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ISSUES OF UNACCOUNTED FOR WATER IN THE URBAN WATER SECTOR

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Abstract

Mismanagement of precious potable water is glaring in urban water utilities throughout the globe. As a result, the most alarming issue is the increasing share of unaccounted for water, and more so in the developing countries. This has major implications both on cost and resource availability for the supplier as well as the consumer. It is observed that the main influencing factors for unaccounted for water are per capita GDP, literacy, technology and institutional structure for water distribution.

The problems of higher share of unaccounted for water and associated cost implications for both suppliers and consumers have been demonstrated in the case of Bangalore urban water utility in the paper. In fact, frequent augmentation to the water potential in the city has ended up in higher share of unaccounted for water than any improvement in the per capita consumption. The pilot study initiated by the Bangalore water utility as a diagnostic measure has revealed that contributions from distribution network as well as consumer meters and illegal connections to the share of unaccounted for water are significant. The study also has highlighted that if adequate policy measures are initiated towards the extension of the study to the entire city and reduction in the share of various components of unaccounted for water would save that much quantity of water which would be equivalent to the quantum of water drawn to the city through Cauvery IIIrd or IVth stage with huge cost escalations. Hence, there is need for appropriate policy measures to be initiated on a priority basis for reducing the share of unaccounted for water to a minimum before initiating any process for fresh augmentation to the existing potential in the city. Reduced share of unaccounted for water would enable the Bangalore water utility to meet the growing water demand to a very great extent, in addition to its credibility for efficient management which draws global attention and encouragements.

Introduction

Urban water utilities throughout the globe are infected with innumerable problems of pricing and economic valuation of water resource (Saleth and Sastry, 2004; Sastry, 2004 a & b; UNESCO, 2003; Rogers, De Silva and Bhatia, 2002; Saleth and Dinar,1997; Saleth, 2001; Hoek, 2001;

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Dinar and Subramanyam,1998; McNeill,1998; Lee, 1994; World Bank, 1992; and WHO, 1987), equity and accessibility to less privileged households (Sastry, 2004 a & b; UNHSP, 2003; UNESCO, 2003; Damme, 2001; Saleth, 2001; Kemper, 2001; Gleick, 1996; Lee, 1994), institutional arrangement for water supply (Saleth and Dinar,2004; UNESCO, 2003; OECD, 2003; Damme, 2001; Saleth, 1996; Lee, 1994; and World Bank, 1992), and water resource management (Saleth and Sastry,2004; Sastry, 2004a&b; UNHSP, 2003; Lee, 1994 and World Bank, 1992). Of late, another significant issue that has emerged as a combination of all the said issues is the increasing share of "unaccounted for water". The issue has emerged from the fact that not all water supplied by the water utilities reach the consumers, and not all water that reach them is properly measured and billed for payment (Thornton, 2002). Hence, unaccounted for water in simple terms is known as water loss and sometimes also known as non-revenue water which is defined as the difference between the quantity of water supplied to a city distribution network and the metered quantity of water consumed by the customers. However, a clarification with regard to non-revenue water is that it includes water supplied by the urban water utilities to some essential services like fire fighting, charitable trusts, etc., with free of cost in addition to the water loss. Hence, by and large, water loss is not a synonym to the non-revenue water, rather it is a component of it. Here, the problem is addressed mainly to that component of water which is lost in the distribution process for which significant revenue loss is incurred by the utilities. Therefore, unaccounted for water is mainly associated with the water distribution system and the available infrastructure and institution for water distribution.

Occurrence of unaccounted for water in a water distribution system has been attributed to three main sources: leakage from pipes, thefts and overflows, improper recording of consumed water by meters, illegal connections and under-registration of water meters. By typology, these three sources of water losses have been categorised into a) real loss, and b) apparent loss. While, real loss is attributed to the technical problems involving physical escape of water from the distribution system which include leakage, theft and overflow before it reaches the end users, apparent loss refers to improper recording of total water consumed by the consumers due to meter error, inaccurate assumption of unmeasured use and unauthorized consumption, and these deficiencies are, by and large, attributed to administrative inefficiency of the urban water utility. Similarly, while main causes for real loss is attributed to varying pressure, inefficient leak detection system, poor workmanship and maintenance of distribution network, apparent loss is due to water quality, poor maintenance of meter, utilisation of faulty meters and illegal water connections. However, appropriate solutions have also been enumerated to control these problems (Table 1). Similarly, the economic distinction between the two losses has also been made as while, real loss is valued on the basis of the marginal production cost of water, apparent loss is done on the basis of the retail cost (Thornton, 2002). Interestingly, higher share of unaccounted for water, in general, and real loss, in particular, has been interpreted positively as it would lead to higher groundwater recharge (AusAID,2002; Thornton, 2002). It is not a logical justification for inefficiency of water utility, as it involves huge loss of resource as well as finance. It has been identified that un-accounted for water problem was so old that even during the world's first water supply system - the Roman water supply system - it surfaced and attempts were made to reduce its share. In general, the problem of transmission and distribution loss prevails in all utility distribution systems like electricity and gas. Hence, by extending this concept to the water distribution system, the issue of unaccounted for water which is similar to the transmission and distribution loss in the energy sector, acquires greater significance as it imposes huge financial implications on the urban water utility, in addition to loss of precious treated water resource. While, the problem of unaccounted for water exists irrespective of the level of development of a country, for obvious technological, financial and institutional constraints, the issue is more serious in the developing countries.

Table 1: Causes and Solutions for Real and Apparent Losses

	Cause		Solution	
	Real loss	**Apparent loss**	**Real loss**	**Apparent loss**
1	Varying pressure in the distribution system	Impact of water quality on water meter	Pressure management and level control	Reduction of meter error by testing, sizing and replacement
2	Inefficient leak detection system, corrosion of pipes in the distribution network	Lack of periodic testing of meters and maintenance of in-house distribution network	Efficient leak detection system, reduced response time for leak repair	Reduction of human error by training, standardising, reporting and auditing
3	Poor network materials, workmanship, periodic maintenance	Installation of incorrect and technically not approved meter, theft and illegal connections, Inefficient reading and billing methods	Improved system maintenance, replacement and rehabilitation of network system	Reduction of computer error by auditing, checking, routine analysis and upgradation
4	Environmental conditions	Environmental conditions	Adoption of appropriate environment-friendly technologies	Reduction of illegal use by education, legal action, prepay measures, pressure control and flow control

Source: Thornton (2002)

The main concern of un- accounted for water is the physical loss of precious natural resource and that too after huge investment involved in the entire process extending from drawing of water from its natural source, treatment and delivery to the distribution network for consumption, in addition to revenue loss. Higher share of real loss imposes extraction, treatment and distribution of higher volume of water to meet the prevailing demand and hence, requires extra cost and energy in addition to limited water supply to the consumers. In particular, leak and overflow which are the components of real loss cause considerable damage to the distribution network. While, higher share of real loss would impose huge financial implication on the water utility in terms of infrastructure management, the economic impact of apparent loss on the water utility may be even greater on account of huge revenue loss. Therefore, higher share of un- accounted for water imposes higher financial burden on water utility, in addition to wide-spread recognition of its inefficiency. In the context of increasing water scarcity and financial constraints, unaccounted for water acquires greater significance as a priority issue to be tackled to save the scarce water resource, besides improvement in the efficiency and financial health of a water utility. The main issue involved in unaccounted for water is the need for appropriate method of estimation of its exact share in order to initiate proper policy measures to reduce its share to a minimum. For obvious physical constraints, it is almost impossible to reduce the share of unaccounted for water to a zero level. This, in turn, would demand a well planned study and efficient distribution network system, and institutional arrangement for its effective policy implementation and monitoring. All these requirements underline the need for a comprehensive approach to address the whole gamut of technical, operational, institutional, planning, financial and administrative issues of water supply.

Global Issue of Unaccounted for Water

It has been estimated that the optimum level of unaccounted for water in a well managed urban water utility is 15-20 per cent (Thornton, 2002). As an illustration, some estimates of unaccounted for water of urban water utilities at the continental level have revealed that Asia (42%) and Latin America and Caribbean (42%) have the highest share of unaccounted-for water followed by Africa(39%). North America (15%) has the lowest but acceptable share (WHO and UNICEF, 2000). In particular, for obvious constraints, the cities of developing countries have been experiencing higher share of unaccounted for water - Rarotonga (70%), Hanoi (63%), Phnom Penh (61%), Laos (61%) and Mandalay (60%), Manila (55%-65%), Jakarta (50%), Mexico (50%) (ADB

Website and Lee,1994). However, it has been demonstrated that unaccounted for water management has also resulted in lower share even in Asian cities of Singapore (6 %), Male (10 %), Penang (20 %) and Johor Bahru (21%) (ADB Website). From the revealed share of unaccounted for water at the continental and country levels, by and large, it is evident that the main influencing factors for unaccounted for water are per capita GDP, literacy, technology and institutional structure for water distribution. Of course, certain exceptions do prevail in terms of efficient management. In this context, it may be noted that in most developed countries which account for lower share of unaccounted for water, urban water supply has been either completely privatised or being provided by public-private partnership (OECD, 1999; UNSCEO, 2004; Sastry, 2004b). Similarly, very low share of unaccounted for water in certain cities of developing countries as revealed above, may be attributed to commitment towards efficient urban water supply management to conserve the most precious natural resource.The Cambodian city of Phnom Penh which had almost 72 per cent as the share of unaccounted for water in 1993 did a miracle by people' involvement and imposing very stringent regulations in almost all aspects of water supply and reduced its share to just 10 per cent in 2004, which was in a span of just ten years (ADB Website). Further, several water utility based studies have identified that apparent loss consistently higher than the real loss. Singapore, the globally known city for its least unaccounted for water share reported the apparent and real loss as 7 per cent and 4 per cent respectively. Similarly, both in Bogota and Colombia, the corresponding values were 26 and 14 per cent. The higher share of apparent loss which is associated with the consumer end, implies that the contribution of institution in terms of administrative inefficiency is more prominent which is most glaring in many urban water utilities of developing countries. This has ended up in a huge revenue loss, thus imposing serious problem to the financial viability of urban water utilities.

Methodological Issues in Estimation of Unaccounted for Water

As stated earlier, the main issue involved with the issue of unaccounted for water is the proper measurement of water released for distribution from the treatment source. Hence, to estimate the quantum of unaccounted for water for a water supply utility, water auditing methodology has been widely adopted which is highly technical and hence, involves elaborate process. The process involves two sets of activities: (a) at the distribution network level; and (b) at the consumer end level. First, at the distribution network level, the activities involved are preparation of technical details of the study and its meticulous documentation, such as (i) complete listing of all the relevant variables involved in the water distribution system like dividing the city into innumerable smaller areas called district meter areas (DMAs); (ii) installation of bulk meters at several strategic points in each DMA to measure the water flow in a specific duration of a day; (iii) identification of leaks and damages in the network through traversing the entire DMA area with suitable leak detection instruments; and (iv) recording of the bulk meter readings installed at different strategic points over different points of time. Secondly, at the consumer end of the distribution system, the activities involved are: (i) testing of consumer meters for its correct measurement, (ii) identification of unauthorized connection; and (iii) usage of water in each DMA area and preparation of water balance charts for all DMA (Appendex1). Hence, it is clear that water auditing methodology invariably involves higher technical skill and related gadgets for complete water usage assessment. This entire process obviously involves huge cost. It is imperative to get an idea of what is happening to the treated precious water resource which is very much in demand in order to meet the needs of the various sectors. Such an effort would also provide several insights into the problem which enable the policy makers to advocate suitable policy guidelines for the reduction of various components of the unaccounted for water. In practical terms, the main diagnostic methodology involved in the identification of the quantum of unaccounted for water and reduction in its share is filling up of all the items of the said water balance chart meticulously for all the DMAs identified in a study area. Therefore, the main tasks involved in the estimation of the share of un-accounted for water are the measurement of the quantity of water supplied to the distribution network, authorised metered consumption, authorised unmetered consumption, derivation of water losses under different components, and analysis of audit results (Appendix 2). The estimation of the magnitude and share of unaccounted for water for a given urban water utility may be adequately attempted with required technical details as indicated above.

Some mathematical formulation for better understanding of the issue of unaccounted for water may be attempted as below. In perfect terms, total drinking water produced by the urban utility for supply (WP) matches exactly with the total drinking water consumed (WC)

$$WP = WC \tag{1}$$

However, due to practical realities of infrastructure and institutional constraints, the above said equation does not hold good. Therefore, the revised mathematical formulation consists of mainly four known and unknown components like total water consumed by consumers for which proper accounting exists and hence, generates revenue as per the prescribed tariff structure (W(R); water supplied to several essential services like fire fighting, public charities for which proper accounting exists but, will not generate any revenue (W(NR1); unaccounted for water due to network constraints like leaks and thefts (W(NR2),and unaccounted for water due to illegal connections and water meter defects (W(NR3). Hence, the final mathematical formulation is in the form

$$WP = W(R) + W(NR1) + W(NR2) + W(NR3) \tag{2}$$

Here, the main issue is the derivation of the total quantity of water that is lost due to various problems and constraints (W(NR2) & W(NR3). Though water distribution system has been adequately presented in a mathematical form, unlike normal economic situation, the estimation of the magnitude of unaccounted for water does not follow an econometric approach as it depends heavily on the technical aspects of the distribution system as well as the associated institutional structure. Generation of time series data on various components of the unaccounted for water is highly expensive and hence, discouraged. If such data is needed for policy decisions, it is normally generated at the required point of time to address the issue. Alternatively, the estimation is possible provided the cross-sectional data on the required variables are available for urban water utilities of different cities for a particular point of time. However, this estimate provides an overview of the problem, while unaccounted for water issue is, by and large, city-specific in nature. As stated earlier, the estimation is more in terms of assessment of various parameters on the basis of the field realities than on mere model fitting exercise practised in any normal econometric analysis. This study attempts to analyse the problem of unaccounted for water and its impact on the water utility for a globally known software city, Bangalore.

Background to the Study Area

Bangalore, the capital of Karnataka, and a globally known software service centre has been experiencing rapid population growth more due to migration. The population of Bangalore in 2001 was very close to 6 million. The area and population of Bangalore in 1901 were 28.9 sq kms and 0.163 million which have increased to 598 sq kms and 5.6 million respectively. As a result, while the area increased by 1,969.2 per cent the population increased by 3,335.6 per cent during the period 1901-2001. The main concern of Bangalore is its abnormal area expansion to accommodate the rapidly growing population. This has obvious implications on the provision of infrastructure and services. While, abnormal increase in area and population of Bangalore has been mainly attributed to its locational advantage for the growth of industries and commerce for which the city has been known since its foundation, it has a very strong production base as reflected by its highest share of workforce engaged in production activities (45.8%) followed by equal importance in trade (27.1%) and services (27.1%). By household income, middle income households dominate the city (46.8%) followed by low income households (38.3%). (AusAID, 2002). These characteristics of the city had also been substantiated by an earlier study on the city by Rao and Tewari (1979) and Sastry, (1994). Though the share of high income households is just 14.8 per cent, they contribute significantly to the future growth and development of the city. In recent decades, the city has been acclaimed for its Information Technology (IT) growth and development which has enhanced the city's growth significantly in terms of export of software related items and concentration of highly skilled workers. As a result, Bangalore has been experiencing functional specialisation in terms of software development and distribution for the entire globe. This specialisation, in turn, has led to high concentration of traditional as well as modern hi-tech manufacturing and commercial activities. The on-going functional specialisation process has attracted all sections of population for work and hence, their assured livelihood. In particular, the city has been attracting professionals and highly skilled workers from the entire country and abroad to meet the city's professional and technical requirements. Rapid in-migration process being experienced by the city and its associated 'multiplier effect' have all led to very high demand for high quality functions and services. For obvious constraints, the city has been finding extremely difficult in providing the required functions and services to the wider sections of the population with adequate quality and quantity, and one such issue is the provision of adequate drinking water.

Sources of Water Supply and Demand

Bangalore, located on the ridge-top at an altitude of about 921 meters from mean sea level, is in the water deficit zone. Bangalore has no perennial water source in the vicinity except the river *Arkavathi,* a tributary to the river *Cauvery,* with a limited water resource. Hence, in an attempt to provide drinking water to the city, the first piped water provision was commissioned in 1896 from the Hesaraghatta lake located at a distance of 18 kms from the city with water supply potential of

22.5 MLD. Later, to meet the growing demand, Thippagondanahalli reservoir was commissioned in 1933 which is located at a distance of 28 kms with water potential of 143 MLD. These two sources originate from the river *Arkavathi.* Meanwhile, Bangalore had started gaining growth momentum on account of industrialisation process initiated by the Government of India and the state government followed by the recent advancement in information technology sector. Hence, to meet the water demand of the growing population, a perennial water source from the river *Cauvery* was identified. Since, *Cauvery*'s water has to be shared by several south Indian states, for assured water supply to the city, the Govt. of Karnataka in consultation with the Government of India has allocated 600 cucetcs (19 TMC) of water exclusively to Bangalore to meet its growing drinking water needs (AusAID, 2002). As a result, the *Cauvery* first stage to Bangalore was commissioned in 1974 by bringing 135 MLD of treated drinking water from the river *Cauvery* to Bangalore city from a distance of about 100 kms and against the head reach of 500 meters. Because of altitudinal difference between the source of water treatment and its distribution centre, continuous pumping of water from its source to the city has become essential, which obviously consumes huge power. In addition, the project cost itself has escalated due to higher input cost (Table 2). Hence, unlike the *Arkavathi* source which works on natural gravity for water distribution in the city, *Cauvery* water has turned out as highly expensive. This has obvious implications on the operation and maintenance cost and, in turn, on the tariff structure as well. However, to meet the increasing water demand, periodical augmentation of water resource to the existing potential from the river *Cauvery* (I, II, III and IV Stages, phase I and II) has been in progress from time to time (Table 2). In addition, to meet the water demand of inaccessible areas, BWSSB is maintaining 6,246 borewells (2,428 energized, 3,818 hand pump based), out of which 5,749 are in working condition (2,334 energized, 3,415 hand pump based). The Board is also maintaining 29 lorries fitted with tankers to meet the demand. There are 6,100 public taps to meet the potable water need of the poor and low income communities (BWSSB, n.d).

Table 2: Sources of Water to Bangalore

Source (1)	Year of Establishment (2)	Distance to Bangalore in kms (3)	Water Potential (in MLD) (4)	Investment (in million Rs) (5)
Arkavathi River				
Hesaraghatta				
Thippagondana	1896	18	22.5	-
halli	1933	28	143.0	-
Aarkavathi	-	-	165.5	
Cauvery River				
Stage -I	1974	98	135.0	360
Stage- II	1982	98	135.0	850
Stage -III	1993	98	270.0	2,400
Stage- IV				
Phase - I	2001	98	270.0	10,720
Phase- II	2003 (planned)	98	500.0	33,830
Cauvery		98	1310	
Total		-	1475.5	

Source: 1. AusAID, 2002; 2.Handbook of Statistics 1997-98 &1998-99;3. Bangalore Water Supply and Sewerage Board, Annual Performance Report, 2004-05;4. Times of India, 4th April,2005.

The water demand for Bangalore has been assessed on the basis of the fixed norms prescribed for various classes of cities by the National Commission on Urbanisation, India,1988 and accordingly, 150 lpcd has been fixed for Bangalore. Bangalore city has been experiencing water problem mainly due to rapid population growth and limited water resource. In fact, during 1971-81, the population of Bangalore grew by almost 76.8 per cent thus becoming the fastest growing city in Asia. In particular, during 1991-2004, the population grew by 5.77 per cent per year, thus demanding more water supply provision. As a result, the demand for water which was 225,935 million in 1991 recorded a gradual increase to reach 346,020 million litres in 2004, thus, recording 4.09 per cent growth per annum. Accordingly, the demand has exhibited a smooth trend with gradual increase. while the potential created in 1991 has been only 141,375 litres which is 62.5 per cent of the demand, and increased to 93.45 per cent in 2004. These demand estimates have been derived on the basis of 150 lpcd norm per person. Efforts to augment the water resource to the city has been in place through the creation of additional potentials from the river *Cauvery* and maximum exploitation of the existing potentials from the river *Arkavathi*. As a consequence, the potential exploited has increased from 88.17 per cent in 1991 to almost 95.15 per cent in 2004. Because of the intermittent increase in the water potential, the curve revealed a zig-zag pattern (Fig. 1). While, production and consumption have also reveled an increasing trend, but positioned far below the demand and potential trends and more so in the case of consumption (Fig. 1). The demand and supply gap derived as the difference between the total water demand estimated and actual water supplied has reduced gradually during 1991-2004 as revealed through the declining trend (1991:39.3%; 2004:11.1%) (Fig. 2). However, demand and consumption gap has persisted consistently throughout the period (1991: 49.39%; 2004:45.98%) (Fig. 2). This is mainly due to the increasing gap between supply and consumption which has increased to an alarming level thus emerging as a major urban water management issue (1991:16.65%; 2004:39.24%) (Fig. 2). In addition, the city water supply has about 20,000 - 30,000 unauthorised private connections.

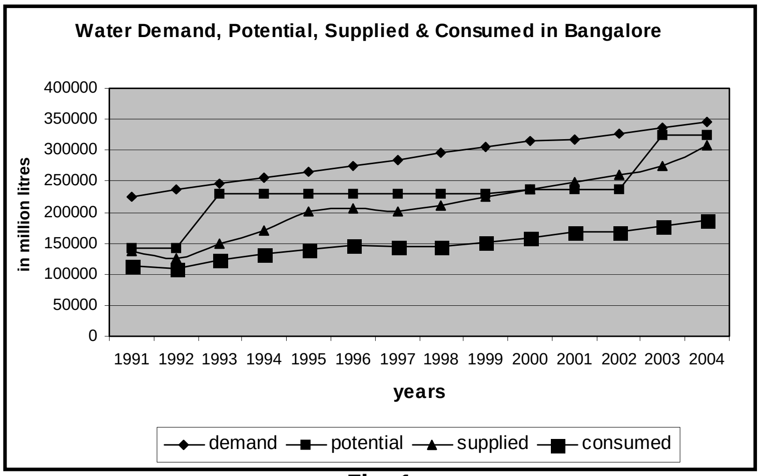
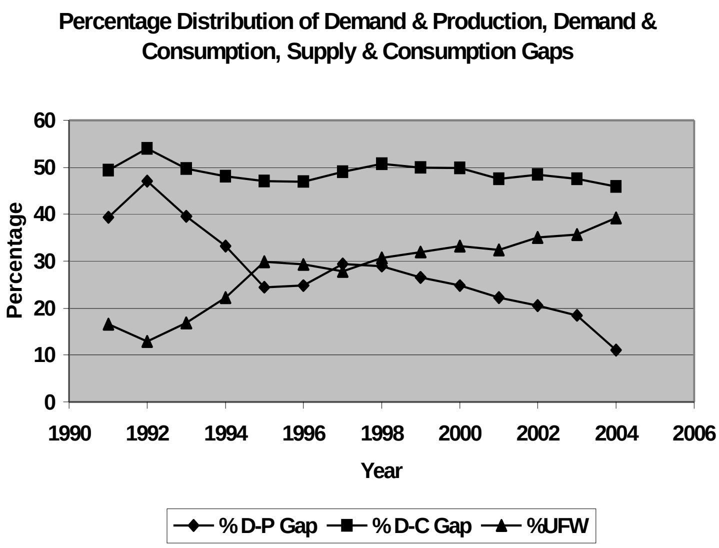


Fig. 1

Fig. 2

With the persisting supply and consumption gap, another dimension of water shortage has emerged in the form of 'unaccounted



for water(UFW)', which has beer
management of urban water sup
cent as the permissible limit of ur
share of unaccounted for water in
(16.65%). However, during 1991-2
doubled from 16.65 in 1991 to 3
issue of shortage (Fig.2). The mo
case of highly expensive water frc
unaccounted for water assessed
high as 44 per cent (AusSAID, 20
capita water consumption (76 lpc
improvement to 81 lpcd in 20
augmentation to the water potenti
in the per capita water supply from
period which was only apparent but far below the prescribed norm of 150 lpcd (Fig. 3). A causal relationship fitted between the water potential

created at different points of time and the quantity of unaccounted for water emerged, has revealed that for every addition of one million litres of water potential to the city distribution system has resulted in almost 0.505 million litres of unaccounted for water with R^2=0.71. Hence, the process of augmentation of water resource by the BWSSB to the existing potential with huge investment to meet the increasing demand has ended up in gradual increase in the share of unaccounted for water, instead of improvement in the per capita consumption. Thus, meticulously planned highly expensive augmentation exercise for the creation of additional water potential has turned out to be a futile exercise. The situation in the other metro cities of India is also not favourable. While Mumbai (18%) had the lowest share of unaccounted for water, with moderate levels in Chennai (20%) and Delhi (26%); Calcutta (50%) has recorded the highest share (Ruet, Saravanan and Zerah, 2002). Even in the neighbouring ‘million’ city of Hyderabad, the share of unaccounted for water has been estimated at 51 per cent (Saleth and Dinar, 1997). The increasing share of unaccounted for water has imposed financial and resource constraints for both supplier as well as consu
required water to meet the essen

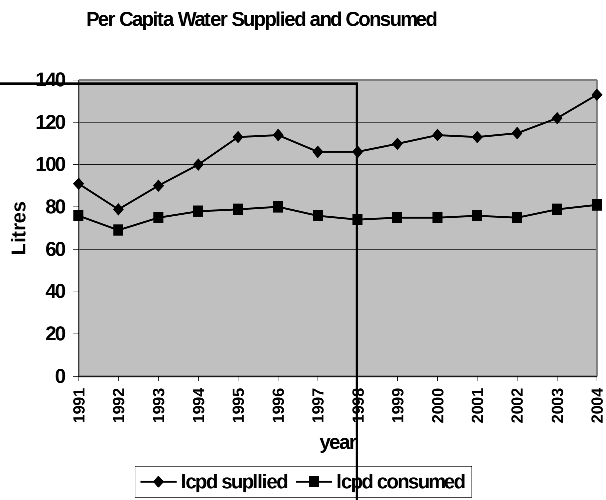


Fig. 3

Let us now look into the financial implication of unaccounted for water on the BWSSB. On the basis of total water produced (247,382 million litres) and the total cost incurred for production and supply (5,722 million rupees) during 2001, the unit cost of production per kilo litre of water in Bangalore is Rs 23.13. This cost includes items like capital, operation and maintenance, interest paid on loans, administration, power charges, and depreciation incurred towards water treatment and distribution. The unit cost of production which was nominal in 1991 (Rs 5.98) had almost increased by four times (Rs 23.13) during 1991-2001 with an annual increase of 28.7 per cent (Cost 1, Fig.4). The unit cost is derived based on the total quantity of treated water received for distribution and the associated cost involved in treatment and distribution. Of course, this cost is derived without adjustment to the unaccounted for water. In Mumbai and Chennai, the cost of production per kilolitre are Rs 2.17 and Rs 5.73 respectively (Charankar and Sahasrabudhe, 2003) which is nominal as compared to Bangalore. In Bangalore, each and every drop of treated water from the river *Cauvery* has to be pumped from its place of treatment to the city distribution centre which has ended up in high production cost. However, with the persistence of unaccounted for water, two more dimensions of production costs has been involved : (a) cost of production by excluding the share of unaccounted for water, and (b) cost of production by including the share of unaccounted for water with suitable adjustment for the minimum allowable limit.

The BWSSB lost almost 80,308 million litres (32.46 %) of precious treated water as 'unaccounted for water' in 2001 and revealed an increasing trend during 1992-2001 which should be brought into our cost calculations to reflect the actual cost of production. Hence, the unit cost of production and supply of drinking water to the city after excluding the share of unaccounted for water in 2001 was Rs 34.25. This cost was just Rs 7.12 in 1991 and has now recorded almost five fold increase which is much steeper than the simple production cost (Cost 2, Fig. 4). Hence, the higher share of unaccounted for water posed huge financial burden on the BWSSB to the tune of Rs 11.12 per kilo litre of water in 2001. This was in addition to restricted water resource to the consumers. During 1991-2001, this difference magnified almost by ten times from Rs 1.14 to Rs 11.12 which had obvious implication on the tariff structure which was subject to frequent revision. The frequent tariff revision had greater impact on the lower socio-economic strata of the city (Sastry, 2004a). Hence, to protect the interest of all consumers as well as to save the precious water resource, it is imperative on the part of the BWSSB to take appropriate measures to reduce the share of water loss at least to an acceptable level (15%). Similarly, the cost calculations reworked by allowing for an acceptable level of 15 per cent loss has revealed that the cost per kilo litre of water as Rs 27.50 (Cost 3, Fig. 4). This might be because of marginal adjustment to the water loss incurred in the process. This cost is in a way close to the cost per kilo litre without the adjustment for the unaccounted-for water(Rs 23.13) as compared to the exclusion of the total quantity of unaccounted-for water (Rs 34.25). Obviously, all the three cost behaviours have revealed an increasing trend with the cost trend with adjustment of unaccounted-for water squeezing in-between the cost per kilolitre excluding total quantity of unaccounted-for water and including the same. The unit cost behaviour is very steep in the case of unit cost of production by excluding the unaccounted for water (Cost.2,Fig. 4). In addition, interestingly, there are differences in the cost of production per kilolitre of water between river *Arkavathi* and *Cauvery*, and further, even among the various stages and phases of the river *Cauvery* , with highest and least cost of production and supply to consumers from the Cauvery stage IV phase (ii) and Arkavathi respectively (Table 3).

Table 3: Differential Unit Costs of Water Supply Incurred by BWSSB in supplying Drinking Water from Different Sources

Water source	Cost per kilo litre (in Rs)
River	cost of production per kilo litre (KL)
Arkavath River	10.00
Cauvery River	18.40
Cauvery Phases	
Cauvery Stage I – III	Rs.23.2/KL
Cauvery Stage IV Phase (i)	Rs.24.9/KL
Cauvery Stage IV Phase (ii)	Rs.26.5/KL

Source: Thippeswamy, 2003

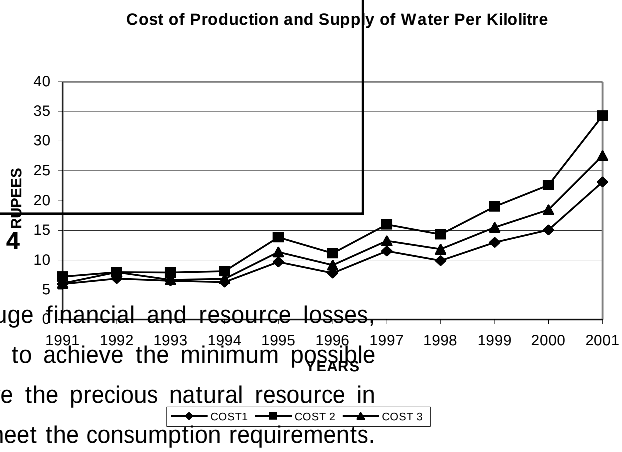


Fig. 4

Hence, in the context of huge financial and resource losses, efficient policy decision is imperative to achieve the minimum possible un- accounted for water level to save the precious natural resource in addition to save huge investment to meet the consumption requirements. In reality, limited water potential and higher share of unaccounted for water have made the water shortage problem to persist. This induced artificial resource crunch emanated out of management and infrastructure deficiencies could be the main reason for the most unpalatable policy decision by the Bangalore Water Supply and Sewage Board (BWSSB) to supply water to the consumers on alternative days. This problem, in turn, has forced the various socio-economic strata of the population to adopt differential strategies to bridge the water shortage. Affordable middle and high income households have gone for private water management to bridge the water shortage through indiscriminate digging of borewells in their residential premises with no regulation what-so-ever on the parameters like intra-borewell distance, quantity of extraction of water, depth of the borewell and sustainability of number of borewells with respect to the groundwater reserve and its recharge etc. As a result, one can roughly estimate the number of private borewells in the city as around 100,000 and it is increasing at the rate of 1,000 borewells per year. This is in addition to 5749 borewells maintained by the BWSSB. In the context of water shortage, another essential infrastructure for private water management at the household level is the storage facilities in the form of sump and overhead tank and water lifting pump. On an average, a middle or high income group household had to spend about one lakh rupees to meet all these infrastructure requirements in addition to spending on the energy for lifting water from the sump/borewell to the overhead tank on a regular basis. This has turned the city water supply as very costly, but an inevitable exercise to meet the water shortage. The poor households, on the other hand, have to depend on alternative sources including vendors by paying huge amount to meet their water needs.

Although BWSSB is aware of the seriousness of the issue of unaccounted for water, however, in terms of action, to begin with, it undertook only passive leakage control measures like repairing visual leaks and leaks reported by the consumers etc., which did not bring about the required results in reducing the share of unaccounted for water. BWSSB has a regular programme for testing consumer meters with qualified, but limited technical staff to monitor the correctness of the meter reflecting the quantity of water consumed by the consumers. By looking at the performance of the consumer water meters repaired during the past five years 1999 to 2005, it is evident that the percentage share of meters repaired per year was meager and varied from 3.57 per cent to 13. 43 per cent of the total meters installed, a large variation in the share with highest share in the year 2004-05 (Table 4). The highest share of water meters repaired during 2004-05 may be attributed to several factors like self- realisation towards the increasing share of unaccounted for water by the BWSSB, as higher share of unaccounted for water is an indication of inefficiency in urban water management, in addition to pressure from funding agencies and similar institutions. It is interesting to note that the BWSSB has bagged several national awards for its efficient handling of various component of urban water management in the Bangalore city.

Table 4: Number of Consumer Meters Repaired During 1999 to 2005

Year	Total number of meters repaired	Average per month	Percentage of meters repaired to total meters installed
1999-2000	23,417	1,952	7.62
2000-01	23,525	1,960	7.29
2001-02	18,246	1,518	5.45
2002-03	12,556	1,046	3.57
2003-04	15,225	1,189	4.16
2004-05	51,094	4,258	13.43

Source: BWSSB n.d

However, the need of the hour is active leakage control measures with full dynamism such as establishment of DMAs, conducting leak detection surveys, repairing leaks quickly, inspecting and replacing defective meters, rehabilitating the water distribution network etc. Recently, by looking at the complexicities of the multiple issues emerging out of the rapidly increasing share of unaccounted for water and associated water scarcity, the Bangalore water utility, viz., BWSSB had initiated a pilot study in 2003 to diagonise the causes for rapid increase in the share of unaccounted for water in the city. The study had covered the twin objectives of identification of various sources of unaccounted for water and distribution system rehabilitation. The pilot project area was chosen from the city core where water distribution network was laid in 1940.The area covered were Johnson Market, Ulsoor Service Area, M G Road and Hosur Road, Vasantha Nagar, Shivaginagar, Coles Park, Lavelle Road, Cubbon Park Road and the areas surrounding the reservoir existing in the study area. The study had a coverage of 33,000 (9% of total connections) service connections and 370 kms (5% of the total distribution network) of distribution network. The scope of the study had covered the formation of district meter area to measure the bulk water supply to each DMA, and their leakage level, inspection of all revenue meters, fixing of new meters where unmetered water connection prevailed, meters not working; testing of meters for its accurate recording, and to measure the difference between the inflow of water into DMAs and water supplied to consumers. In all, 21 DMAs were formed and according to the requirements, 39 District Meters were fixed for the purpose. For proper recording of water flows into DMAs and to identify the problems of unaccounted for water, water balance chart was developed for each DMA. The DMA measurements were taken between 12.00 midnight and 04.00 am when consumption in the DMA was at a minimum and the water flow was maximum.

A meticulously planned pilot study on water loss has revealed several interesting results which has significant policy implications towards reduction in the share of unaccounted for water for Bangalore. The overall baseline leakage level of the study area at the beginning of the project, estimated on the basis of weighted average of all the DMAs, was 134 l/c/hr, and this leakage level had reduced by 53.7 per cent (72 l/c/hr)as on November, 2004, in the study area. This was a great achievement in a very short span of the project period. The reduction in unaccounted for water at various DMAs with the implementation of project activities was significant during the project period in the study area. The study identified 6,741 leakage points from various sources in the project area. The major sources of leaks were from the main lines (38.1%) in the water distribution network followed by service pipes (32.8%) and standposts (17.6%) (Table 6). The study area being an oldest area of the city with age of the main line being almost 70 years and with a minimum maintenance, the maximum leakage from the main line was probably justifiable. The total number of leaks and their distribution pattern normally vary with the age of the study area in the sense, the number of leaks and age of the study area may exhibit an inverse relationship and similarly, there distribution pattern may also vary. The immediate implication of this problem was rehabilitation of old mains with the new inputs of latest quality and technology. A similar interpretation holds good for the prevention of leaks from service pipes as well. However, the main culprit was the 'stand post' which accounted for almost 18 per cent of the total leaks. Here, the problem is that since, it is no one's baby, it goes with the syndrome NIMBY (NOT IN MY BACKYARD) and hence, no one took personal care in the maintenance of stand posts on a regular basis except, either BWSSB or Bangalore Mahanagara Palike during acute problem. Hence, standposts required special attention in reducing the leaks. In this context, the AusAID (2002) study of the water supply and sanitation master plan of BWSSB suggested that the leakage problem of standposts might be solved by people's participation by identifying a consumer group with a standpost for its effective maintenance. Such a policy initiative by the Board would serve the dual purpose of people participation in the water supply system, a much needed policy direction for the involvement of the people in the water supply system, and the personal involvement of people would considerably reduce the share of unaccounted for water attributed to the standposts. Similarly, from the consumers' side, almost 31 per cent of the consumer meters were found defective with improper recording of water consumed by the consumers (BWSSB, 2004). The study ultimately assessed on the basis of meticulous calculations by assuming that if all the problems associated with various leaks and meter problems were reduced to the minimum on extending the unaccounted for water study to the entire city, the BWSSB might save to the tune of about 276 MLD of water (BWSSB, 2004). Such an effort of plugging the huge water loss was equivalent to the quantity of water brought into the city through Cauvery Stage III in 1993 with an estimated cost of 2,400 million rupees or Cauvery Stage IV Phase (i) with an estimated cost of 10,720 million rupees in 2001. Hence, this exercise underlines the slogan "prevention is far better than the cure" and similar to the slogan used in the oil conservation such as "conservation is better than production". Such a policy decision is very much needed on a priority basis to reduce the share of un- accounted for water in the city. In fact, with the saying 'conservation is better than production', it is a priority to extend the project to the entire city to reduce the share of unaccounted for water in the city, instead of mechanically augmenting to the existing water potentials through extra water from the river *Cauvery* or from some such source which the Board has been contemplating to meet the future demand with huge investment. It has been demonstrated that such mechanical augmentation without proper control towards unaccounted for water share would end up in huge share of unaccounted for water than improvement in the per capita water consumption level of the consumers. Such a sustainable policy exercise, in addition to positive impact on finance, water supply and per capita consumption level, would conserve the precious water resource for future generation.

Table 5 : Types of Leakage and Their Per cent Share in the Pilot Project Area

Sl. No.	Type	Per cent
1	Main	38.1
2	Service pipe	32.8
3	Standpost	17.6
4	Main valve	6.6
5	Meter joint	2.0
6	Stopvalve	1.6
7	Ferrule	0.7
8	Airvalve	0.1
9	Others	0.5

Source: BWSSB n.d

Summary and Policy Issues

Urban water utilities throughout the globe are infected with innumerable problems of pricing, accessibility, inequity in distribution, quality, and sustainable use and management. Of late, as a combination of these problems, the issue of unaccounted for water has emerged as the most alarming issue, and for obvious constraints, the problem is more acute in the developing countries. Increasing share of unaccounted for water has imposed serious problems to both water supply utilities and consumers in meeting the water shortage. This is, in addition to huge loss of precious resource that too after huge investment towards treatment and distribution. The quantity of unaccounted for water is influenced by factors like per capita GDP, literacy, infrastructure and institutional structure for water management. Unaccounted for water is a global issue and attempts are being made at the urban water utility levels to reduce it to a minimum.

Bangalore, a globally known software centre has been experiencing acute problems of infrastructure and services, on account of its rapid growth, expansion and functional speciallisation. Supply of clean and adequate potable water to its consumers is one such serious issue. In particular, increasing share of unaccounted for water which was almost 40 per cent in 2004, has imposed huge financial burden on the BWSSB, in addition to colossal loss of precious resource and limited supply to the consumers. Simultaneously, consumers also have cost implication in making up the water shortage emerging out of unaccounted for water, and associated policy of limited water supply by the BWSSB. Interestingly, mechanical augmentation of water resource to the existing potential with huge investment by the BWSSB has ended up with higher share of unaccounted for water instead of improvement in the per capita consumption by the consumers. Thus, the issue of increasing share of unaccounted for water calls for immediate policy measures for its reduction.

The pilot study initiated by the BWSSB, in an effort to diagnose the causes of unaccounted for water, has identified that the most prominent sources of leakage are associated with mains, service pipes, standposts, meter defects as well as unauthorised connections. The study has also made a precise assessment that if the study is extended to the entire city area and appropriate policy decision is taken towards reduction in the share of unaccounted for water, it would save the treated drinking water to the tune of 276 MLD per day. This is nothing but the quantity of water brought to the city from the river *Cauvery* in 1993 and 2001 with an estimated cost of 2,400 and 10,720 million rupees respectively.

In order to rectify the impact of higher share of unaccounted for water, it is a priority issue for the BWSSB to extend the pilot study to the entire city to assess the exact magnitude and the types of leakages. In this regard, while, leaks and overflows which have emerged from the city study may be rectified through elaborate rehabilitation of the network system; thefts, illegal and unauthorized connections and defect meters may be set right through efficient monitoring, regulation and replacement on the basis of appropriate institutional structure which can handle the problem very effectively. However, the main issue is the reduction of leakage from the standpost. In this regard, BWSSB may have to come up with a new policy direction to encourage public participation in the form of consumer groups attached to various standposts. Such an effort would meet the dual purpose of reduction of unaccounted for water share as well as much needed involvement of people through their effective participation in urban water management. Standposts are the main source of water for less privilaged household. While BWSSB is encouraging less privilaged households with private connections, enmasse acceptance is restricted due to obvious constraints. Though extension of the study to the entire city is highly expensive, but worth initiating under the concept' resource conservation is better than additional production'. Such a policy initiative would save both huge investment towards new projects and precious water resource. Since unaccounted for water is a serious issue in urban water management, there is need for development of proper data base with good periodicity at all urban levels, and aggregated to the regional and national levels to review its position periodically for its planned reduction.

Appendix 1: Water Balance Chart of DMA

<table>
<tr><td rowspan="9">Water produced</td><td rowspan="6">Water accounted for</td><td>Residential/</td><td rowspan="5">Water billed</td><td rowspan="5">Revenue Water</td></tr>
<tr><td>commercial</td></tr>
<tr><td>domestic</td></tr>
<tr><td>industrial</td></tr>
<tr><td>Institutional</td></tr>
<tr><td>Special /operational consumption</td><td rowspan="4">Non-billed water</td><td rowspan="4">Non-Revenue water</td></tr>
<tr><td rowspan="3">Water not accounted for</td><td>Illegal connection</td></tr>
<tr><td>leakage</td></tr>
<tr><td>Meter error</td></tr>
</table>

Source: BWSSB, 2004

Appendix 2: Tasks Involved in Water Audit

Task No.	**Task details**
Task 1	Measure the supply • Identify and map sources of water • Measure water from each source • Adjust figures for total supply
Task 2	Measure authorised metered use • Identify metered users • Measure metered uses • Adjust figures for metered uses
Task 3	Measure authorised unmetered use • Identify unmetered use • Estimate unmetered use
Task 4	Measure water losses • Identify potential water losses • Estimate losses by type
Task 5	Analyse audit results • Identify recoverable leakage • Quantify the value of recoverable leakage • Quantify the cost of recoverable leakage • Calculate the cost of leak detection

Source: Thornton, 2002

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