)	8886.85	199
Godavari	25	6,919,320	623.43	(80.8)			147.93	(19.2)	771.36	120
Indus	15	4,192,909	212.75	(28.1)	282.8	(37.3)	262.3	(34.6)	757.85	229
Krishna	27	12,659,457	864.87	(50.3)	4.8	(0.3)	850.03	(49.4)	1719.7	151
Mahanadi	9	2,476,450	221.84	(56.3)	114.35	(29)	58.16	(14.7)	394.35	184
Mahi	3	1,311,534					206.2	(100)	206.2	196
Narmada	4	1,183,593	13.62	(8.5)			147.04	(91.5)	160.66	145
Pennar	6	971,371	50.9	(63.5)			29.2	(36.5)	80.1	86
Sabarmati	7	3,678,921	24.54	(3.7)	22	(3.3)	613.63	(93)	660.17	181
Subarnarekha	2	1,059,883	358.54	(100)					358.54	364
Tapi	8	3,444,041	180.2	(50.6)			176	(49.4)	356.2	128
Sub Total	233	97,403,783	4178.56	(27.1)	1180.46	(7.6)	10080.39	(65.3)	15439.41	182
Coastal	29	23,275,720	3428.93	(84.2)	62.96	(1.5)	579.39	(14.2)	4071.28	200
Non-Major Basin, Non Coastal	37	7,434,362	528.39	(48.2)	298.8	(27.2)	269.36	(24.6)	1096.55	171
Grand Total	299	128,113,586	8135.88	(39.5)	1542.22	(7.5)	10929.14	(53)	20607.24	183

Source: CPCB (2000a)

Table 3: Basin-wise Per Capita Water Supply in Class II Towns: 1999-2000

Major River Basin	No.of Cities	Population	Surface Source (mld)		Ground Source (mld)		Combined Source (ml)		Total Water Supply (mld)	Per Capita Water Supply (Ipcd)
Brahmani	1	41,202			4	(100)			4	162
Brahmaputra	9	611,617			17.5	(33)	35.6	(67)	53.1	132
Cauvery	18	1,155,954	7.6	(14.8)	21.1	(41.1)	22.6	(44.1)	51.3	66
Ganga	119	7,903,938	119.1	(15.4)	331	(42.7)	325.3	(42)	775.4	110
Godavari	37	2,405,618	47.2	(29.7)	13.2	(8.3)	98.3	(61.9)	158.7	74
Indus	20	1,336,496			106.4	(61.3)	67.3	(38.7)	173.7	175
Krishna	22	1,464,861	27.6	(23.2)	22.3	(18.7)	69.3	(58.1)	119.2	96
Mahanadi	9	548,883	19.6	(59)	4.7	(14.2)	8.9	(26.8)	33.2	93
Mahi	4	238,770			4	(15.4)	22	(84.6)	26	111
Narmada	5	330,307	10.7	(31.8)	18.9	(56.3)	4	(11.9)	33.6	108
Pennar	5	338,500	0		0		19.2	(100)	19.2	65
Sabarmati	6	342,993	4.5	(11.4)	35	(88.6)			39.5	120
Subarnarekha	2	133,164	5	(54.9)	4.1	(45.1)			9.1	98
Tapi	5	371,292			23.1	(100)			23.1	67
Sub Total	262	17,223,595	241.3	(15.9)	605.3	(39.8)	672.5	(44.3)	1519.1	104
Coastal	16	966,375	12.5	(23.5)	13.4	(25.2)	27.2	(51.2)	53.1	100
No Major Basin	67	4,185,618	53.5	(14.7)	219.1	(60.2)	91.4	(25.1)	364	1 0 1
Grand Total	345	22,375,588	307.3	(15.9)	837.8	(43.3)	791.1	(40.9)	1936.2	103

Source: CPCB (2000b)

Meeting some part of the total water requirement in Class II towns can be attributed to its smaller population base, and limited economic and political power to draw water from surface sources located outside their municipal boundaries.

5.2 Water Supply Scenario in Class I Cities and Class II Towns

Table 4 shows the factors influencing total water supply for cities and towns of India. It clearly brings out two important facts: 1) the level of dependence of larger cities on surface water is much higher than of smaller cities; and 2) the larger cities have higher average per capita water supplies. Further, over the years, the dependence of class I cities for on surface water sources for municipal water supplies had increased, and some improvements in per capita supplies are also seen. Contrary to this, in the case of Class II towns, the dependence of water utilities on groundwater had increased, and some reduction in per capita supplies is observed.

We have estimated multiple regression models based on the available information on urban water supply for 209 Class I cities and 239 Class II towns in India. The results, presented in Table 5, show that population elasticity of water supply (ep) change with time and space. For example, for Class I cities ep with reference to 1981 population is 1.19 whereas and with respect to 1988 population is 1.13. The results show that - a) water supply grows more than the population growth rate. The results also shows that Class I cities have better water supply as compared to Class II towns. For Class I cities and Class II towns together ep is 1.22 with respect to 1981 population and 1.13 with respect to 1988 population. However, the results show the supply side aspects of

Table 4: Decadal Trend of Water Supply in Class l Cities and Class ll Towns in India (1978-79 to 1994-95)

Parameters	Class I cities			Class II Towns		
	1978-79	1988-89	1994-95	1978-79	1988-89	1994-95
Number of Class I Cities	142	212	299	190	241	345
Population (millions)	60.16	102.85	128.03	12.76	20.7	23.62
Distribution of Class l cities according to catchment area						
Major river basins	112	170	233	135	168	262
Coastal	17	23	29	13	20	16
Non-basin, non coastal	13	19	37	42	53	67
Distribution Population of Class I cities according to catchment area(millions)						
Major river basins	42.7 (71.0%)	74.4 (72.3%)	97.4 (76.1%)	9.2 (72.1%)	14.7 (71.0%)	17.2 (72.8%)
Coastal	12.8 (21.3%)	20.6 (20.0%)	23.2 (18.1%)	0.81 (6.3%)	1.69 (8.2%)	2.23 (9.4%)
Non-basin, non coastal	4.66 (7.7%)	7.85 (7.6%)	7.43 (5.8%)	2.75 (21.6%)	4.31 (20.8%)	4.19 (17.7%)
Total Water Supply (mld)	8638	15191	20607	1533	1622	1936
Ground (mld)	784 [9.1%]	3528 [23.2%]	1542 [7.5%]	499 [31.5%]	700 [43.2%]	838 [43.3%]
Surface (mld)	5261 [61%]	11132 [73.3%]	8136 [39.5%]	1018 [64.3%]	814 [50.2%]	307 [15.9%]
Combined ground and surface source (mld)	2582 [29.9%]	531 [3.5%]	10929 [53%]	66 [4.2%]	108 [6.7%]	791 [40.9%]
Per capita water supply (lpcd)	143	148	161	124	78	82

Source: www.indiastat.com

Note: Figure in the parenthesis shows the percentage share in total population of Class I cities
Figure in the bracket shows the percentage share in total water supply

water supply not the demand. It is known that in most of the urban centres in India water supply is not adequate, therefore actual demand for water is much higher than what is supplied. However, this analysis shows that there is need to augment water supply for urban centres as population pressure is mounting up in urban centres and it is mostly Class I cities which is attracting growing urban population. The results show that better water supply coverage significantly influence total water supply, therefore in order to achieve cent percent coverage water supply needs to be augmented from all possible sources. Water supply in urban centres falling in arid and semi-arid regions is worst hit as their water supply is relatively lower.

In order to understand the factors influencing the water supply coverage, multiple regression models were estimated separately for 190 Class I cities and 240 class II towns. Table 6 and Table 7 show that when the share of surface water in municipal water supplies increases, the water supply coverage improves, and arid and semi-arid regions urban centres are more dependent on surface water sources. The regression analysis shows that with growing population in urban centres, it is necessary to augment the water supply for providing better access and coverage for urban dwellers. Current level of water supply is not enough to achieve cent percent coverage; while access to water supply is also meager in many urban centres. In arid and semi-arid parts of

India, urban water supply is in stress and to cope up with population pressure, there is need to look for surface water source to augment water supply.

As size of the cities increases, it becomes difficult for water supply agencies to meet growing demand

Table 5: Factors influencing Total Water Supply (LNWSTOT) in Cities and Towns of India: 1988-89

LNWSTOT	Class I Cities: 1988		Class II Towns: 1988		Class I Cities and Class II Towns: 1988	
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	-12.864*** (0.664)	-12.402*** (0.821)	-6.289 ** (2.509)	-3.656 * (2.13)	-12.922*** (0.431)	-12.182 * (0.627)
LNPOP1981	1.189*** (0.042)		0.64*** (0.224)		1.218*** (0.036)	
LNPOP1988		1.127*** (0.057)		0.396 ** (0.184)		1.13 ** (0.051)
WSCOV	0.019*** (0.005)	0.019*** (0.005)	0.014*** (0.002)	0.014*** (0.002)	0.016*** (0.003)	0.017*** (0.003)
ARID	-0.158 * (0.094)	-0.124 (0.103)	-0.414*** (0.089)	-0.427*** (0.09)	-0.301*** (0.064)	-0.3*** (0.07)
No. of Obs.	*209*	*209*	*239*	*239*	*447*	*447*
Adj. R2	0.746	0.711	0.205	0.184	0.736	0.704
D-W Stat	1.407	1.548	1.816	1.79	1.61	1.614
F -Stat	204.375	171.255	21.447	18.877	416.413	354.158

Note: Figure in the parenthesis shows the White Heteroskedasticity-Consistent Standard Error for the estimated coefficient
LNPOP1981: Natural Logarithm of 1981 Population
LNPOP1988: Natural Logarithm of 1988 Population (estimated)
WSCOV: Percentage of population covered under organized water supply
ARID: Whether the city/town fall under Arid and Semi-arid zone (1, 0)
***, ** and *-imply estimated coefficient is significant at 0.01, 0.05 and 0.10 level respectively.

for water solely from local sources as a result they tap the water from distant sources which are mostly surface water sources (e.g., large reservoirs and tanks). However, in cities like Chennai and Coimbatore of Tamil Nadu, a large number of water vendors supply water mostly drawn from open wells or deep wells due to demand from urban dwellers as their groundwater quality problematic. Water footprint of urban centres in India is growing up and it is mostly away from the urban centres (Kampman, 2007). However, due to growing dependence on distant sources protection of local sources is often neglected (Mukherjee, 2008), as a result Major challenges that water supply sector in India is facing today are not only to meet the large investment requirement to augment the water supply, but also additional investment burden to tackle the water quality related problems.

Multiple regression analysis has been carried out by considering per capita water supply (lpcd) as dependent variable, and water supply coverage, type of climate and share of surface/ground water in total water supply as independent variables. The results show that per capita water supply (in lpcd) goes up as water supply coverage improves and in arid regions lpcd is low. However, factors like of share of surface water to total water supply or share of groundwater to total water supply do not have significant impact on access to water supply. Regression analysis for Class I cities based on the sample survey carried out by NIUA (2005) shows that as

Table 6: Factors Influencing Share of Surface Water Source(s) in Total Water Supply in Cities/ Towns (SHARESW) (in percentage) in India: 1988-89

LNWSTOT	Class I Cities: 1988		Class II Towns: 1988	Class I Cities and Class II Towns: 1988	
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	-82.71 ** (39.682)	-90.443 ** (39.769)	-205.481 *** (72.54)	-40.92 (27.009)	-60.833 ** (25.493)
LNPOP1981	7.987 ** (3.324)			4.429 * (2.339)	
LNPOP1988		8.486 ** (3.272)	18.913 *** (6.387)		6.077 *** (2.166)
WSCOV	0.42 ** (0.173)	0.411 ** (0.173)	0.416 *** (0.152)	0.43 *** (0.114)	0.42 *** (0.113)
ARID	13.847 ** (6.365)	14.073 ** (6.338)	21.639 *** (6.197)	18.124 *** (4.448)	18.26 *** (4.421)
No. of Obs.	190	190	240	414	415
Adj. R2	0.075	0.079	0.092	0.074	0.084
D-W Stat	1.15	1.156	1.245	1.245	1.235
F -Stat	6.107	6.374	8.556	11.924	13.63

Note: Figure in the parenthesis shows the White Heteroskedasticity-Consistent Standard Error for the estimated coefficient
***, ** and *-imply estimated coefficient is significant at 0.01, 0.05 and 0.10 level respectively.

Table 7: Differences in level of access to public water supplies with changes in sources for Class I cities in 1999

Dependent Variable	SHARESW Coefficient	LNWSTOT Coefficient
Constant	-645.11 ** (321.802)	77.779 ** (37.772)
LNPOP1991	240.673 ** (117.256)	-41.995 ** (20.401)
LNPOP1991^2	-20.661 * (10.536)	7.6 ** (3.649)
LNPOP1991^3		-0.441 ** (0.216)
ARID	23.447 *** (7.426)	
No. of Observations	163	163
Adj. R2	0.101	0.672
D-W Stat	1.29	1.669
F-Stat	7.099	111.472

Note: Figure in the parenthesis shows the White Heteroskedasticity-Consistent Standard Error for the estimated coefficient
***, ** and *-imply estimated coefficient is significant at 0.01, 0.05 and 0.10 level respectively.

distance (dist) between drinking water source and urban centres increases access to water supply (as measured by lpcd) improves.

6. SUMMARY AND FINDINGS

An analysis of sources of water supply across urban agglomerations of different sizes shows that as the population pressure on city grows up, dependence on surface water reservoirs for water supply increases. Dependence of Class I cities on surface water reservoirs for urban water supplies is much more than that of Class II towns. In arid and semi arid regions, urban centres are more dependent on surface water sources for municipal water supplies as compared humid and sub-humid regions. Larger urban centres (Class I cities) have greater capacity to respond to the increasing water demands induced by population growth and urbanization when compared to smaller ones (Class II towns), as reflected in the higher values of population elasticity of water supply in the case of Class I cities.

7. LARGE RESERVOIRS: ARE THEY THE LAST OASIS FOR THE CITIES?

Large dams have played significant role in achieving national food security, rural employment, hydro power generation and flood control. Enactment of National Water Policy-2002 has recognised the importance of large reservoirs in domestic and industrial water supply also. The reason is that earmarking water from aquifers for high priority uses like drinking is still not possible through administrative measures due to the common pool nature of the resource. The future population growth, economic development and urbanisation would demand further increase in the role of large reservoirs in domestic and industrial water supply. The counter effects of these developments would be on higher water demands for food production and hydropower generation. In nutshell, the role of large dams is going to be more critical in the years to come.

As it is projected, by 2050 around 45% of India's total population would be living in urban areas (Kundu, 2006). In India, the current domestic water use (urban and rural both) of about 25 BCM is expected to increase up to 67 BCM by 2050 (MoWR, 1999). Moreover, the water supply coverage in urban areas is steadily improving. In 2000 around 69% of total households were covered under water supply system, which has increased at 2% annually during last two decades (GoI 2004, as cited in Amarasinghe et al., 2007). The authors project that most of the urban population will be covered with drinking water supply by 2050. This would increase per capita water consumption even in poor households. Looking at this increasing demand for domestic water supply, it would not be an exaggeration to say that cities would not be able to cope up with their water demands without relying on large reservoirs.

This view has been counter-argued on the grounds that the local water resources including lakes, ponds as well as groundwater are unrestrictedly exploited in process of urbanisation, which resulted into their depletion, pollution and destruction (SANDRP, 1999). The same paper further argues for various options for augmenting water supply in urban India through rainwater harvesting, groundwater recharge and wastewater recycling. Ironically, such arguments are largely based on the success of some individual cases, not sufficient to take decision about replicating them on larger scale. Kumar (2004) shows that roof water harvesting systems would not only be hydrologically and economically unviable in urban areas in most parts of India[4], but also would lead to inequity in access to urban water supplies, if they are subsidized. It points out the small per capita roof area available for urban dwellers and the pattern of occurrence of rainfall against water demand pattern as the major reasons. Another work by Kumar et al., (2006) shows that rainwater harvesting and groundwater recharge offer extremely limited potential in arid and semi arid regions in terms of hydrological opportunity and economic viability.

Notably, suggestions such as institutional reforms, demand management, wastewater treatment, promoting water efficient technologies in production (see Postel, 1992, Brown, 2008) are most welcome. In fact, they are essential to achieve equity and environmental sustainability in longer terms. These interventions would certainly have positive impacts on total water demands of the cities, but in case of India, they can certainly not

[4] Except high rainfall, hilly and mountainous regions.

guarantee non-reliance of cities on large reservoirs. The reasons are - firstly, India has a wide population base, and so urban population growth would remain high in actual terms even when the percentage growth would be minimal; secondly, not necessarily all Class I cities and Class II towns would have enough financial resources and political abilities to implement such interventions successfully; and lastly but not in the least, the growth of cities in arid and semi-arid regions of the countries would always thrust ahead by importing water from other regions. In other words, the growth of cities located in arid and semi-arid regions cannot sustain without large water reservoirs.

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