Chapter 24
Water Scarcity in Delhi: Mapping for Solutions and the Way Forward

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Abstract Almost the whole of India is currently witnessing a massive drought due to the relentless increase in water demand to cater its more than one billion people alongside the growing demand for water for agricultural activities, industries and other allied activities. However, there is a lack of research focusing on water scarcity in India. Central Water Commission data shows that water levels in 91 major reservoirs have reached staggeringly low. This chapter, however, aims to assess the water supply system in Delhi, the capital city of India and the world's third largest conurbation after Tokyo and Mumbai. Currently, there are nine major Water Treatment Plants (WTP) in Delhi, National Capital Territory responsible for catering water to its 16.8 million people. Using Geographical Information System (GIS) alongside the 2011 Census data of Delhi and taking into account the water supply norm of Delhi Jal Board (DJB), which is 60 Gallon Per Capita per Day (GPCD), a simple metric is developed to calculate the freshwater demand of its people residing within the command area of each WTP. For this, the 2011 Census population size of each WTP is multiplied by 60 GPCD to retrieve the approximate water demand of the people residing in each WTP, which in turn allows us to seek the amount of water scarcity/surplus for each of the WTP command area. Based on the findings and the current understanding of the guiding indicators of water scarcity, we map for possible solutions.

Keywords Water scarcity · Water demand · Geographic information system · Delhi jal board · Delhi · India

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24.1 Introduction

Water as a resource and the lifeline for every individual (both human and animal) increasingly suffer from the risk of scarcity. Approximately, 80% of the population of the world (in 2011, 5.6 billion people) continue to face a threat to water security (Gilbert 2010; Pulla et al. 2018); out of which 4 billion people suffer from severe water scarcity (Mekonnen and Hoekstra 2016; Pulla et al. 2018). While water scarcity is defined as 'the shortage in the availability of freshwater relative to water demand' (Gain and Giupponi 2015: 120), water security is defined 'as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies' (David and Sadoff 2007: 545).

There is a large literature on water scarcity risk, emerging crises, sustainable allocation and privatization of water across the living planet (Arnold (Tony) 2009; Dinar et al. 1997; Eckstein 2009; Gain et al. 2011; Gain and Giupponi 2015; Glennon 2005; Hoekstra et al. 2012; Mekonnen and Hoekstra 2016; Pulla et al. 2018; World Water Development Report 2015). The notion 'water scarcity' also embraces the notions of water stress, water shortage (or deficits) and water crisis. Studies suggest that alongside limited water resources, a number of other intersecting geographical factors contribute to water scarcity—these are—'flawed water planning and management approaches, institutional incapability to provide water services, unsustainable economic policies, unequal power relationships, inequality and poverty' (Gain and Giupponi 2015: 120; Human Development Report 2006; World Water Development Report 2015).

In the context of India, there is a lack of geographical research focusing on water scarcity. Few studies suggest that the issues of water scarcity could be tackled through practices of rainwater harvesting and wastewater recycling (Suresh 2001; Srinivasulu 2008). Very little, however, is known about the prevailing conditions and the constraints of the freshwater supply system of Delhi, the capital city of India and the world's third largest conurbation after Tokyo and Mumbai. Considering the acute water shortage that Delhi continues to face apace with its rapidly growing population pressure, we use Geographical Information System (GIS) based on a simple water demand calculation developed by us to examine the water supply and the growing demand of the city while teasing out the deficits and mapping for possible and sustainable solutions.

24.2 Background

Based on a resolution taken by the United Nations General Assembly in 1992, every year the 22nd of March is celebrated as a World Water Day. The key aim of this day is to generate awareness about different issues connected to water. As far as urban water supply in India is concerned, more than 90% of its population has access to drinking water, although, no cities of India have access to piped water supply 24 × 7 and '[w]ater quality has deteriorated in most receiving bodies and shallow groundwater as a result of uncontrolled discharge of raw domestic and industrial waste-water'[1] (Bhattacharya and Borah 2014; Mandal and Sanyal 2019). This crisis, however, is not unique to India only—indeed, as stated above, the growing scarcity of water and depletion of groundwater and drying up of rivers are phenomena of many regions of the globe (Mekonnen and Hoekstra 2016; Hoekstra et al. 2012; World Water Development Report 2015). Nonetheless, the water scarcity problem was confronted openly by honourable Prime Minister of India, Mr. Narendra Damodar Modi when he officially launched the *Swachh Bharat Abhiyan* (Clean India Mission) on Gandhi Jayanti on 2 October 2014 at Rajghat, New Delhi emphasizing on building toilets for 600 million, who defecate in open space; and develop infrastructure (water security projects via *Jal Kranti Abhiyan*)[2,3] for 130 million households that fail to access drinking water (Bhattacharyya 2014: 2, 2015).[4] Statistics retrieved from the Ministry of Water Resource reveals that the whole country is facing an acute crisis of water shortage arising from the lowering of potable water table. That said, in 91 major reservoirs, the live storage[5] capacity stand at just 22% capacity signalling that 34.082 Billion Cubic Meter (BCM) of water was available in these reservoirs by the end of April 2016 against their total capacity of 157.799 BCM, which is approximately 35% lower when compared to the previous year available stock of 53.5 BCM and 24% lower when compared to the 10-year average storage levels of 46.5 BCM for the same period.[6] Figure 24.1 illustrates the region-wise differences in 'live storage'. Indeed, in 2015 out of a total of 676 districts, 302 suffered from drought hit (Mohan 2015).

The magnitude of water scarcity has been so grave that currently, 540 million people are struggling for everyday survival where rural women and young girls in most parts of India {to name a few—Jammu, Bundelkhand region of Uttar Pradesh (UP), Uttarakhand, Odisha, Maharashtra, Karnataka and Telangana} trudge the rugged landscape for miles to collect drinking water (Dyson 2014; Singh 2014, 2015a, b; also, Bhattacharyya 2015), where they remain at high risk of going missing/kidnapped or being sexually assaulted (Bhattacharyya 2017, 2019). Alongside water scarcity, these regions have been suffering from crippling food and fodder shortages. Ostensibly, these problems have been transformed into perennial phenomena in most areas

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[1]Urban Water Supply in India, The World Bank, Retrieved from: http://www.worldbank.org/en/news/feature/2011/09/22/urban-water-supply-india.

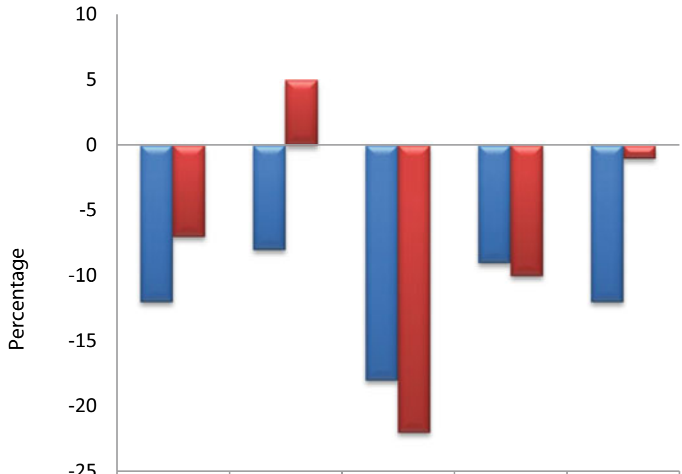
[2]Water Security Pilot Projects, Ministry of Drinking Water and Sanitation. Retrieved from: http://www.mdws.gov.in/water-security-pilot-projects.

[3]Jal Kranti Abhiyan, Step by step implementation Guide, Ministry of Water Resources, River Development and Ganga Rejuvenation, Retrieved from: http://wrmin.nic.in/writereaddata/JalKrantiAbhiyan_StepByStepGuide.pdf.

[4]Ministry of Drinking Water and Sanitation, retrieved from:http://tsc.gov.in/tsc/nba/nbahome.aspx.

[5]Live storage capacity refers to that part of the reservior which could be used for production of power, flood control, navigation and downstream releases.

[6]Ministry of Water Resources, River Development & Ganga Rejuvenation, Retrieved from: http://wrmin.nic.in/Default.aspx.



	Northern	Central	Western	Southern	Eastern
Difference from last year (in %)	-12	-8	-18	-9	-12
Difference of average of last 10 years (in %)	-7	5	-22	-10	-1

Fig. 24.1 Difference in live storage, region wise, India, April 2016 (*Source* Reservior storage, central water commission; Courtesy: Authors)

(Bathla and Kannan 2016). Unsurprisingly, water scarcity had sparked row over T20 cricket tournament of Indian Premier League (IPL) for 20 matches that started in Maharashtra from 09 April 2016 where approximately 60,000 L of water was required daily to maintain the pitches. In the wake of the extreme drought in Maharashtra as a whole (and Latur district in particular, the epicenter of drought), on 27 April 2016, the honourable Apex Court quashed the joint Special Leave Petition of Maharashtra and Mumbai Cricket Associations to upheld the Bombay High Court's order to shift out all IPL matches post-01 May 2016.[7] Sadly, it is worth mentioning here that between 2012 and 2014, approximately 3000 farmers claimed their own lives,[8] where drought is perceived to be one of the central causes alongside other causes like debts, alcohol and drugs.[9] The National Water Policy (2012), which stressed on treating water as an 'economic good', also recommends drafting a National Water Framework Law,

[7]Supreme Court dismisses MCA's plea against moving matches out of Maharashtra (2016, 27 April). *The Times of India, Sports*. Retrieved from: http://timesofindia.indiatimes.com/sports/ipl/news/Supreme-Court-dismisses-MCAs-plea-against-moving-matches-out-of-Maharashtra/articleshow/52007508.cms.

[8]Over 3,000 farmer suicides in the last 3 years (2015, 22 April). *The Hindu*. Retrieved from: http://www.thehindu.com/data/over-3000-farmers-committed-suicide-in-the-last-3-years/article7130686.ece.

[9]NCRB DATA: 2,568 farmers ended lives—another highest (2015, 20 July). *The Indian Express*. Retrieved from: http://indianexpress.com/article/cities/mumbai/ncrb-data-2568-farmers-ended-lives-another-highest/.

wherein *inter-alia*, it suggests that 'every individual should have a right to a minimum quantity of potable water (not less than 25 L per capita per day) for essential health and hygiene and within easy reach of the household, which may be provided free of cost to eligible households, being part of pre-emptive need' (Annual Report 1: 15). Against these backdrops, and on consideration, that to date, apart from a plethora of news reports, there is no systematic study on the issues of water scarcity in Delhi. The next section discusses the geographical location and methodological issues deployed by this study. This is followed by a section that paints the existing freshwater supply scenario of Delhi.

24.3 Location and Methodological Issues

Geographically, Delhi is located in between 28.61 °N latitude and 77.23 °E longitude (Fig. 24.2). The state of Haryana borders in its three sides—north, south and west while UP is located in its east. The area of Delhi, the National Capital Territory (NCT) is 1483 km^2 (573 sq. mile) and is home to 16.8 million (urban—16.4 million or 97.5% and rural—0.4 million) (Census of India, 2011). The population distributions of Delhi (Census of India 2011) are mapped in Fig. 24.3. In 2016, the population was estimated to be 19.9 million and projected to reach 23 million by 2021 by Delhi Development Authority (DDA). The 2016 population of NCT was equivalent to the total population of Romania (19.4 million) but more than the population of Netherlands (16.9 million), Zambia (16.7 million), Guatemala (16.6 million) and Ecuador (16.3 million).[10]

Since the 1990s, NCT has been expanding rapidly towards its periphery, thereby, decreasing its rural area and subsequently, increasing its urban area reproducing a 'conurbation'. In 1991, the rural area of NCT was 797.66 km^2, while its urban area was 685. 34 km^2. In 2014–2015, while NCT's rural area reduced to 369.35 km^2, its urban area, increased to 1113.65 km^2, signalling that NCT is a region of the ever-growing urban population, which also indicates, inter-alia its pressure on its water supply and other basic amenities.

Delhi is located in the Alpide belt or Alpine-Himalayan orogenic belt, a high-risk seismic zone prone to earthquakes ranging between the intensity of 8–9 on the Richter scale. Topographically, Delhi is flat, approximately, 210 MSL except for certain bits of small rocky (ridges) areas rolling out from north-northeast to south-southwest in central and south Delhi, respectively. The climate of NCT is humid subtropical with an average temperature above 36 °C (97 °F) during April–July; its average winter temperature between December and February is below 18 °C (64 °F). NCT depends mainly on monsoon between July and August, with its mean annual rainfall being 28.1 inches (714 mm). According to the World Health Organization (WHO), the air pollution level of NCT has triggered a lethal hazard and is one of the ninth worst

[10]Countries in the world by population (2016). *Worldometers*. Retrieved from: http://www.worldometers.info/world-population/population-by-country/.

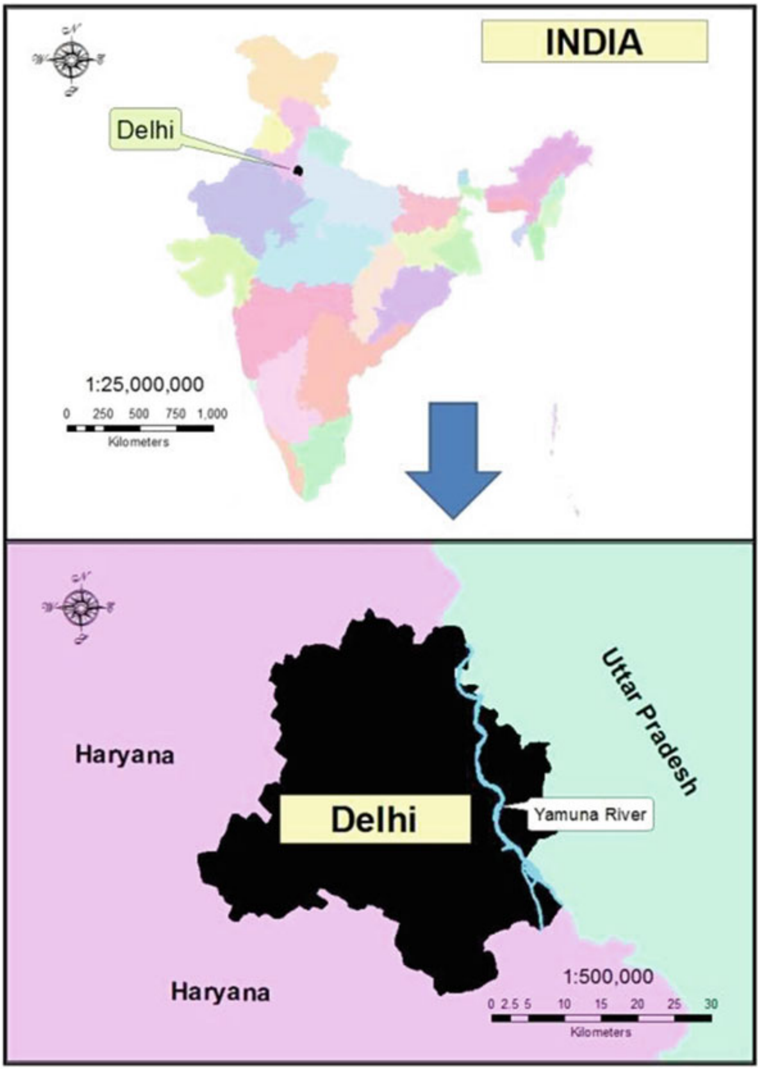


Fig. 24.2 Location map of Delhi (*Source* Produced by Authors)

polluted cities in the world,[11] which has far-reaching implications on its increasing population and of course, on its water quality and demand.

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[11]Vienna Tops Latest Quality of Living Rankings (2015, 4 March). *Mercer.* Retrieved from: http://www.uk.mercer.com/newsroom/2015-quality-of-living-survey.html and Four out of world's five most polluted cities in India: WHO report (2016, 12 May). *Hindusthan Times*. Retrieved from: http://www.hindustantimes.com/delhi/four-out-of-top-five-polluted-cities-are-in-india-delhi-not-among-them/story-Gn2htcLbESB3BpeYJ4mY8K.html?utm_source = browser&utm_medium = push_notification&utm_campaign = PushCrew_notification_1463019233&_p_c.

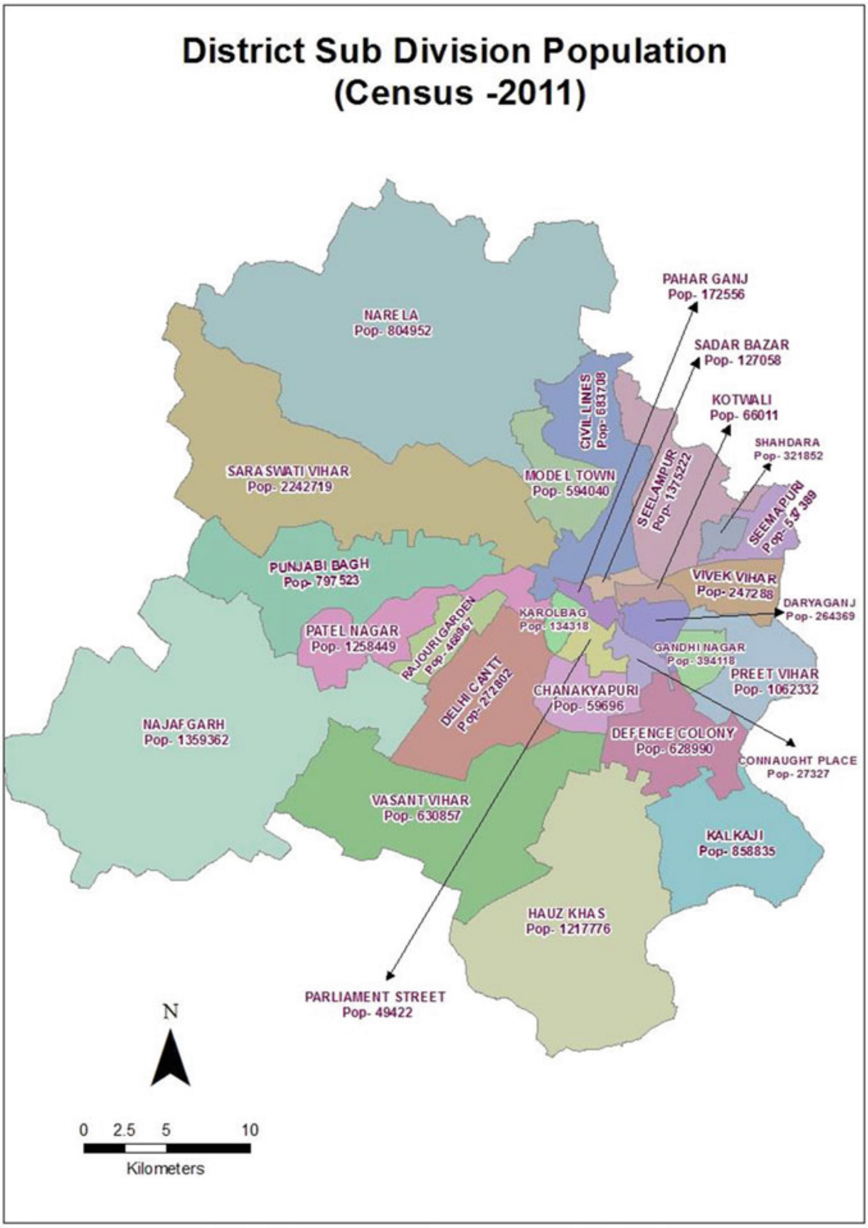

Fig. 24.3 Distribution of population (*Source* Census of India, 2011; Courtesey: Authors)

This research aims to assess the freshwater supply vulnerability for the population of NCT using Arc GIS. For this, it considers the studies titled (Study on Improvement of Water Supply System in Delhi in the Republic of India 2011) developed by Japan International Cooperation Agency (JICA) and Ministry of Urban Development National Capital Territory of Delhi, Delhi Jal Board (DJB), an autonomous body of the Government of India (GOI), and Economic Survey of Delhi (2014)–(2015) and Delhi Statistical Handbook 2015.

There are currently nine major Water Treatment Plants (WTP) in Delhi, NCT responsible for catering water to its 16.8 million people. The water supply norm of DJB is 60 Gallon Per Capita per Day (GPCD). Hence, as per 2011 Population Census, the total water requirement of Delhi is estimated at 1020 MGD, which also includes industrial, commercial and community requirements, fire protection and floating population and special uses in restaurants, hotels and embassies. In order to calculate the water demand, we developed a simple metric to retrieve the water scarcity/surplus of Delhi, NCT (Table 24.4). For this, using GIS and Census of India (2011) data, we calculated the population of each of the command area of the major WTPs. To calculate the population of the WTP command areas, the population density was calculated for each sub divisions (please refer to Fig. 24.3), which was then extrapolated to the WTP command areas, which gave an estimated population for each command area (Fig. 24.4). Following this, based on the water supply norm of DJB, and together with the help of Figs. 24.3 and 24.4, we calculated the water demand, which in turn helped us to estimate the amount of water scarcity/surplus of each WTP command area (Table 24.4). Building on these findings and the current understanding of the guiding indicators of water scarcity, we map for possible solutions.

24.4 Water Supply Scenario of Delhi

As stated above, Delhi continues to witness water scarcity across its ever growing and thickly populated landscapes. Insufficient raw water remains a key driver for inadequate water supply distribution. The problem is indeed deeply embedded (Bathla and Kannan 2016). According to the Census of India 2011, Delhi houses 3.34 million households, out of which 2.72 million households (81.30%) have access to piped water supply—from this, 75.20% households receive supply from treated sources whereas 6.10% from untreated sources. While 0.461 million households (13.8%) are depended on tube wells/deep bore hand pumps/public hydrants, the rest 0.164 million (4.90%) live on other sources such as river, canal, ponds, tank, spring, etc. (Fig. 24.5). As far as the availability of drinking water is concerned, 78.40% of households have water facilities within their premises, 15.40% near the premises and 6.20% of households have away from their premises. DJB is at the helm and accountable for bulk water acquisition and its treatment in Delhi; it is responsible for supplying drinking water not only in the three Municipal Corporations of Delhi but also accountable for supplying treated water to Delhi Cantonment Board and New

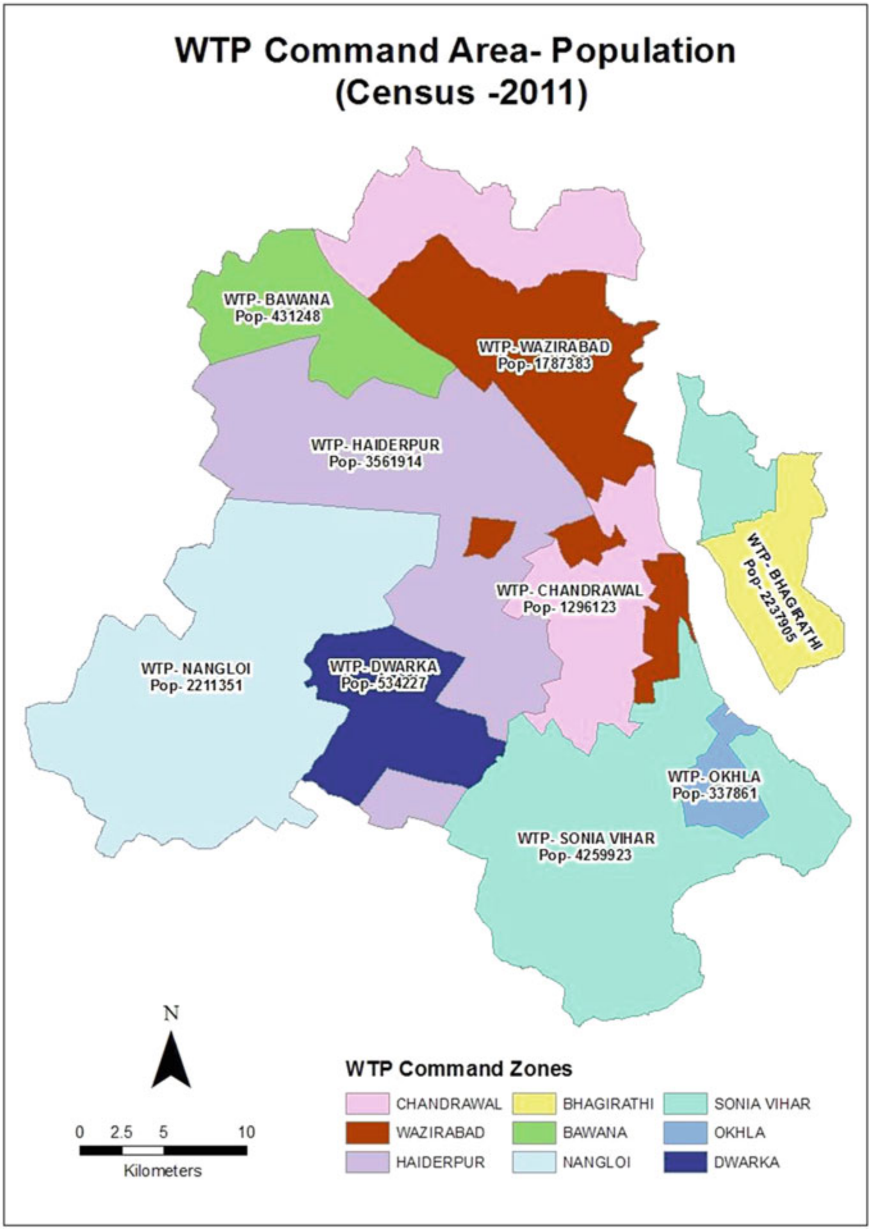

Fig. 24.4 Population catered by nine major water treatment plants (*Sources* Census of India 2011 and study on improvement of water supply system in Delhi in the Republic of India (2011); Courtsey: Authors)

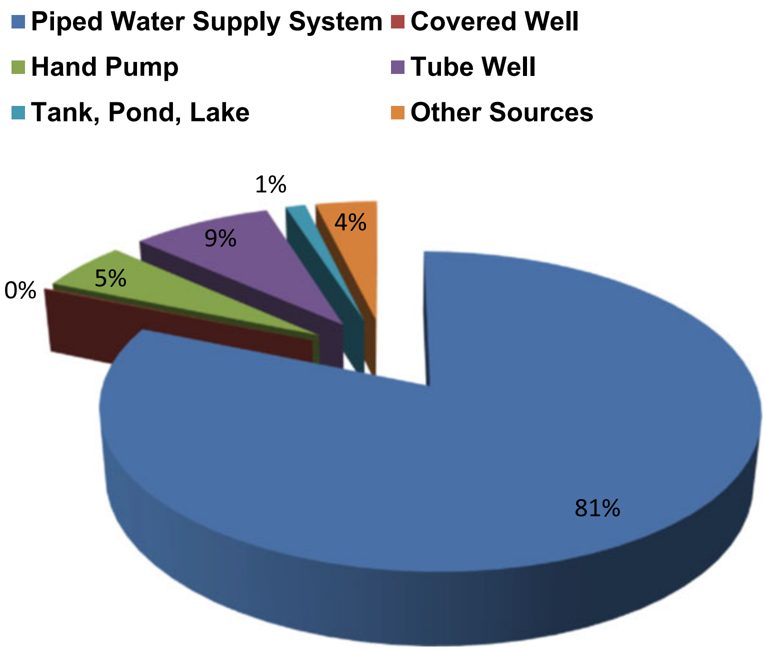

Fig. 24.5 Distribution of households by Sources of drinking water in Delhi (*Source* Delhi Jal Board; Courtesy: Authors)

Delhi Municipal Corporation (NDMC). Sources of water are situated at the lower levels of the river Yamuna; here, all water requires to be pumped out to supply the treatment plants.

The breakdown of the sources of raw water treated by DJB WTPs is outlined in Table 24.1. As of March 2014, DJB WTPs treated, respectively, 755 MGD surface water and 80 MGD groundwater.

Clearly, Table 24.1 indicates that the sources of raw water for DJB mainly feed on rivers Yamuna and Ganges, Bhakra Storage and Groundwater/Ranney Wells/Tube wells. These sources, however, pass through a number of states. For example, the river

Table 24.1 Sources of raw water treated by Delhi Jal board water treatment plants (March 2014)

Sources	Quantity (MGD)
Yamuna river	330
Ganges river	207
Bhakra storage	218
Ground water/Ranney well/Tube well	80
Total	835

Source Delhi Jal Board and Chap. 13: Water Supply and Sewerage, Economic Survey of Delhi, 2014–2015

Yamuna which is 1,376 km (855 miles) in length is the second largest tributary to the river Ganges and flows through Uttarakhand, UP, Haryana, then it crosses Himachal Pradesh (HP) and then Delhi. Similarly, the river Ganges, which is the largest river in India, is 2,510 km (1,560 miles) flows through Uttarakhand, UP, Bihar, Jharkhand and West Bengal before entering Bangladesh. And the Bhakra Storage built on the river Sutlej in HP supplies power and water to its partner states HP, Rajasthan, Punjab, Haryana, Delhi and Chandigarh. Although, currently, Delhi has not been connected with the Interlinking of Rivers (ILR) Programme of the Ministry of Water Resources for equitable distribution of water; given the current water scarcity scenario across the country, it is not difficult to predict that maintaining even the current levels of availability from these sources (Table 24.1) would be difficult in the foreseeable future; water sharing could soon become a site of contestation triggering a tumultuous development process.

Nonetheless, DJB is currently responsible for supplying water to approximately 16.8 million people of NCT using 14,000 km long pipelines and approximately 107 Underground Reservoirs (UGRs) covering both its planned and unplanned areas. The UGRs fitted with booster pumping stations have been provided in the water transmission system for onward delivery via the transmission distribution systems. However, there remain certain areas where the water is tapped directly from the transmission systems. Nevertheless, DJB supplies water to 903 unauthorized colonies. In addition, 50 unauthorized colonies that embrace a population of 0.2 million, benefit from the supply of filtered water by DJB. DJB also supplies water through tanker system. For efficient water tanker supply delivery system, DJB has introduced GPS fitted 407 stainless steel water tanker. Currently, DJB controls 3961 functional tube wells and 14 Ranney wells. However, water supply service remains highly uneven and the volume of supply ranges from 2 to 73 m^3/month. It is distressing to note that the Yamuna river water suffers from high seasonal turbidity of 5000 Nephelometric Turbidity Unit (NTU). Moreover, depletion of groundwater is a grave concern—in few locations of North-West, South, South-West Delhi—here, the level of groundwater has attained 20–30 m below the ground level containing a concentration of high salt and fluorine, surpassing the prescribed limit of 1.5 mg/l in 30% of the wells. In Shahdara and Kanjhawala locations, the content of nitrate has exceeded more than 1000 mg/l. Unquestionably, uncontrolled exploitation and reduced recharge of groundwater due to massive concretization aggravate the debilitating crisis. Besides, the Ranney wells located in the Yamuna flood plain suffer from increasing coliform pollution and high concentration of iron and ammonia. Evidently, the discharges of effluent waste also cause serious damage to the availability of water for use. Apparent consequence results in shutting of the WTPs for days and sometimes for weeks. Ostensibly, like the sources of raw water, the major canals carrying water to Delhi, NCT also cross the neighbouring states—Haryana, UP, Uttarakhand and HP. All these states have their water crises and other social problems too, which could sporadically trigger public and political unrest. For instance, in February 2016, the newly built 102 km parallel *pucca* (permanent) Munak canal from Munak to Haiderpurat at an estimated cost of INR5.2 billion to plug seepage, and which feeds the WTPs of Delhi, NCTwas sabotaged by the *Jat* community protesters of Haryana over an issue of reservations in education and jobs. This triggered unprecedented water crisis among the residents of Dwarka, Munirka, Janakpuri, Rajouri Garden, Palam, Vasant Kunj, Punjabi Bagh, Green Park, Saket and Lodhi Colony when the angry mobs coerced in shutting of several WTPs by breaking its control apparatus in Haryana.[12] The insufficient water back up plan of DJB to manage this crisis further tantalized the problem. This had caused heavy losses to the Government exchequer. Arguably, the ever-changing political scenarios and an increasing tussle between the states might further embroil situations. With the plummeting level of water sources and groundwater, it remains paramount that the existing WTPs (the majority of which were built before 2000 and manually operated) and pumping stations are maintained efficiently and economically to sustain the water demand for its ever-growing population. The following section discusses the installed treatment capacities of the WTPs.

24.4.1 Water Treatment Plants

Currently, there are nine WTPs responsible for distribution of water to the people of Delhi. Conventional treatment methods by sedimentation/coagulation/flocculation and rapid sand filtration are used in six WTPs. Two new WTPS have been built at Dwarka (50 MGD) and Okhla (20 MGD). These two WTPs access raw water from the Munak canal. In addition, Bawana WTP (20 MGD) is likely to be commissioned after the availability of raw water. To treat the water of Ranney wells, DJB applies a special treatment by aeration; for the newly built Okhla Treatment Plant, biological filtrations are applied. However, the water quality transmitted from all these WTPs complies with the WHO standards after meeting the Indian Standards requirements. The trends of the installed capacity of the WTPs are illustrated in Fig. 24.6. Following this, in Table 24.2 water supply capacity trend of the individual WTPs is shown. This is followed by a discussion of water demand.

24.4.2 Water Demand

Water demand is calculated by 'multiplying planned population by per capita demand' (Summary Part I Master Plan 2011: 4–5). Studies unfold that basic water requirement for an individual for *drinking purpose* is 5 L per day; for sanitation, an individual requires 20 L per day; it is 15 L per day for bathing; and for food preparation, it is 10 L per individual per day. Adding these requirement norms, the total water requirement is calculated at 50 L per day per individual (Brown and Matlock 2011; Gleick 1996). As stated above, the water supply norm of DJB is 60 GPCD

[12]Top priority to open supply today: Haryana cop on Delhi water crisis (2016, 21 February). *Hindusthantimes*. Retrieved from:http://www.hindustantimes.com/cities/jat-stir-in-haryana-may-dry-up-delhi-aap-govt-moves-sc-over-water-crisis/story-nPdIGg1yKq9cGB3LjsdkZI.html.

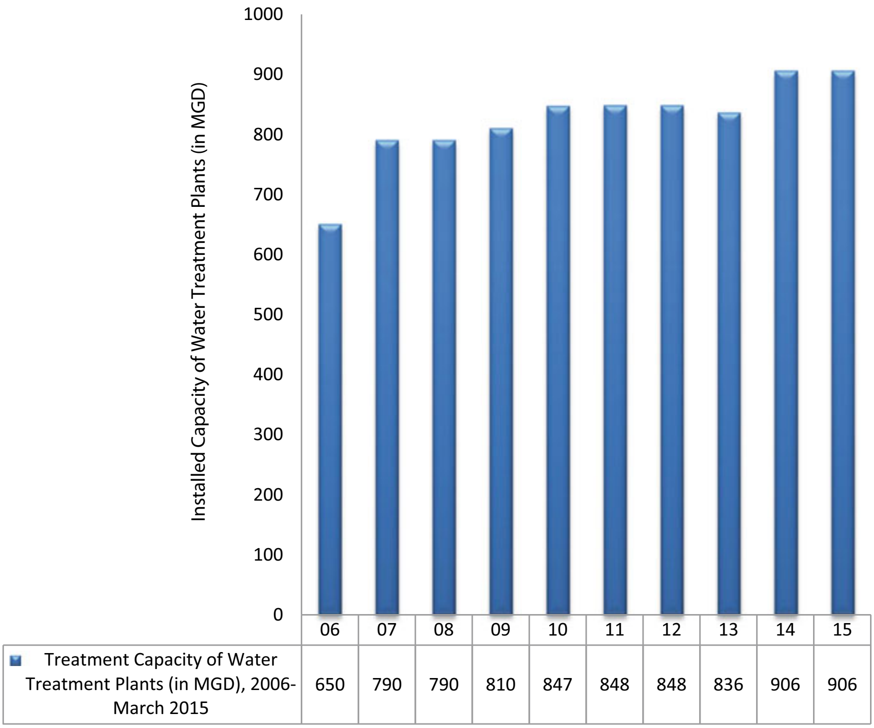

Fig. 24.6 Installed treatment capacity of water treatment plants (in MGD), Delhi, 2006–March 2015 (*Source* Economic survey of Delhi, 2014–2015)

but according to the Master Plan of Delhi (MPD), 2021 prepared by DDA, it is 80 GPCD. Of this, domestic requirement entails 50 GPCD, while for non-domestic requirement, it is 30 GPCD. However, 50 GPCD of domestic requirement consists of 20 GPCD for non-potable water needs and 30 GPCD for potable usage as illustrated in Table 24.3.

It is apparent from Table 24.4 that except for Wazirabad, Chandrawal and Dwarka, all other WTPs suffer from water scarcity, albeit Ranney wells and tube wells, recycling of water at Bhagirathi, Haiderpur and Wazirabad and Commonwealth games village supplies an additional 146 MGD (Table 24.2). Nevertheless, the amount of water supplied is far less than the water demand—999 MGD are required per day for a population of 16.8 million (Census of India 2011). This, of course, excludes other miscellaneous requirements and the floating population where the total estimated requirement is 1020 MGD; in addition, it should be noted that the current 2016 population is estimated to be 19.9 million. This observation of water scarcity reinforces the previous literature on water scarcity problems linked to drinking water in the cities of Bengaluru, Chennai and Guwahati (Bhattacharya and Borah 2014; Suresh 2001; Srinivasulu 2008).

Table 24.2 Water supply capacity of individual water treatment plants, 2006–March, 2015

Name of plants	Capacity (MGD)									
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Chandrawal Water house No. I and II	90	90	90	90	90	90	90	90	90	90
Wazirabad I, II and III	120	120	120	120	120	120	120	120	120	120
Haiderpur	200	200	200	200	200	200	200	200	200	200
North Shahdara (Bhagirathi)	100	100	100	100	100	100	100	100	100	100
Bawana				20	20	20	20	20	20	20
Nangloi	40	40	40	40	40	40	40	40	40	40
Sonia Vihar		140	140	140	140	140	140	140	140	140
Ranney wells and Tube wells	100	100	100	100	100	100	100	100	100	100
Recycling of water at Bhagirathi, Haiderpur and Wazirabad					37	37	37	45	45	45
Commonwealth games village						1	1	1	1	1
Okhla									20	20
Dwarka									50	50
Total	650	790	790	810	847	848	848	836	906	906

Source Delhi Jal Board and Economic Survey of Delhi, 2014–2015

Table 24.3 Water requirement norms as per DJB and MPD-2021

As per DJB water requirement norms		As per MPD-2021 water requirement norms			
Details	Requirement of water	Norms	Quantum(GPCD)		Sources of non-potable water
			Potable	Non-potable	
Domestic	172 LPCD[a]	**Domestic @50 GPCD**	30	20	
Industrial, commercial and community requirement based on 45000 L per hectare per day	47 LPCD	Residential	30	20	Recycling and permissible ground Water extraction at community Level
Fire protection based on 1% of the total demand	3 LPCD	**Non-domestic @30 GPCD**	5	25	
Floating population and special uses like Hotels and Embassies	52 LPCD	a. Irrigation, horticulture, Recreational, construction, fire @6.65LPCD		10	Recycling from Sewerage Treatment Plants (STPs) and Permissible Ground Water Extraction
		b. Public, semi-public, industrial and commercial	5	15	Recycling from Common Effluent Treatment Plants (CETPs)
Total	274 LPCD **(60 GPCD)**	**Total@80GPCD**	**35**	**45**	

[a]LPCD = liter per capita per day

Source Delhi Jal Board and Chap. 13: water supply and sewerage, economic survey of Delhi, 2014–2015

Table 24.4 Estimated water Deficit/surplus among the population of the water treatment plants command area

Water treatment plants	Population (Census of India, 2011)	Water demand (in Gallons) = PopulationX 60 GPCD	Water demand (in MGD)	WTP installed capacity (in MGD)	Deficit/Surplus (in MGD)	Deficit/Surplus
Bawana	431249	25874935	26	20	6	Deficit
Bhagirathi	2237906	134274356	134	100	34	Deficit
Chandrawal	1296123	77767406	78	90	−12	Surplus
Dwarka	534228	32053659	32	50	−18	Surplus
Haiderpur	3561914	213714846	214	200	14	Deficit
Nangloi	2211351	132681091	133	40	93	Deficit
Okhla	337861	20271672	20	20	0	Balanced
Sonia Vihar	4259923	255595395	256	140	116	Deficit
Wazirabad	1787383	107242985	107	120	−13	Surplus
		Total	999	780	219	Deficit

Source Calculated by the Authors

The rate of water demand notwithstanding is higher in the summer; DJB is committed to maintaining a consistent production of 835 MGD/day and at times, even allocate water tankers when demand supersedes the amount of supply. Evidence suggests that in July 2014, DJB recorded its production reaching 843 MGD. Reconnaissance observations, however, suggest that the WTPs like Dwarka and Nangloi fail to receive enough raw water to match the installed capacities. Arguably, the inadequate supply of raw water has resulted in irregular water supply. Nonetheless, based on the 60 GPCD norms, the estimated requirement of water in 2021 for 26 million (3 million more than as estimated by DDA) would be approximately 1,560 MGD [which also includes 15% of Non-RevenueWater (NRW) (JICA 2011). NRW is that amount of water which has been produced and transmitted but cannot be invoiced to its customers because it is the water that is lost either through leakage or overflow or both or even used by people who are not billed for the same]. Hence, to tackle the water scarcity, it remains paramount for efficient management. In the concluding section, we map for possible solutions.

24.5 Mapping for Possible Solutions

MPD-2021 aims for equitable and continuous water supply vis-à-vis extension of water supply to its peripheries [covering 15.3 million people of the urban areas and 7.7 million people outer (rural) areas of Delhi]; demand management via curtailment of water loss and reviewing of tariff to dissuade water wastage; energy management aims at preventing excessive pumping through proper rationalization of the system; lastly, to accomplish 24 × 7 water supply.

In 2002, the quantity of water treated by DJB was 650 MGD, which increased to 906 MGD by 2015 (Table 24.2). Evidently, in 2004, 40% of water supply was lost due to leakage in the pipelines, and therefore, only 60% could reach its residents, which was estimated to be 368 MGD against the demand of 600 MGD in the said year. Regrettably, in the water carrier system of Western Yamuna Canal System and river Yamuna, 30–50% raw water is wasted in its discharge from Tajewala Headworks. To address these leakages, various measures have been adopted. For instance, a Leakage Detection and Investigation (LDI) cell has been launched by DJB; and approximately, 1200 km of old, damaged and leaky pipelines have been replaced, bringing down the loss to approximately 20%, albeit the whole water supply system, as mentioned above, is entangled with approximately, 14,000 km of supply mains, of which, majority of the pipelines are approximately 40–50 years old. Notwithstanding, the newly built Munak canal, which became dysfunctional due to the *Jat* protesters for days was built by the Haryana Government (on behalf of the Delhi Government), to control water loss and anticipated that water availability would increase to about 95 MGD within the prevalent phenomenon at Munak. There remains a consensus nevertheless that water supply system of Delhi suffers from mismanagement, poor governance, lack of accountability alongside poor infrastructure, low levels of technical and managerial skills. This observation bears resonance with earlier literature (Gain and Giupponi 2015; Human Development Report 2006; World Water Development Report 2015). The following are the possible measures to improve the freshwater supply system of Delhi.

24.5.1 Water Tariff, Willingness to Pay and Affordability to Pay

'Use more pay more' was the principle of DJB until the new government of Aam Admi Party (AAP) took an oath to rule Delhi in February 2015. Before the AAP rule, statistics unfold that the total tariff collection as of March 2015 was INR 10922.5 million as against the estimated revenue collection of INR 12686.9 million, a collection efficiency estimated to be 86% (Economic Survey of Delhi 18). However, up to 20 kl per month (700 L a day) of free-water-scheme promises as made in the AAP election manifesto was transformed into reality with effect from 14 August 2015 for those households having functional water meter (Table 24.5). Evidently, within one and a half years of AAP Government, 1.05 million consumers including co-operative group housing societies' residents became the beneficiaries of this scheme. In addition, the AAP Government has reduced the water development charges and sewer development charges to the consumers of unauthorized colonies, respectively, from

Table 24.5 Water tariff of Delhi Jal Board 2015

Category- I (Domestic consumers):		
Monthly Consumption (Kiloliter)	Service Charge (INR)	Volumetric charge (Per Kiloliter)
Up to 20	146.41	4.39
20 to 30	219.62	21.97
Above 30	292.82	36.61
Category- II (Commercial/Industrial)		
00 to 06	146.41	14.64
06 to 15	292.82	21.96
15 to 25	585.64	29.28
25 to 50	1024.87	73.21
50 to 100	1171.28	117.13
Above 100	1317.69	146.41
Plus Sewer maintenance charge: 60% of volumetric water charge (for both domestic and commercial/industrial)		
Category- II A (Rainwater harvesting or wastewater recycling)		
Category- C consumers owning 2000 sq. Yards or larger size plot area will receive 10% refund from the total bill amount if rainwater harvesting or wastewater recycling exists in operational forms and 15% rebate from the total bill amount if both these services exist.		
Sewerage Maintenance Charge	60 % of Water Consumption Charge	
Water Cess Charge	@ 2 Paise Per Kl	
Late Payment Surcharge 5% of the total bill amount		

Source Delhi Jal Board

INR 440/sq. m to INR100/sq. m and from INR 494/sq. m to INR 100/sq. m.[13] While we agree with and praise the AAP government in helping reduce the bills of the residents of the unauthorized colonies, we also acknowledge that supplying 20 kl per month of water might motivate people to spend less water in order to receive water for free, but there are no incentives for those households (comprising of one or two people), who can manage their monthly requirements even for less than 10 kl. Table 24.5 illustrates a detailed picture of water tariff of DJB as applicable from 14 August 2015. Notwithstanding, Delhi's domestic consumer water tariff is one of the least when compared to some countries of the world (Table 24.6). Arguably, NCT is home to 545 Ultra-High-Net Worth Individuals (UHNWI) with net assets of over $30 million after Mumbai (with 1,094 UHNWI).[14] Moreover, as evidenced

[13] 100-day AAP govt: Free 20 kl water, low charges Delhi Jal Board's feats (2015, 24 May). *The Financial Express*. Retrieved from: http://www.financialexpress.com/article/economy/100-day-aap-govt-free-20-kl-water-low-charges-delhi-jal-boards-feats/75339/.

[14] AAP govt: Free 20 kl water, low charges Delhi Jal Board's feats (2015, 24 May). *The Financial Express*. Retrieved from: http://www.financialexpress.com/article/economy/100-day-aap-govt-free-20-kl-water-low-charges-delhi-jal-boards-feats/75339/.

Table 24.6 Water tariff in some countries

Country/City	Water tariff		Average monthly payment for a family of 4 consuming 20 KL	
	Local currency	INR	Local currency	INR[a]
India/Delhi	INR 4.39/21.97 (20/Above/KL)	4.39	0	0
Japan/Tokyo	22/128 Yen/m3 (10/20 KL)–Average75 yen/KL	46	1500 yen	920
Brazil/Sao Paulo	1.35 $/m3	90	US $ 17	1130
Ukraine	0.14 $/m3	9.5	US $ 2.8	186
China/Beijing	RMB1.98/m3	22	US $ 6.6	440
South Africa/Durban	Rand 9.5/11.25/m3 (9/Above)	48	US $ 14.52	965

[a]Conversion rate as on 28 April 2016@1 US$ = INR66

Sources Delhi Jal Board; Family Income and Expenditure Survey in 2014 by Ministry of Internal Affairs and Communications; Las Tarifas De Agua Potable Y Alcantarillado En América Latina, The World Bank Group, Retrieved from: http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2005/07/06/000011823_20050706103726/Rendered/PDF/Las0tarifas0de1llado0Borrador0Final.pdf; Ukrainian Upgrades. Retrieved from: http://www.waterworld.com/articles/wwi/print/volume-25/issue-4/regional-spotlight/easter-europe/ukrainian-upgrades.html; China Water Risk. Retrieved from: http://chinawaterrisk.org/opinions/pricing-water/; Hartley, Wyndham (2010, 5 May). South Africa: Water Tariffs Set to Rise to Reduce Need for Borrowing. Business Day, allAfrica. Retrieved from: http://allafrica.com/stories/201005050084.html

from the Delhi (Statistical Handbook 2015), in 2014–2015, among all the states, Delhi recorded the highest per capita income of INR 2,40,849; a rise of INR 28,630 when compared to the financial year 2013–2014. That said, in a survey conducted by JICA in the WTP command areas of Chandrawal, Wazirabad, Haiderpur, Bhagirathi and Sonia Vihar, the ‘willingness to pay’ water tariff was found to be ‘high’ in the Chandrawal WTP command area followed by ‘medium’ willingness to pay in the command areas of Wazirabad, Haiderpur and Sonia Vihar, while in the Bhagirathi WTP command area, ‘low’ level of willingness to pay was found. Although, water is a basic human need, but due to its rising demand and as per the National Water Policy (2012), we urge the DJB to treat water as an ‘economic good’and re-revise its water tariff and implement the methods of ‘willingness to pay’ and ‘affordability to pay’ as and where it applies to its consumers.

24.5.2 Non-revenue Water

There are no adequate statistics on NRW. Nevertheless, in the financial year 2008–2009, it was estimated that the loss was as high as 66% (including leakage). The

World Bank recommends an NRW loss of less than 25%. Evidently, cities like Melbourne (3%), Singapore (4%), Amsterdam (6%), Osaka (7%), New York (10%), Toronto (10%) and Tokyo (2.7%) (Bardies 2012) have reduced their NRW benchmarks rigorously.[15,16] Diligent low-level NRW benchmarks for NCT, Delhi can be accomplished by the following measures:

- Installation of 100% metering, and stringent meter reading, along with replacement of faulty meters.
- Corruption at all functionary levels—meter readers, law enforcement agencies and planning levels should be checked regularly and plug the loopholes in these functionaries for better coordination.
- Detection of illegal connection plus proper and regular maintenance of the facilities like pipelines, valves including detection of underground leakages, etc. This will not only reduce the distribution/transmission losses and leakages but also recover the expenses invested in the measures for reduction of NRW.
- Successful NRW programmes of the cities above, perhaps, Tokyo (that supplies water to its 12 million people and its NRW level is one of the lowest in the world) must be learnt and implemented according to the local needs of Delhi supply system (see, Bardies 2012).

24.5.3 Mandatory Rainwater Harvesting

As stated above, the average annual rainfall of Delhi is 714 mm (28.1 inches) and depends mainly on monsoon. The breakdown of average annual rainfall in NCT, Delhi is shown in Table 24.7.

DJB has already initiated mechanisms for mandatory harvesting of rainwater aimed at recharging of groundwater or water storage in reservoirs through 151 installations and imparted financial assistance of INR 8.2 million for 172 cases in the institutional category. In addition, DJB has launched a 'rebate scheme' to attract rainwater harvesting (Table 24.5: Category-II A) to its consumers. Given the current crisis, more needs to be done for storage of rainwater; perhaps, more reservoirs need to be installed to capture water to its fullest potentials (in colonies, temples, hotels, educational institutions and in industrial estates). But unlike North East India, Kerala, Goa, the pattern of Delhi's rainfall is mainly from June to September. Hence, for better management of water demand, larger tanks are perhaps required as the water crisis is more likely to be never-ending. Apart from the colonies, institutions and industries, very few individual homeowners of East of Kailash, Greater Kailash, Saket, Nizamuddin West, Kirti Nagar and Najafgarh have started harvesting rainwater

[15]Figures in the parentheses indicate the values of NRW levels.

[16]Stated NRW (Non-Revenue Water) Rates in Urban Networks (2011). Smart Water Networks Forum (SWAN). Retrieved from: http://www.swan-forum.com/uploads/5/7/4/3/5743901/stated_nrw_rates_in_urban_networks_-_swan_research_-_august_2011.pdf.

Table 24.7 Rainfall in national capital territory, Delhi

Stations	Rainfall (mm)
Chandrawal	886.5
Safdarjung	712.2
Delhi university	887.6
Palam	793.9
Okhla	792.4
Mehrauli	499.0
Delhi sadar	647.6
Nangloi	337.2
Shahdra	451.9
Najafgarh	398.9
Badli	516.1
Alipur	448.9

Source www.rainwaterharvesting.org

through the installation of rainwater harvesting structure within their own premises. Depending on their sizes, the prices of these rainwater harvesting structures ranges from INR 1500 to INR 6000. These structured systems have been making positive impacts not only in yielding tube well improvements but also in the enhancement of groundwater quality.[17] The success stories of these few homeowners (Suresh 2001; Srinivasulu 2008) should perhaps be aired in the media, which could encourage other homeowners to follow suits. Also, to attract homeowners for installation of rainwater harvesting structure, the Delhi government should perhaps launch a new irresistible incentive policy. Concomitantly, strict measures should be taken to stop illegal groundwater extraction.

24.5.4 Reuse of Wastewater

There is evidence to suggest that out of the total water consumed per person only 20% is used for drinking or potable purposes. The rest 80% goes back to the drain contributing to the sewerage flow. So, it is advisable not to be using potable water for toilets, washing clothes, cars, gardening, etc. Instead, sewage water should be recycled and treated to encourage consumers for non-potable uses. Dual pipe system should be encouraged and made mandatory in upcoming and existing planned colonies. JICA (2011) argues that although the dual piping system sounds impressive theoretically, however, there is a high risk associated with it from connecting drinking/potable water pipes with pipes of other usages, until and unless the engineers

[17]Database, New Delhi. Retrieved from: http://www.rainwaterharvesting.org/people/People-urban_database_delhi_individ.htm?#yudhavir.

and other humanpower delegated for these jobs carry extra vigilance and carefulness with all the nuanced issues linked to fitting pipes. Nonetheless, we argue that the dual pipe system would reduce water demand considerably. Therefore, we urge DJB to implement a policy for execution of the dual pipe system, where highly skilled dedicated workforce should be entrusted to implement this system. At the same time, the residents must be made aware of its positive impacts and emphasized that the system could only be executed with full cooperation from every resident. In addition, while it remains paramount to creating public awareness in making sustainable use of water, it is also important to increase 'will power' at the policy levels.

24.5.4.1 Crisis Management Including Earthquake

As mentioned above, Delhi is located at a high-risk intensity seismic zone capable of yielding high-frequency earthquakes. Hence, for natural emergencies and other fabricated crises (as in the case of *Jat* protestors), there needs to be preparedness. The existing water storage facilities must be evaluated against possible crises (including earthquake) and strengthened its capacities in addition to strengthening a backup plan.

24.6 Conclusion

A novel water scarcity scenario of NCT, Delhi has been presented in this chapter. As far as we are concerned, this is one of the first comprehensive studies on water scarcity in Delhi. In doing so, we tried to address three pertinent issues—using GIS, we calculated the water deficit/surplus among the population residing within the WTP command areas; that water scarcity in Delhi is both a natural and a human-made problem, and we have addressed few solutions to improve the effectiveness of the water supply system. Though the solutions presented herein are not going to solve the water scarcity problem of Delhi completely, nonetheless, if rationally followed and implemented, it would improve the sustainable efficacy of the system and build people's lives more comfortable. Nevertheless, if DJB fails to achieve these solutions, then the degree of water scarcity would be further widened, which would make it difficult to achieve an equitable distribution.

While this study is an addition to water scarcity literature, it is a useful research to proselytize public awareness, which can also be replicated to examine the water scarcity scenarios of other parts of the country.

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