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Making Every Drop Count – Micro-Level Water Demand Accounting Challenges and Way Forward

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MAKING EVERY DROP COUNT – MICRO-LEVEL WATER DEMAND ACCOUNTING CHALLENGES AND WAY FORWARD

Chaya Ravishankar*, Sunil Nautiyal and S Manasi*****

Abstract

In peri-urban areas, lack of piped water supply and sewerage system has led to excessive groundwater abstraction, resulting in the proliferation of private water tanker business and unmanaged wastewater flows. To have efficient water supply and wastewater management in these data-constrained groundwater dependent communities, which do not have either metered connections or formal water supply, the paper addresses the question on how to quantify water demand for consumptive and non-consumptive uses through a typical qualitative/ observational primary survey method. Such surveys are scarce in literatures. The present study was conducted in Bellandur, a 26.4-sq km peri-urban ward of Bangalore city. With 11% growth in population in the last decade, it uses nearly 38% of its water demand for non-consumptive purposes. At present, 60% of the demand of the sampled size is being met through borewells and 35% through tankers. The remaining 5% get their water through a metered piped system. The findings of this study will aid water utility boards like Bangalore Water Supply and Sewerage Board (BWSSB) to put in place resilient planning and maximize the benefits out of water supply schemes by efficient allocation of water.

Introduction

Groundwater forms 97 percent of world's readily available fresh water resource. Its volume ranges from 7 to 23 million km^3, which is a guesstimate (Kundzewicz & Doell, 2008). Groundwater is the major source for 2 billion people around the world across rural, urban, industrial and irrigation sectors (Water & Sanitation Programme). An estimated 269 million urban dwellers depend on wells as their principal source of drinking water (Grönwall *et al*, 2010). In fact, more than half of the world's megacities (metropolitan areas with more than 10 million inhabitants) depend on groundwater, in the sense that it constitutes at least a quarter of these cities' water supply (Morris *et al*, 2003). Urbanization is contributing to rapid development of peripheral areas of cities, which is taking away access to water for peri-urban residents, both in terms of quality and quantity. The urban areas depend on groundwater directly for a wide variety of purposes and it is very difficult to get a general trend of the varied patterns (Grönwall *et al*, 2010) as the growing urban peripheries have unregulated abstraction of groundwater through their own borewells, and water utility providers are also encouraging and providing borewells as they are unable to make investments in piped water supply. This has not only reduced groundwater

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resources but also created a new market, making groundwater a priced commodity. As a result, there is a lucrative business in water and mafia groups are thriving (Morris *et al*, 2003).

Studies (Drangert, 1993; Kenway *et al*, 2011) favour demand side water management as against supply side approach to help in sustainable water resource management. In industrialized countries, several meta analyses have examined the determinants of household water demand (White *et al*, 2002; Mehta & Yates, 2012) but such analysis for developing countries is complicated due to their dependency on a wide variety of water sources. It is estimated that India uses 230–250 cubic kilometers of groundwater each year, or about one-quarter of the global groundwater usage — more than the United States and China combined. More than 60 per cent of irrigated agriculture and 85 per cent of domestic water use now depend on groundwater (Biswas, 2012).

The purpose of this study is to investigate different end uses of water on a temporal and spatial scale in the basic administrative unit of a ward for planning water supply sources by employing the fit-for-purpose water use concept. This study is carried out in a region where there is absolutely no account of how much water is used and consumed, and the situation is similar in most urban peripheries where no piped water supply infrastructure and sewerage exist.

Therefore, three objectives were laid out to understand the structure and functional attributes of groundwater flows by considering one peri-urban ward as one system boundary. The objectives are as follows:

1. Identify the present patterns of groundwater use and quantify the demand of unaccounted uses
2. Develop0 a better understanding of challenges for accounting non-consumptive uses
3. Suggest priority areas for intervention and alternatives for improving allocative efficiency.

Research Gap

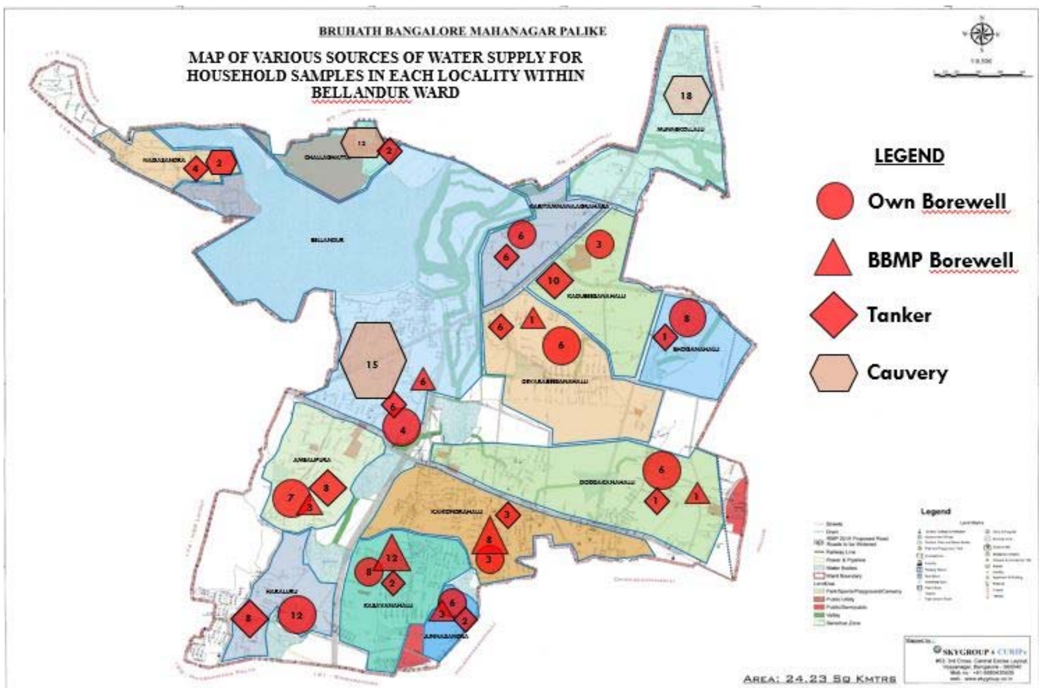
Although some analyses of household water demand in developing countries had been done in 1970s (Katzman, 1977; Howe & Linaweaver, 1967), they are still limited in number. Such analyses are difficult to perform as conditions surrounding water access vary across households, and the sources of supply are different, with characteristics and levels of services too differing (price, distance to the source, quality, reliability etc.). Besides, they also require a socio-ecological approach, specifically in regard to groundwater usage in urban ecosystems.

While models predicting or forecasting the demand of municipal water use have been brought out, field level investigations of water usage based on socio-cultural attributes have not been carried out. Keeping the research gaps in view, this study helps us in understanding the present patterns of water use in the study area, which is linked to multiple stakeholders or users in a diverse socio-cultural setup.

Description of Study Area

The study area Bellandur (Figure 1) is the second largest ward in Bangalore spanning an area of approximately 26.4 sq km. This ward falls under the administrative jurisdiction of BBMP (Bruhat Bangalore Mahangara Palike), which is a local body governing the peri-urban expansion of Bangalore. The salient features of this ward are many in terms of administration, water supply and socio-economic characteristics. The ward gets its name Bellandur from one of the localities out of the 14, of which 10 were under the Gram Panchayath until 2005. They were later included under the urban local body after declaring some portion of this ward as a Special Economic Zone (SEZ). The SEZ development in 4 localities of this ward and its location there formed a bridge or connectivity to two other major IT hubs, namely Whitefield and Electronic city, which paved the way for the drastic development of residential and commercial establishments. With respect to source of water supply, the localities of Challaghatta, Munnekollal, Bellandur and Belur Nagasandra have piped water supply with the source being Cauvery. Only 984 connections are metered by BWSSB, and these connections account for 5% of the entire ward's water requirement. Although a gram panchayath (village council), Bellandur demanded piped supply of Cauvery water in 1990s and got metered connections. The remaining 10 localities are entirely dependent on borewells. The borewells are drilled by the residents and in some places where these had gone dry, BBMP has drilled borewells and residents have taken connections from it.

Figure 1: Location Map of Study Area Showing Sample Distribution Based on Various Sources of Supply



Source: BBMP 2015

Methodology and Conceptual Framework

This paper applies the principles of a tightly coupled socio-ecological system (Ostrom, 2009), and the first step in implementing this approach in the water sector is the construction of the city's "system boundary" (Kenway *et al*, 2011). Here, Bellandur ward is the system boundary. Several authors note the importance of the "system boundary" to arrive at research conclusions (French & Geldermann, 2005; Satterthwaite, 2008). System boundary definition is a critical first step in modelling analysis.

Without knowing the boundary, it would be impossible to know which factors should be included in, or excluded from, the analysis. The term boundary unequivocally influences decisions of the apparent "best" option (Satterthwaite, 2008), and suggests that most large cities have three or four different boundaries: (i) the core; (ii) the contiguous built-up area; (iii) the metropolitan area; and (iv) the extended planning region. He points out that our current loose definition of cities leads to great difficulty in comparing basic parameters. Even something as fundamental as the urban population can vary by several million depending on the definitions adopted. The ward considered here falls under the extended planning region outside the city, i.e. the urban peripheral region. Within this system boundary, we have considered the groundwater resource flow in 3 stages using the System of Environmental and Economic Accounting (SEEA)

1. From the environment to the economic entity
2. Within the economic entities and
3. From the economy, back to the environment

Figure 2: Conceptual Framework for Water Demand Estimation (derived by the Author)

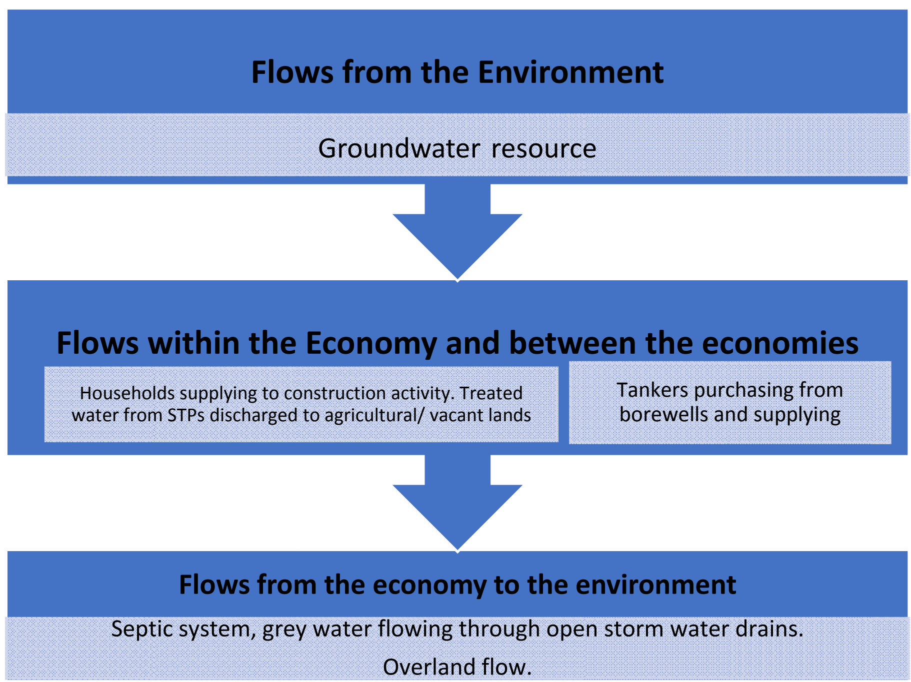


Figure 2 is the conceptual framework developed for the ward, which is considered as an economic entity to accommodate a decentralized system for water management. Then the matrix of flows of water in the economy from ground water abstraction to household and commercial usage, consumption and discharge to treatment systems, and return to the environment will help us distinguish water usage versus water consumption. The difference between water supply and water use will give the water consumption. This water use, henceforth termed as non-consumptive use, is for non-potable purposes. Urban runoff to lakes, precipitation, evaporation and lakes are not considered. Within water

accounting, the interest lies in linking the abstraction and use of water in physical terms with the estimates of output and the total final consumption of households.

The residential demand consists of two components, indoor usage and outdoor usage. The variables largely considered to reflect outside characteristics are irrigable area per dwelling unit and garden size (Nieswiadomy & Molina, 1989). There is also a third major unaccounted component prevalent in the Indian context, which is the overflow of Over Head Tank (OHT).

Demographic and household data were collected from the households, and this data included information on household size, dwelling type, vehicles owned, method of water storage and presence of OHT.

This research is based on primary survey of the study area carried out from February 2015 to June 2015. Questionnaires were used to assess the water consumption patterns related to socio-economic attributes. The determination of sampling size for the implementation of research was based on the commonly utilized statistical equation (Walpole & Myers, 1985). The degree of confidence (% of people who can answer our questions with utmost confidence) was considered to be approximately 90%. An acceptable error of approximately 4-5% was considered to be appropriate for this computation.

The minimum required sampling size can be determined using the following equation:

$N = ((Z(1-\alpha/2) \times S)/e)2$

Where,

N = Sampling size (minimum required)

$Z_{(1-\alpha/2)}$ = Number of units of standard deviation from a normal distribution curve based on degree of confidence.

For a degree of confidence of 90%, the value of Z from standard normal cumulative probability table is 1.96 (area under the Z-curve is 0.950).

S = Standard deviation. A standard value of 0.5 is considered when true population is unknown.

e = Acceptable error considered for questions answered by the respondents.

Keeping the degree of confidence at 90% and an acceptable error of 4%, the minimum required sampling size is 275. The study area is of a heterogeneous nature in terms of land use type and sources of water supply. Hence, the sample size was increased to 350. However, practical considerations of time and budget limited the sample size to 350 across 14 localities. Out of the 350 samples, based on land use type classified in Table 1, the number of residential sample size was 285 while the commercial sample size was 65.

Water Demand Calculation

To get the actual water demand for the sample, we need accurate measurements of flow and quality determinants for single or small numbers of dwelling units, but this is difficult due to the intermittent nature of flows at source. The demand was therefore calculated based on respondents' information on different sources of supply they use. These were as follows:

1. Own borewell/ BBMP borewell: Number of times motor is being switched on per day and their OHT size or sump size. The reasoning behind this is that the motor is switched on every time the OHT is emptied. So, the volume used up by the residents of a house with a household size of X to empty an OHT of Y litres capacity and switching on motor 'N' number of times = N * Y.
   a. If they did not have any OHT, information on their storage method and the containers they used to store was sought. The size of the container was noted and the number of times they fill or empty the container per day was used to calculate the total daily usage/ demand.
2. For respondents who depended exclusively on tankers, the number of loads they purchased per week was used to calculate the demand.
3. Respondents with Cauvery connections were asked to give their monthly water bill and also their OHT capacity, and the number of times they switched on the motor was used to calculate the demand.
4. Target respondents with mixed sources were asked about hours of supply of Cauvery water or borewell water and the frequency of purchase of tanker water.

Table 1: Sample Size Distribution in the Study Area

Land Use	Types	Percentage distribution	Sample size
Residential	Individual homes	57%	162
	Apartments	27%	77
	PG	15%	44
Commercial	IT	8%	5
	Recreational Centre/ Malls	3%	2
	Slum	3%	2
	Shops	58%	38
	Hospitals	9%	6
	Hotels	22%	14

Source: *BBMP Property Tax collected for the year 2015*

Challenges for Water Demand Estimation

While capturing the heterogeneity among these categories of supply and land use, five major challenges were observed, which were related to lack of metered connections, different sources of supply, land use classification, present water demand and water use behavior.

Lack of Metered Connections

The meters are provided by BWSSB to the users of Cauvery water supply. This piped water supply is metered only for 5% of the ward's water requirement. The split up is given in Table 2. These 984 connections are provided by BWSSB. There are also some apartments and gated communities which have installed meters to monitor individual consumption and charge accordingly for the water purchased through tankers at high prices.

As we can plan only what we know, the rest of the ward's water supply and demand details had to be collected only through a physical survey.

Table 2: Billed water connections in Bellandur ward

Land use types	No of connections
Residential	904
High-rise apartments	35
Commercial	45
Total	984

Source: *BWSSB 2015*

Sources of Supply

In the study area, most of the households have access to various modes of water supply, which is mainly ground water abstracted from own borewells or through connections to BBMP borewells or obtained through water tankers. Surface water sources, mainly from Cauvery, is provided by BWSSB to four localities, namely Kempapura/Challaghatta, Bellandur and Munnekollal. Only one public stand post is seen in Kaikondrahalli, which caters to the backward community residing there for the past three decades. Though this ward is primarily dependent on groundwater through borewells, we have accounts on the number of borewells in the ward only in regard to those dug by BBMP and not the individual private owners. The BBMP/ BWSSB have currently made it mandatory to register the borewell information, a process which is still in progress. In the results below we will see how many respondents have their own borewells.

Table 3 shows that the ward has 74 functional borewells out of the 100 that have been sunk by BBMP. BBMP has the records on the number of borewells installed but they have not been monitoring the yield or the number of connections per borewell.

Table 4 shows that the major source of supply to the ward is through tankers, which is 32% of residential demand, followed by own borewells supplying 21% of residential demand.

Table 3: Availability of Borewells in the Study Area

Sl. No	Name of the localities	Functional Borewells	No. of Dry Borewells	Total
1	Ambalipura	8	2	10
2	Kaikondrahalli	3		3
3	Kasavanahalli	7		7
4	Doddakanahalli	15	5	20
5	Devarabeesanahalli	15	7	22
6	Harlur	6	3	9
7	Boganahalli	4	3	7
8	Kadubeesanahalli	8	1	9
9	KariyammaAgrahara	6	2	8
10	Junnsandra	2	3	5
Total		**74**	**26**	**100**

Source: *BBMP Bellandur ward office.*

Groundwater cannot be easily observed and measured, like other subsoil assets. The depth of water table can be measured and this is sometimes used in lieu of actual volume. Tracking the depth of water tables does not give information if the aquifer is being replenished naturally at the rate that water is being extracted from it without knowing the volume of the aquifer. However, this gives only a partial understanding of the rate at which the asset might be depleted.

Table 4: **Distribution of Sample Based on Source of Supply**

Source of supply	Residential	Commercial
Borewell	21%	4%
Cauvery	13%	4%
BBMP Borewell	16%	2%
Tanker	32%	9%

Source: *Author's survey*

Land Use Type

We can still account for unmetered and different sources of supply but the third interlinking factor is the land use classification. The source of supply and the water demand varies with different land use types and allocating land use to certain classifications raises an array of classification problems in peri-urban areas.

i. For residential land, the major problem relates to the treatment of retail activity within residential neighbourhoods.
ii. Users from different industries may occupy different floors of an office building or the ground floor of residential buildings may house retail space, which is common in the study area. For offices, we assumed a uniform land use per employee and considered the National Building Code (NBC) 2005 to assess water quantity.
iii. For public services and social/ cultural/ medical categories, rough estimates of land use type by each activity were considered.

This procedure, though approximate, is a reasonable way to allocate data in order to make initial estimates, and they provide an interesting way to understand water use pattern or demand for each category.

The predominant land use type in one locality may not be the same for the other. ***Table 5*** indicates predominant land use type in each locality. This helped in assessing the socio-economic characteristics of each locality. For example, Devarabeesanahalli and Kadubeesanahalli are major Special Economic Zones having IT parks. The residential samples from these localities are of high income group and variations in water usage pattern were observed.

Table 5: Percentage Distribution of Sample across the Localities Based on Predominant Land Use Pattern

Sl. No.	Localities Within Bellandur Ward	Predominant Land Use Type	Number of Household samples (% of total)	Number of Commercial samples (% of total)
1	Ambalipura	Residential & Commercial	23 (8%)	6 (9%)
2	Bellandur	Slums, Residential & Commercial	39 (14%)	10 (15%)
3	Bhoganahalli	Residential & Commercial	12 (4%)	4 (6%)
4	Challaghatta	Residential & Commercial	14 (5%)	3 (5%)
5	Devarabesanahalli	SEZ area (IT parks) & Residential	15 (5%)	4 (6%)
6	Doddakanahalli	Residential & Commercial	16 (6%)	4 (6%)
7	Haraluru	Residential	26 (9%)	4 (6%)
8	Junnasandra	Residential	19 (7%)	3 (5%)
9	Kadubeesanahalli	SEZ area (IT parks) & Residential	17 (6%)	5 (8%)
10	Kaikondrahalli	Residential & Commercial	20 (7%)	5 (8%)
11	Kariamma Agrahara	Paying Guest Accommodations	17 (6%)	2 (3%)
12	Kasavanahalli	Residential & Commercial	38 (13%)	7 (11%)
13	Munnekollalu	Paying Guest Accommodations	22 (8%)	7 (11%)
14	Nagasandra	Residential & Commercial	7 (2%)	1 (2%)
	Total Sample	350	285	65

Source: *Author's survey from BBMP Property Tax data for 2015*

Water Demand Based on Land Use Type

Table 6: Actual Water Demand for Various Land Use Patterns in the Surveyed Sample

S. No.	Localities	Water Demand for Individual homes (litres per day)	Water Demand for apartments (litres per day, Lpd)	Commercial Water Demand (lpd)			
				IT	Shops	Hospitals	Hotels
1	Ambalipura	15625	794,500		990		48780
2	Bellandur	26375	901,600		1490	8500	3500
3	Bhoganahalli	8850	614,600		890		
4	Challaghatta	10315	380,800		770		
5	Devarabeesanahalli	13300	422,100	855000	150	157500	
6	Doddakanahalli	6885	1,338,400	675000	900		
7	Haraluru	15870	423,500		840		21000
8	Junnasandra	10825	226,100		270		
9	Kadubeesanahalli	12875	333,900	315000	1150		36000
10	Kaikondrahalli	12500	942,900		590	22100	25500
11	Kariammana Agrahara	8855	237,300	18000	0		
12	Kasavanahalli	18050	1,947,400		1490		7000
13	Munnekollal	22970	176,400		1400	450000	9750
14	Nagasandra	4885	24,500		60		
	Total	**1,88,210**	**87,64,000**	**18,63,000**	**10,990**	**6,38,100**	**1,51,530**

Source: *Author's Calculation*

Table 6 shows that approximately 7% (0.18 million litres per day or MLD) demand for water is coming from individual homes alone while apartments are consuming approximately 8.7 MLD. Commercial establishments (including IT parks, shops and hotels) are consuming approximately 71% (2 MLD) through supply from tankers as they get very limited quantity through borewells, which cannot supply their large demand. Hotels alone require approximately 6% (0.15 MLD), which is again sourced from borewells and tankers. From the survey, we find that the average actual demand per day per person is 235 litres, which is a little more than the prescribed 200 lpcd used for estimation as per Central Public Health Environmental Engineering organization (CPHEEO) norms.

Water Demand in Apartments

As per the National Building code 2005, water requirement for apartments is taken as 150 lpcd and ***Table 7*** shows that there are 42,526 flats, which require 31.9 MLD of water per day. During the survey, it was observed that not all apartments are 100% dependent on tanker supply. Individual apartments had groundwater wells which catered to some percentage of the actual demand while the balance was being met by tankers with varying capacities. Generally, for the sampled apartments within each locality, tankers with capacities 6000 litres and 12,000 litres were observed and recorded during the survey. The average tanker capacity was determined based on these two tanker volumes and the number of apartments sampled within each locality, to arrive at a figure close to the accurate water demand met by tankers alone. This average tanker capacity was multiplied by the supply gap encountered due to insufficient supply from groundwater wells to arrive at the approximate total number of tankers required/supplying water to all the existing apartments in each locality within Bellandur ward.

Table 7: Actual water demand for apartments sampled in the ward and number of tankers

Localities within Bellandur Ward	Sample Size Water Demand (lpd)	Water Demand to be Met by Tankers	% of Demand Met by Tankers	Approx. No. of Tankers in the Sample Size
Ambalipura	794,500	364,563	46%	32
Bellandur	901,600	343,500	38%	30
Bhoganahalli	614,600	274,125	45%	25
Challaghatta	380,800	28,500	7%	3
Devarabeesanahalli	422,100	197,813	47%	16
Doddakanahalli	1,338,400	528,500	39%	46
Haraluru	423,500	110,688	26%	12
Junnasandra	226,100	64,913	29%	11
Kadubeesanahalli	333,900	120,688	36%	13
Kaikondrahalli	942,900	435,313	46%	38
Kariammana Agrahara	237,300	65,213	27%	9
Kasavanahalli	1,947,400	968,663	50%	92
Munnekollal	176,400	46,138	26%	8
Nagasandra	24,500	2,500	10%	1

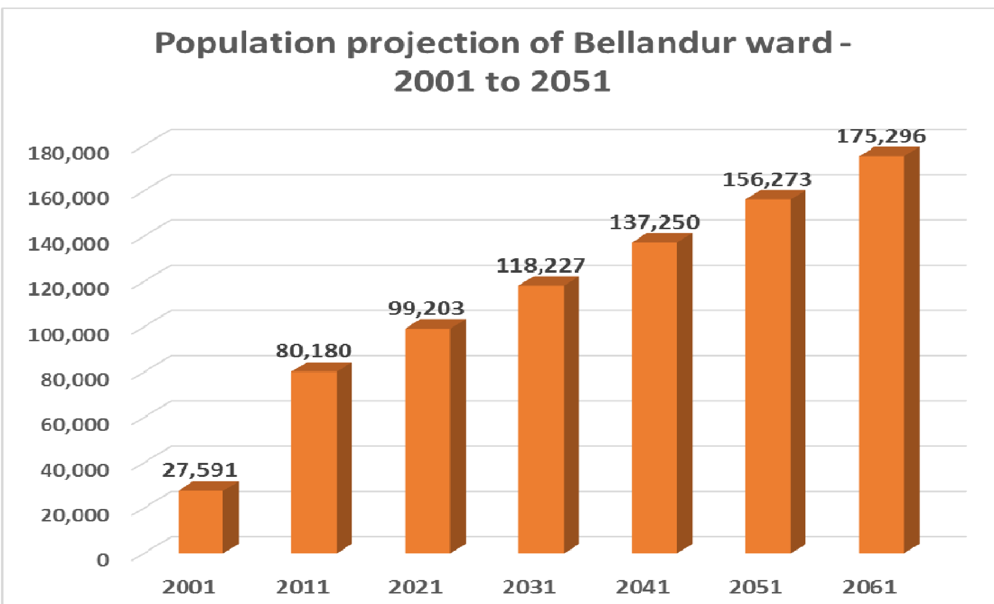
Source: *Author's construction based on survey*

We see that for apartments 40% to 50% is supplied by tankers, but IT and shops have 90% of their water supplied by tankers.

Present Water Demand

Calculating the present water demand using population data was considered as an option, and it was found that BBMP and BWSSB do not have complete population records of the Bellandur ward. There is a huge data gap as Census 2011 gives a population of 80,180. BBMP, on the other hand, has tax data for households and commercial/retail establishments which have paid property taxes and the associated population (as per BBMP records) for the year 2015 was 79,431. However, this data cannot help in population assessment completely since several properties/establishments are under certain legal obligations such as tax liabilities and hence the data available with BBMP may not be authentic. Based on a discussion with BBMP, a scale up coefficient of 20% has been considered to account for lack of supporting data and this is factored into the population estimation.

Figure 3: Population Projection of Bellandur Ward 2001 – 2051



Source: *Census 2010*

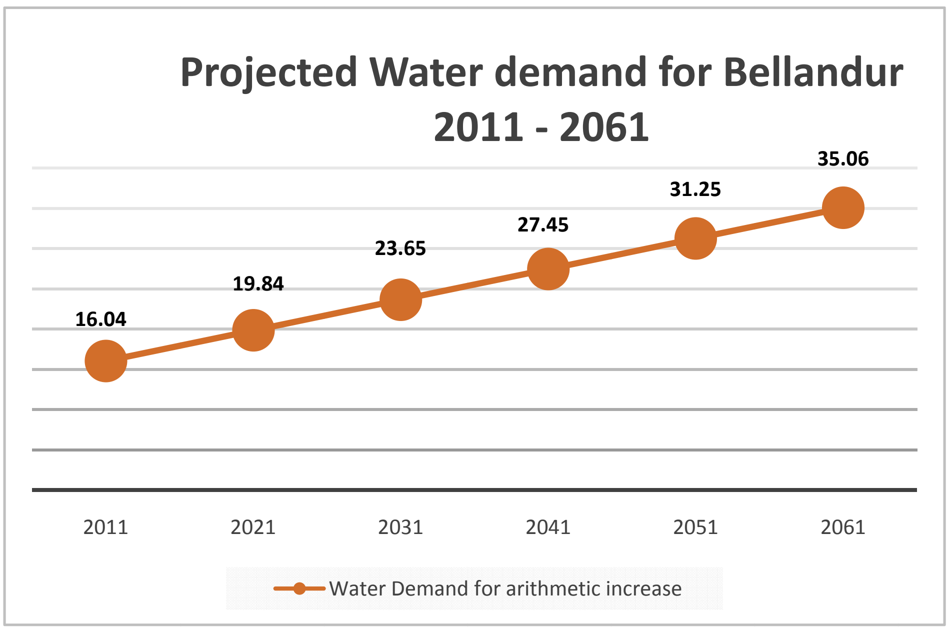
From Census 2001 to Census 2011 we see a population growth rate of 11% and using standard projection methods, we can observe that in 2051 Bellandur ward will have a population of 1.5 lakh (Figure 3). This alarming growth rate is an indication of what has happened, and what will. The present water demand is approximately 18.31 MLD and the estimated demand for 2051 is twice the current demand (Figure 4) using the arithmetic projection method (Table 8).

Table 8: Water Demand for the Projected Population

Year	Arithmetical Increase (AI)	Water demand at 200 lpcd	Water Demand (MLD)
2001	27,591	5,518,238	5.52
2011	80,180	16,036,000	16.04
2017	91,593	18,318,790	18.31
2021	99,203	19,840,650	19.84
2031	118,227	23,645,300	23.65
2041	137,250	27,449,950	27.45
2051	156,273	31,254,600.00	31.25
2061	175,296	35,059,250.00	35.06

Source: *Author's calculation based on Census data 2015*

Figure 4: Projected Water Demand for Bellandur ward 2011-2061



Water Use Behavior

To account for non-consumptive uses of groundwater, a survey was carried out on the two predominant practices of car washing and street washing. A third aspect that also needs to be accounted for is wastage. Estimating these quantities posed a challenge, but ***Table 9*** makes an attempt.

Table 9: Challenges for Estimating Demand of Non-consumptive Uses

S. No	Activity	Reasons	Our approach for demand estimation
1	Car washing	Number of cars - owned cars could be obtained by survey but taxi cars or private cars could not be procured.	Questionnaire survey of 285 households, with no. of cars. The property tax information collected from BBMP gives us the car parking area details from which we could work out estimated number of cars.
		Frequency of washing	Survey interaction included car owners, cleaners to identify method, frequency of cleaning.
		No uniform method	For bucket wash, 25 litres of water quantity is assumed. For spray wash, mechanic shops have air spray
		The cleaning method varies from individual to individual	
2	Street washing	Mode of washing used varies. Some users use hose pipe and others use buckets. The purpose also varies, either for dust suppression alone or for application of Rangoli.	Observations were recorded during early morning when commercial and residential establishments use/spray water to suppress dust.
		Spatial factor: the area washed cannot be limited to the surrounding space and cannot be demarcated or measured	
		Seasonal variation	
		Cultural factors: during festivities, washing is more periodical	People were asked to come out with the motive behind this; responses claimed that it was mainly for one of the following three reasons: i. religious practices ii. Dust suppression iii. Habitual reasons or the influence of others who practise it.
3	OHT overflow	Period of overflow varies. The sampled households show the period of overflow ranging from 15 mins to 2 hours. Some residences have overflow throughout night.	Whenever overflow was observed, we requested respondents to permit us to measure the flow rate. The time taken to fill one bucket was noted and that gave us the flow rate.

Source: *Author's construction based on survey*

Using the methodology outlined above, the survey found that there is lack of knowledge among respondents about their actual water usage levels since their usage is not metered at the household level. The various socio-economic characteristics affecting the demand in general and specifically for non-consumptive uses are discussed below.

Socio-economic Characteristics Affecting Water Demand for Non-consumptive Uses

Occupancy / Household Size

The number of people living in a household (Occupancy) has a direct influence on per capita consumption. Although an increase in the number of inhabitants per household increases the total domestic water consumption, there is a general agreement that per capita consumption decreases with increased occupancy (Edwards & Martin, 1995), which was also the case in this study region as seen in ***Table 10***. The average family size of the study region is 4. The majority of the respondent families have a family size of 3 or less (54%). While 33% have a family size between 4 & 6, the remaining have a family size greater than 7. There were 3 families with a household size of 10 and their average water usage was surprisingly less, i.e. up to 188 litres per person per day.

Table 10: Average Water Usage Based on Household Size

Household Size (member per household)	Average usage (Litres per capita per day)
1	215
2	266
3	181
4	315
5	265
6	243
7	347
8	295
9	250
10	188

Source: *Author's calculation based on survey*

Income Vs Demand: The sample respondents had mixed income levels, with a majority (28%) of the respondents falling under the income category of 30,000 to 60,000 (60K). Approximately 12% came under 60k to 1 lakh income category. Household income had a positive, significant effect on water usage as seen in ***Table 11***. Similarly, education had a positive correlation with demand (Table 12) as highly educated individuals and families had a better income and standard of living, which increased their water usage.

Table 11: Variation in domestic water use as a function of income

Income	Average usage (Litres per capita per day)
< 5,000	115
5,000 to 10,000	177
10,000 to 30,000	218
30,000 to 60,000	287
60,000 to 1 Lakh	295
> 1 Lakh	295

Source: *Author's calculation based on survey*

Table 12: Influence of education on water demand

Education	Average usage (lpd)	Average usage (lpd) for Non-consumptive purposes	% Non-potable usage
Illiterate	135	10	7%
Primary to Higher Secondary	207	14	7%
Undergraduate	278	30	11%
Post Graduate	283	38	13%

Source: *Author's calculation based on survey*

This analysis provides useful insights to understand the socio-cultural dimensions influencing the present patterns of water use, quantify unaccounted water supply sources to tap groundwater, identify opportunities for water savings, and help water authorities to plan the governance mechanisms applicable to such peri-urban wards.

Understanding the demand by end users is necessary to build a policy support framework for assessing water supply and demand management options. Studies around the world provide such a rich set of information. Therefore it is important to combine the considerations introduced by the different studies and the best practices implemented in other countries (Rathnayaka *et al*, 2016). Evaluating a comprehensive list of water supply options conjunctively with demand management options proves to be very useful in long term planning (Mukheibir & Mitchell, 2011)**.** Residential water use demand for consumptive uses have been analyzed in various literatures (Renwick & Archibald, 1998; Beal *et al*, 2016). But this study also tries to account for non-consumptive/ non-potable uses such as washing vehicles like buses and cars, uses which are not commonly included in the literature on the subject (Paxeus, 1996; Renwick & Archibald, 1998; Al-Odwani *et al*, 2007; Boussu *et al*, 2007; Zaneti *et al*, 2012; Abagale *et al*, 2013). It was observed that on average 15 litres per day is used for car wash alone, 30 litres per day for washing streets using hose pipes, and 10 litres per day by shops for dust suppression on streets. This evaluation has quantified the demand and collected relevant information on various sources of water supply and types of demand existing in the ward.

Conclusion

The following are the conclusions drawn:

1. The paper revealed the basis for understanding the physical flow of water within a system boundary (ward). This understanding can come only from a proper study of groundwater dependent areas and areas where water supply is not metered. The results of this study have shown broader relevance, particularly to other water scarce peri-urban areas facing similar water management issues.
2. The social relations that generate these physical flows pose challenges for estimating demand, and different end use studies are essential to successfully meet the challenges. The studies must employ methods such as:
    i. Qualitative data gathering techniques to capture the heterogenous nature of demand at residential and commercial level. This will provide the rationale for "fit-for-purpose" allocation of water.

ii. Micro scale engagements which yield insights into various factors to help build data, as no secondary data is available.

3. To prioritize interventions that focus on reducing non-consumptive uses, use of fit-for-purpose water, mainly by recycling, and rain water harvesting are needed. Policies should be framed to target specific uses instead of being generic, which will not benefit end users. Challenges that hinder the development of mechanisms to incentivize the reduction of fresh water usage for non-consumptive uses and promote reuse are tabulated in ***Table 13***.

Table 13: Challenges for Reclaimed Water Usage for Non-consumptive Uses

S. No	Interventions or mechanisms	Operational challenges	Behavioral challenges	Economic challenges
1	Distribution network from STP to Households.	Laying pipeline networks, pumping stations	Public will question as to why this alternate provision, instead of fresh water supply pipelines	Additional infrastructure. Cost of construction and maintenance.
2	House service connections – dual piping	Construction and rework on existing buildings	Public acceptance is very difficult. Ex: RWH structure with very little alteration of structure would come under opposition	Cost to the consumers for construction and maintenance.
3	Storage	Quality will deteriorate if kept for too long. People cannot provide separate tanks	Spatial constraints will not allow public to accept the idea at the first instance.	Additional cost for maintenance and disposal

Source: *Author's calculation based on survey*

The outcome of this study can be directly applied to other growing wards of this city and the methodology could be applied to the overall peri-urban context of India and other groundwater dependent regions. This would be very useful in designing suitable policies as one blanket policy cannot address all the categories for wise water management.

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