

## **Anthropology of changing paradigms of urban water systems**

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3

4 **Abstract**

5 The dynamic interaction between society and nature is influenced by the prevailing normative,  
6 cognitive, and regulative societal systems, which guide the relationships between society and nature  
7 or ecology. Therefore, mature cities with increasingly complex urban interactions must shift from the  
8 simple agenda of demand-supply to multi-criterion models that takes into account factors like impacts  
9 of climate change, variation in settlement patterns, human vulnerability, and resource optimization to  
10 balance the society–ecology relationship. However, rapidly growing megacities have failed to balance  
11 their development and associated societal goals. This paper presents an assessment of the paradigm shift  
12 in the relationship between people and water as a resource, or the hydro-social construct, along a  
13 temporal gradient from about AD 1206 to the present for an ancient Asian city, namely Delhi. The  
14 city struggles at present with many challenges, including demographic fluctuations, increasing  
15 geographic spread, economic restructuring, changes in land use and settlement patterns, and, most  
16 relevant here, the transition from a water-sensitive city to a water-scarce city. The study identifies the  
17 causes of shifts in the water–society relationships and areas of interventions, that takes into account the  
18 physical, economic, and social characteristics of the city’s water resource to ensure that water, a basic  
19 human need, must be accessible to all inhabitants of the city.

20 **Keywords:** Hydro-Social Construct; Urban Water; Society; Sustainability; Governance

21

22 **Introduction**

23 The relationship between society and nature is dynamic and is directed not only by the balance  
24 between natural resource endowment and their demand but is also governed by drivers as the societal  
25 systems with their three pillars, namely the normative, cognitive, and regulative systems (Brown et al.  
26 2009). Cities are centres of major developmental activities and therefore subject to continual socio-  
27 economic restructuring; at the same time, cities strive to optimize their resources and to provide utility

28 services to their inhabitants sustainably (Weisz 2011). Therefore, the current understanding of  
29 the association between people and nature needs to incorporate a contemporary angle to the classical  
30 module of sustainability to balance a city's growth with its societal goals (Andries et al. 2004), and the  
31 transformations of the city's physical, institutional, and governance structures are prime towards the  
32 balance (Brown et al. 2009).

33 The present study assesses the paradigm shift in the relationships between people and water  
34 as a resource, or the hydro-social construct, along a temporal gradient from about AD 1206 to the  
35 present for an ancient Asian city, namely Delhi. Such a study can help to understand the changes in the  
36 society-water relationship for other cities as well. Hydro-social constructs have been studied  
37 for several cities (Kim et al. 2001; Onodera et al. 2008; Weisz 2011; Mehta et al. 2013). However, this  
38 paper traces the evolution of the society-water relationship with its drivers and its impact on the city's  
39 growth. Initially, water was the only factor that governed Delhi's socio-economic development; later  
40 on, socio-cultural and economic changes became the governing factors for the city's hydrological  
41 profile (Hardiman 2002; Mann 2007). This pattern of evolution, in which water and its management  
42 played a key role in the city's socio-cultural changes, make Delhi particularly suitable to study the  
43 interaction between society and water. Historically, the water management systems have been  
44 reformed from a distinctly decentralized, community-driven, and state-patronized system to a  
45 completely state-managed public system. Information on the water management in the past was  
46 collected from the archives of the Delhi government and through interactions with key informants,  
47 and information on the present-day urban water system was obtained by interviewing officials of water  
48 utility agencies and from documents published by the state and central governments in India.

49 The new institutionalism (Hall and Taylor 1996) was used as an analytical approach to  
50 understand the evolving urban hydro-social construct because the institutionalism focuses on  
51 developing a sociological view of institutions to comprehend the way a hydro-social system interacts  
52 and affects society. These institutions comprise three mutually reinforcing pillars: (1) cognitive:  
53 dominant knowledge, thinking, and skills; (2) normative: values and leadership; and (3) regulative:  
54 administration, rules, and systems. These three pillars together shape the patterns of practice.  
55 Moreover, the new institutionalism provides insights into institutions outside of the traditional views

56 of economics by explaining why and how institutions emerge in a certain way within a given context  
57 and, if they change, the pattern of that change or transition. Besides, the ‘cumulative socio-political  
58 drivers’ of the transition must reflect shifts in the normative and regulative dimensions and include the  
59 impact of ‘service delivery functions’ (Brown et al. 2009) on the cognitive dimension of the hydro-  
60 social construct. However, for institutions to remain stable or to be able to withstand changes, a  
61 mutually reinforcing shift is mandatory within each pillar.

62 Accordingly, the present paper presents the shifts in the *pattern* and in the *institutions* related  
63 to water management over time to contribute to the present-day debate on urban hydro-social  
64 constructs. The debate, which revolves round a question, namely ‘How did the water–society  
65 relationship in Delhi change from the pre-Colonial to the post-Colonial period?’, is to be seen in the  
66 light of many other suppositions, including the following: 1) water is a finite resource without  
67 substitutes (MoEF 2010); 2) the horizontal urban growth of Delhi (Ghosh and Kansal 2014) pushes  
68 human settlements away from the natural sources of surface water (Sohail et al. 2013); 3) water  
69 demands of an urban area, in most cases, outstrip its renewable stocks (MoEF 2010; CGWB 2013);  
70 and 4) high population density and economic restructuring of the city (Bhagat 2011; Census of India  
71 2011) have a tendency to alter the character of the water from ‘blue’ to ‘grey’, endangering the  
72 environment.

73

## 74 **Delhi and its water resources: current status**

75 Delhi, also known as the National Capital Territory of Delhi (NCTD), extends from 28°24'17" N to  
76 28°53'00"N and from 76°50'24" E to 77°20'37" E and is spread over 1483 km<sup>2</sup> (GNCTD 2015). In  
77 2011, Delhi had a population of more than 16.78 million (Bhagat 2011). The territory has nine districts  
78 and shares its borders with six states, namely Himachal Pradesh, Haryana, Punjab, Uttar Pradesh,  
79 Uttarakhand, and Rajasthan (Sohail et al. 2013).

80 Historically, Delhi’s urban growth has been horizontal, starting from the walled city during  
81 the pre-Colonial period and expanding in concentric circles, engulfing the smaller surrounding  
82 villages, and merging with New Delhi (Hardiman 2002; Mann 2007; GNCTD 2015). The concentric

83 growth of the city is the result of its two ring roads. The inner ring road was developed following the  
84 first master plan for Delhi and the outer ring road, which girdles the city, was developed following the  
85 second master plan drawn up by the Delhi Development Authority (DDA 2010). Thus, the urban form  
86 of Delhi has been largely influenced by the planning process (DDA 2010). The territory is part of the  
87 Yamuna floodplain and lies at the foot of the Aravali hills. Geographically, Delhi is a conurbation  
88 (Fig. 1) surrounded by its satellite towns (Faridabad, Ghaziabad, Gurgaon, and Noida), which are  
89 under different political administrations and share the region's natural resources with Delhi (GNCTD  
90 2015).

91 Delhi receives water from three main sources: surface water, groundwater, and rainwater.  
92 Major sources of surface water in Delhi are Yamuna, Bhakra, and Ganga reservoirs (GNCTD 2010;  
93 Sharma and Kansal 2011). Apart from Yamuna, the main river in the city, water is supplied to Delhi  
94 through different interstate arrangements, and the sources also include such subsurface sources as  
95 Ranney wells (RW) and tube wells (TW) (CGWB 2013; Ghosh et al. 2016). The net annual  
96 availability of groundwater in the NCTD is 0.29 billion cubic meters (BCM), the annual estimated  
97 extraction is 0.39 BCM, and the stage of development is 137% (CGWB 2013). However, annual  
98 groundwater draft for all the purposes to net annual availability in different zones of Delhi shows a  
99 significant decline except in a few areas (Table 1). The annual rate of decline is as high as 1.7–2 m in  
100 some areas (South and South-West districts) (Shekhar et al. 2006) with the depth varying from 6 m  
101 (floodplains) to 60 m (the southern ridge) (GNCTD 2010).

## 102 **Figure 1**

## 103 **Table 1**

104 Figure 1 shows changes in land use in Delhi over the past four decades (1973–2013). Similar  
105 to the pattern of urbanization experienced by other emerging economies, Delhi too has witnessed a  
106 tremendous increase in built-up area and a commensurate decrease in farmland. Although the extent  
107 of Delhi's forested area (which comes under the jurisdiction of the state administration and the  
108 defence services) has remained unchanged, natural vegetation has increased considerably, which  
109 includes parks in residential and institutional areas, roadside greenery, and other recreational areas. A  
110 reduction in fallow land and wasteland shows that land is increasingly used for settlements and

111 recreation at the cost of farming: today, farmland in Delhi is only about 50% of that in 1973. Figure 1  
112 also shows a marginal decrease in the area occupied by water bodies. However, many of the water  
113 bodies today comprise pools of untreated sewage resulting from lack of adequate drainage and  
114 sewerage systems (Sharma and Kansal 2011). This pattern of growth has implications for  
115 groundwater recharge and urban flooding.

116

## 117 **Water transition in Delhi: a historical account**

118 Delhi's history as it relates to water can be divided into three periods: 1) Pre-Colonial, which itself  
119 can be divided further into three sub-periods (Pre-Sultanate, Sultanate, and Mughal), 2) Colonial  
120 (during the British rule in India), and 3) Post-Colonial (Spear et al. 1994; Cherian 2004). During the  
121 Pre-Colonial period, the pattern was mostly decentralized, with groundwater and water-harvesting  
122 structures such as *ashauzes* (lakes), *baolis* (stepwells), and *nahars* (streams). From the Colonial era and  
123 particularly after 1857, water as a resource began to be centralized in administrative terms to meet the  
124 health and hygiene concerns of the ruling elite. The old structures were either dismantled or  
125 abandoned during this period. The post-Colonial period begins after India gained independence, in  
126 1947. This period can be further divided into three, namely 1947–1956, 1957–1991, and 1992–2015,  
127 based on major shifts in the administrative structure of Delhi (Delhi Municipal Corporation (DMC)  
128 Act, 1957). Despite all the differences in methods and structures of water management, the role of  
129 power relations was vital in the society–water relationship.

130         Until the beginning of the 19th century, the river Yamuna was never a major source of water  
131 for Delhi's population, which depended mainly on groundwater and stored water (Cherian 2004). It  
132 was only after the introduction of piped water supply that the Yamuna became a major source of  
133 water. The tree-covered ridge, the alluvial plain, and the bed of the river Yamuna have played a major  
134 role in making Delhi a very habitable location (Fig. 2). The drainage basin of the Delhi region was  
135 formed by many small streams. However, the river Yamuna, shifting eastwards, was one of the  
136 deciding factors that changed the settlement pattern in the region. The city at present is a water-deficit  
137 region: small streams and lakes have disappeared, and water storage structures are scarce or missing

138 altogether. The river Yamuna, after crossing the city's boundary, runs dry for nearly eight months in a  
139 year (MoUD 2012); a significant percentage of water supply comes from a source a few hundred  
140 kilometres away, and groundwater development is 137% (CGWB 2013), which is critical and  
141 significantly constrained for access to water resources.

142 **Figure 2**

143

144 **Pre-Sultanate Period (before AD 1206)**

145 Hauz Rani, Lal Kottal [*tal* is Hindi for a lake], Anangtal, and Mahipalpur dam are the prime water  
146 storage structures attributed to the pre-Sultanate period. Large lakes such as Surajkund [*kund* is Hindi  
147 for a pond] and Anangtal are fine examples of water harvesting from this period. Smaller streams of  
148 the river Yamuna were tapped to feed these large lakes. The supply was augmented by wells, which  
149 collected run-off during the rainy season and recharged the groundwater through wetland seepage and  
150 percolation through fissures in rocks (Agarwal and Narain 1997). The complex geology and  
151 subterranean flows also allowed a hierarchy of wells (Spear et al. 1994; Cherian 2004).

152

153 **Sultanate Period (1206–1526)**

154 Several cities were built in the region of the Aravali hills with a wide variety of water-harvesting  
155 systems during the Sultanate period. Large tanks such as Hauz-i-Sultani and a network of stepwells  
156 including Gandhakkibaoli, Rajaonkibaoli, and Hauz-i-Shamsi are examples of water structures from  
157 this period (Spear et al. 1994). All new forts and the capital city itself were constructed in  
158 coordination with the eastward-flowing river Yamuna and its underground streams. Storage structures  
159 near the river were filled by underground movement of water and those at a distance were filled by  
160 run-off that recharged groundwater during the monsoon (Shah, 2009; Bottrall, 1992). The *baolis* were  
161 non-spiritual structures constructed mainly for the public, irrespective of religion, for access to safe  
162 water for all. Silting of one tank or well had no effect on the structures elsewhere, a feature of the  
163 decentralized nature of the water system. The *baolis* were maintained by the locals, and larger

164 structures such as lakes, tanks, and bunds were under the jurisdiction and the responsibility of the  
165 central authority, namely the ruling king (Cherian 2004).

166

## 167 Mughal Period (1527–1540; 1555–1857)

168 Water management during the Mughal period relied on the existing *baolis* and wells. However,  
169 improvements in these structures and technological standardization made Delhi rich in hydrologic  
170 terms (Habib 1982). The embankment along the river Yamuna, arresting its shift, and a network of  
171 canals through the city are the most important contributions of the Mughal period (Bottrall 1992; Shah  
172 2009). Band-i-Akbari and Band-i-Shahjehani are examples of bunds that continue to save Delhi from  
173 flooding even now. The Hisar–Firuza canal, built earlier, was repaired and became a permanent  
174 structure in the city of Shahjahanabad (the walled city of Old Delhi, which was the capital of the  
175 Mughal empire until the British took over the country) and was referred to as Nahar-i-Faiz or Nahar-i-  
176 Behist. In the main city, the canal recharged the *dighis* (square or circular reservoirs) and wells, and  
177 the job of *kahars* (palanquin bearers and appointed especially to draw water) was to draw water from  
178 the *dighis*. Most houses had their own wells and *dighis*, which served as a stand-by if water supply to  
179 the city through the canal failed. In 1843, Shahjahanabad had 607 wells, of which 52 provided  
180 particularly sweet water.

181

## 182 *Hydro-social construct and urban water transition for Pre-Colonial period*

### 183 *Attributes*

184 **Normative** During the pre-Colonial period, water was considered a social service, and there is little  
185 evidence that power relations influenced access to water. Water structures were part of the community  
186 life.

187 **Cognitive** The local masonry and hydraulic skills of the Sultanate and Mughal periods formed the  
188 cognitive basis of water management in these times. This amalgamation brought standardization in  
189 old practices and improvements in structures.



190 **Regulative** The management of water was decentralized. Cleaning and maintenance were carried out  
191 through public participation: only the large structures were under the control of the central authority.

### 192 *Hydro-social construct*

193 The hydro-social constructs during the pre-Sultanate, Sultanate, and Mughal periods were influenced  
194 by the natural constraints of the landscape and waterscape of those times. Places for settlements were  
195 chosen with due consideration to the availability of water and of an affordable technology to tap that  
196 water. The dependence on storm water and wells ensured that water was available not only during the  
197 rainy season but also round the year. Thus, there is no evidence to show that water was used by the  
198 rulers to exercise their authority or that there was any biophysical scarcity of water.

199

### 200 Colonial period (1857–1947)

201 The state in the British era sought total ownership of water resources and established a centralized  
202 system to control water supply. The existing structures were considered primitive and were  
203 dismantled, and a distinct proprietary element was introduced (Bottrall 1992). Water was taxed at all  
204 levels, and charges for water were made a part of the land-tax system (Hardiman 2002). The elite and  
205 the well-to-do, mostly the British and few rich Indian landlords, were the only beneficiaries of this  
206 system of financing new water infrastructure (Willcocks 1984), consisting of an electrically powered  
207 and pumped water system, to supply water to the public. As the population kept increasing and driven  
208 by health concerns, the British ruling India at that time lived mostly in civil lines and cantonment  
209 areas, and the planning of sanitation systems serving these areas was separated from the rest. In 1931,  
210 the newly established capital city of British India, called New Delhi, was formally inaugurated and  
211 thereafter, all municipal works remained focused on this part of Delhi; the ‘old’ Delhi was neglected  
212 totally (Mann 2007). Table 2 provides details of the water works undertaken during this period. The  
213 villages surrounding Delhi, which are now part of modern Delhi as urban villages (Sohail et al. 2013),  
214 had *johads* (village ponds) as a source of water for the commoners; these ponds were an integral part  
215 of the communal life and were regularly cleaned and maintained by the vicinal community (Sengupta  
216 1985).

217 **Table 2**

218 *Hydro-social construct and urban water transition for Colonial period*

219 *Attributes*

220 **Normative** The ruling elite, who believed that advanced technology was invariably superior and that  
221 they knew more about providing public services, discarded the old decentralized methods of water  
222 management and thus destroyed the surrounding communal life. The normative sense of the  
223 British elite favoured centralized water systems with focus on central management and vigilance for  
224 better sanitation, hygiene, and health.

225 **Cognitive** The Colonial period saw advances in testing chemical parameters of water, long-distance  
226 pumping of water through electric pumps, and recognition of waterborne diseases.

227 **Regulative** The authorities were unidimensional in perception and hence regulation of water created a  
228 new privileged class of those who could afford to pay taxes. This excluded a large section of the  
229 population living outside the city boundaries. Thus, the sources of water supply were centralized  
230 under the ownership of British state rule.

231 *Hydro-social construct*

232 The Colonial period marks the advent of anthropogenic changes in hydrology to suit human  
233 settlement. Delhi saw a strong centralized control over water resources, wherein water was supplied  
234 based on political considerations and to those who could afford to pay taxes (Hardiman 2002). This  
235 period saw a paradigm shift in the hydro-social construct and a total disconnect with the previous  
236 arrangements (Mann 2007). The hydro-social construct during the Colonial period promised water  
237 supply and hygiene to the British and the local elite through a centralized public water supply and  
238 distribution system. Community institutions were pulled down, thereby excluding the larger  
239 population, which remained confined to the old and densely populated settlements. Moreover, the  
240 British taxation system changed the approach of water provisioning from a 'social service' to a 'get as  
241 you pay' service, dividing the society into the privileged, who had access to piped water, and the non-  
242 privileged, who did not.

243

244 Post-Colonial period (1947–1956, 1957–1991, and 1992–2015)

245 The DMC Act, 1957, and The Constitution (69th Amendment) Act, 1991, were the turning points in  
246 modern Delhi's administrative structure. The Delhi Joint Water and Sewerage Board, constituted in  
247 1926, was amalgamated with the DMC (DMC Act, 1957), and the corporation formed the Delhi  
248 Water Supply and Sewerage Disposal Committee. In 1991, Delhi was accorded the status of a state  
249 (with certain exceptions) and later, in 1998, water supply, drainage, and sewerage were transferred to  
250 an autonomous managing authority, namely the Delhi Jal Board (DJB) (*jal* is Hindi for water) (DJB  
251 1998).

252 The post-Colonial period adopted the so-called 'management' of water provisioning with  
253 respect to clean drinking water to citizens and proper discharge of wastewater. Drinking water was  
254 supplied by sharing water from large dams and by exploiting groundwater, and the city's wastewater  
255 was discharged by using natural drains, ponds, and wetlands and by discharging it into the river  
256 Yamuna—polluting these sources and destroying their ecology. These attempts at water and  
257 wastewater management could not be sustained in the face of rapid socio-economic changes in Delhi  
258 and their impact on water provisioning.

259 Even now, the ways to augment future water supplies remain unchanged and include  
260 centralized appropriation of water by building dams several kilometres away (for example, the  
261 Renuka, Kishau, and LakhwarVyasi dams). Although such eco-friendly options as recycling,  
262 controlling losses, and rainwater harvesting have been considered in recent decades, they have not  
263 been implemented on the required scale. Universal coverage of the water supply network and  
264 sewerage connections and equitable supply of water are said to be the DJB's mission, but the results  
265 are yet to be seen.

266

267 *Hydro-social construct and urban water transition for Post-Colonial period*

268 *Attributes*

269 **Normative** After India attained independence, the main concern of people was to get clean and  
270 potable water. It is only recently that citizens have started paying attention to pollution of the river

271 Yamuna and drying up of other water bodies. However, the understanding of environmental limits is  
272 not widespread yet, and technology transfer is often misconstrued as the solution to all water-related  
273 challenges. Seasonal water shortages and the vulnerability of the sources of supply to political  
274 disturbances aggravate the problem. At present, a large number of people do not have access to piped  
275 supply of treated water, and the pressure to provide such access is expected to increase. Sewage  
276 connections serve less than 50% of the population—all of which point to a progressive deterioration  
277 of water bodies. Therefore, it is difficult to imagine any major shift in values until basic water services  
278 are delivered to all.

279 **Cognitive** Hydraulic engineering and urban hydrology have advanced greatly during the past three  
280 decades. Environmentalism has gathered increasing momentum with the concern for sustainable  
281 development since Bruntland Commission's report and that for climate change since the 1990s.  
282 However, urban planners in Delhi are aware of technical advancements and such concepts as  
283 sustainable city development and have tried to incorporate them into government policies (as claimed  
284 by officials during our interactions with them, although no evidence exists to support these claims).  
285 Using information and communication technology (ICT) for managing water treatment plants and  
286 geographic information system (GIS) for mapping the flow of water through a network of pipelines  
287 are some recent developments. Water accounting and measures to check water losses and to make  
288 waterworks more energy efficient are also being implemented.

289 **Regulative** Centralized supervision has continued to manage Delhi's water resources and water as a  
290 utility during the post-Colonial period, although the control of this utility shifted from the central  
291 government to the state government in 1991. This shift has brought greater accountability into the  
292 system, and services have improved since. However, the functioning and the focus have largely  
293 remained the same. The methods of collecting water taxes and managing revenue have recently been  
294 modified and improved.

### 295 *Hydro-social construct*

296 It is noteworthy that during the post-Colonial period, Delhi has become increasingly dependent on  
297 external sources of water, some of which are even a few hundred kilometres away. This has reduced

298 water to a mere commodity instead of being a natural resource. Catering to the water demand of the  
299 city was the sole focus of this period: the rapidly growing population and the expanding city simply  
300 did not offer any scope to set priorities.

301

## 302 **Changes in hydro-social constructs**

303 The hydro-social construct and the transitions in water metabolism (Newman et al. 1999) of Delhi  
304 have varied over the years and are completely different today from what they were a few centuries  
305 ago. Identifying the factors that led to such transitions required a good understanding of water  
306 movement within the city and its associated drivers and limitations, and that understanding can be  
307 used in developing water management schemes for a sustainable city. Although problems related to  
308 water supply have been reported earlier, the discrete and sectoral approaches that were adopted to deal  
309 with the problems could not be sustained. Therefore, the present study recommends a multi-  
310 dimensional approach for a 'smart' water city.

311 From the analysis of the paradigms of Delhi's water management schemes in the past, it is  
312 apparent that pre-Sultanate, Sultanate, and Mughal Delhi had more attributes similar to those of a  
313 *water-sensitive city* (Brown et al. 2009). During the pre-Colonial period, Delhi was self-sufficient for  
314 water and used groundwater and stormwater sustainably. The institutions followed the participatory  
315 approach, and with the community life centred around water, communities were also responsible for  
316 the maintenance of water sources: water was neither a means for rulers to exercise their authority nor  
317 a commodity to be taxed and used as a source of revenue. Besides, the pattern of settlements was  
318 shaped by the availability of water. Water structures of those periods, so carefully and beautifully  
319 designed and constructed, demonstrate the importance of water in lives of people of those  
320 times. Nevertheless, the caste system and class biases in India were prevalent during the pre-Colonial  
321 period, and it cannot be denied that access to water structures was based on these axes. There was no  
322 mechanism to treat wastewater, which was directly discharged into water bodies, yet no water  
323 pollution was evident because of low population pressure (Spear 1994; Cherian 2004), and the  
324 discharge was well within the carrying capacity of the water bodies. During the Mughal period, as can

325 be ascertained from literature (Cherian 1994), the localities surrounding water structures were  
326 homogenous and therefore without any major problems related to discrimination. The Colonial period  
327 marked major advances in waterworks construction, a change in the scale of management, and  
328 technology transfer. These were useful developments for the growing population and the expanding  
329 city. However, the administration of the time was inclined more towards asserting power and less  
330 towards meeting the needs of people. Thus, the old structures were dismantled, which destroyed the  
331 normative values associated with water. The regulative framework was bent to favour only a few.  
332 Thus, the advantages of this period turned into a bane. Further, in independent India, the population  
333 kept growing at an unimaginable rate both from growth within and from migration (Bhagat 2011).  
334 The technological structures and methods that were transferred to the newly independent state by the  
335 British were adopted without change and were considered the symbols of modernization and therefore  
336 strengthened accordingly. The sanitation system served only the inhabitants of civil lines and  
337 cantonments, meant for the elite and the rulers. The trend of class-based inequality towards water  
338 access and negligence of sanitation systems has continued even in independent India (Hardiman  
339 2002). During the first fifty years of India's independence, the emphasis was more on the supply of  
340 drinking water and less on sanitation. Reasons for this are many. First, water supply itself was  
341 woefully inadequate, even below 140 to 200 litres per capita per day (lpcd)—the minimum required  
342 for a sewage system to function (BIS 2003), and underground drainage was not a priority except in a  
343 few large cities. Secondly, limited financial resources did not allow the state to do justice to the  
344 sanitation sector. Yet, proper collection, treatment, and hygienic disposal of sewage are necessary to  
345 protect drinking water from contamination. Therefore, these two sectors – water supply and sanitation  
346 – require synchronization at operational levels, which is missing in Delhi's water management  
347 schemes at present. Hence, the cognitive merits of the system overshadowed the institutional and the  
348 normative disadvantages, an oversight that has consigned Delhi to a perpetual scarcity of water.

349 Thus, the hydro-social construct has remained limited to merely providing water. Although in  
350 recent years, the management of sewage and drainage has received some attention, the management  
351 lacks effective inclusion of sanitation and sustainability aspects.

352

## 353 **Conclusion**

354 A paradigm shift in the pattern of water management in Delhi has led the city to rethink its water  
355 systems. With socio-economic changes, rising population, and changes in landuse, Delhi has changed  
356 from a water-sensitive city (Wong and Brown 2009) to a water-scarce city. According to Brown et al.  
357 (2009), cities must change their priorities for water management as they mature; from a mere demand-  
358 supply system, the cities must switch to a multi-criterion system that deploys advanced technologies  
359 and policy interventions to deal with such challenges as climate change, vulnerability, and human  
360 settlements. However, Delhi and similar megacities of the world, being clusters of several  
361 developmental activities, fail to manage their resources efficiently and thus fail to meet the demands  
362 of a mature city.

363 The present paper sought to answer two questions: ‘Do past changes in water provisioning  
364 offer any key inputs to the present-day water debate in Delhi?’ and ‘Can a city be made water  
365 sustainable when water is reduced to a mere commodity that money can buy?’ These questions can be  
366 understood better in light of the following challenges.

- 367 1) Finite availability of water.
- 368 2) Shift in income pattern from primary to tertiary and a population moving farther from  
369 water sources, which constrains the availability of good quality water even further.
- 370 3) An exponential increase in water demand from a necessity to a luxury (water for gardening  
371 and a 24/7 supply) that stretches supply and increases wastage at the same time.
- 372 4) High population density that not only deteriorates the quality of surface water but also  
373 threatens hitherto safe groundwater reserves, resulting in outbreaks of water-related diseases,  
374 worsening the quality of life.

375 All these factors disturb the balance between progressive urban developmental agendas  
376 related to water and societal goals—the crux of the debate on the sustainability of the urban hydro-  
377 social construct. The present paper identifies some factors, based on a study of the past, which need to  
378 be taken into account in strengthening the hydro-social construct in the context of large cities.

379 One school of thought suggests that to make Delhi a water-sensitive city, it is necessary to  
380 revisit the past practices of decentralized planning and community participation, along with modern  
381 technologies customized for Delhi. The current form of decentralized planning and public  
382 participation will therefore be different from that in the past. However, we put forward, two questions:  
383 1) 'Is the city of Delhi facing the side effects of flawed design and assumptions stemming from the  
384 commodification of water and centralized planning in the name of modernization?' and 2) 'Is it not  
385 really feasible – that is, are there real barriers – to adapt the old water systems to the present, or is  
386 blaming the past for the present situation only a convenient excuse for not doing so?'

387 Since it is evident that the city of Delhi has undergone a major transition in its hydro-social  
388 construct and that the current water management schemes are inadequate to meet the city's needs, the  
389 present study offers fresh insights into framing contemporary water schemes in line with the criteria  
390 for labelling a city as water-sensitive. Such schemes should consider the following four measures.

- 391 1) Control the use of water.
- 392 2) Ration water and redistribute it among competing sectoral demands taking into account  
393 spatial and temporal variations in demand.
- 394 3) Measure water as a commodity using fiscal and economic instruments.
- 395 4) Undertake predictive studies to strengthen the estimates of future changes in the ratio of  
396 water demand and water supply.

397 Also, water schemes for the changing water-society relationship need support of policy  
398 initiatives, such as, curbing illegal water markets, allocating subsidies and incentives fairly, promoting  
399 water conservation schemes and ensuring their proper implementation, promoting synergy among  
400 sectoral water planners, and encouraging community participation to ensure that people use water  
401 judiciously. An even larger issue is to balance the physical, economical, and social characteristics of  
402 water and superimpose on them a constraining function that establishes access to safe water as a basic  
403 human right.

404 Delhi in the post-Colonial period has seen severe pollution of surface water as a result of  
405 reduced community engagement, water management being considered the responsibility of only a  
406 central authority. However, the modern pattern of urban settlement has reduced groundwater recharge



407 that is vital to maintain a city's water stock. Moreover, schemes of water supply drawn up during  
408 the Colonial times cannot cope with the rapid change in land use, and this inability has resulted in rapid  
409 depletion of groundwater, pollution, and dependence of sources of water far away from the site of  
410 demand. Accordingly, the present study suggests that water schemes be revisited for improved water  
411 supply, water structures be revived to enhance groundwater recharge and replenish water stocks,  
412 decentralized sources be adopted for fair allocation of this precious resource, and communities be  
413 encouraged to use water efficiently.

414 If Delhi is to be a water-sensitive city instead of a water-scarce city, it should have its own  
415 sources of water. The city can be made independent by reinvigorating the hydro-social construct  
416 (taking into account the shifts in socio-economic patterns), by a greater understanding of water mass  
417 balance (water flow pattern and stocks maintained within the city), and by adopting effective  
418 management tools (material recycling and a closed-loop economy, for example) to make Delhi a  
419 'smart' city in terms of its use of water.

420

## 421 **Acknowledgement**

422 We acknowledge the contribution of Mr Yateendra Joshi for copy-editing the manuscript.

423

## 424 **References**

425 Agarwal A, Sunita N (1997) Dying wisdom: rise, fall and potential of India's traditional water  
426 harvesting systems, fourth citizen report on the state of India's environment. Centre for Science  
427 and Environment, New Delhi

428 Andries JM, Jansen MA, Ostrom E (2004) A framework to analyse the robustness of social-  
429 ecological systems from an institutional perspective. *Ecology and Society* 9(1):18

430 Bhagat RB (2011) Emerging pattern of urbanisation in India. *Economic and Political Weekly*  
431 46(34):10-12

432 BIS (1993) Indian standard code of basic requirements for water supply, drainage and sanitation  
433 (fourth revision). Bureau of Indian Standards, New Delhi.[http://dasta.in/wp-](http://dasta.in/wp-content/uploads/2015/04/CB_Code_2002.pdf)  
434 [content/uploads/2015/04/CB\\_Code\\_2002.pdf](http://dasta.in/wp-content/uploads/2015/04/CB_Code_2002.pdf). Accessed 26 September 2018

435 Bottrall A (1992) Fits and misfits over time and space: technologies and institutions of water  
436 development for South Asian agriculture. *Contemporary South Asia* 1(2):227-247

437 Brown R, Keath N, Wong T (2009) Urban water management in cities: historical, current and  
438 future Regimes. *Water Science Technology* 59 (5) 847-855. [https://doi: 10.2166/wst.2009.029](https://doi.org/10.2166/wst.2009.029)

439 Census of India (2011) Registrar General and Census Commissioner, Ministry of Home Affairs,  
440 Government of India, New Delhi. <http://censusindia.gov.in>. Accessed 19 September 2018

441 CGWB (2011) Groundwater information booklet. Ministry of Water Resources, State Unit Office,  
442 New Delhi.[http://cgwb.gov.in/District\\_Profile/Delhi/New%20Delhi.pdf](http://cgwb.gov.in/District_Profile/Delhi/New%20Delhi.pdf). Accessed 26 September  
443 2016

444 CGWB (2013) Dynamic ground water resources of India for July 2011. River development and  
445 Ganga rejuvenation, Central Ground Water Board, Ministry of Water Resources, New  
446 Delhi.<http://cgwb.gov.in/Documents/Dynamic%20GWRE-2013.pdf>. Accessed 6 November 2016

447 Cherian D (2004) Pairing mega events and hydrological systems for urban sustainability: strategy  
448 framework for Delhi beyond the Commonwealth Games 2010. Dissertation (MCP),  
449 Massachusetts Institute of Technology

450 CPCB (2008) Central Pollution Control Board report 2007-2008. Status of groundwater quality in  
451 India part II. Groundwater Quality series: GWQS/ 10/2007-2008. Central Pollution Control  
452 Board, Delhi.  
453 [http://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvTmV3SXRlbV81MF9ub3RpZmljY](http://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvTmV3SXRlbV81MF9ub3RpZmljYXRpb24ucGRm)  
454 [XRpb24ucGRm](http://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvTmV3SXRlbV81MF9ub3RpZmljYXRpb24ucGRm). Accessed 6 November 2016

455 DDA (2010). Master Plan of Delhi-2021. Delhi Development Authority,  
456 Delhi.<https://dda.org.in/ddanew/pdf/Planning/reprint%20mpd2021.pdf>. Accessed 8 November  
457 2018

458 DJB (1998) Delhi Water Board. <http://ielrc.org/content/e9802.pdf>. Accessed 6 September 2016

459 DMC Act. (1957). Delhi Development Act. [http://www.urbanresearch.in/e-](http://www.urbanresearch.in/e-library/Delhi%20Development%20Act,%201957_59.pdf)  
460 [library/Delhi%20Development%20Act,%201957\\_59.pdf](http://www.urbanresearch.in/e-library/Delhi%20Development%20Act,%201957_59.pdf). Accessed 26 September 2016

461 Ghosh R, Kansal A (2014) Urban challenges in India and the mission for a sustainable habitat.  
462 INTERdisciplina, CIUDADES 2(2):281-304.

463 Ghosh R, Kansal A (2016) Water energy nexus in water supply and end use water infrastructure.  
464 National Seminar on Innovative Green Technologies for Sustainable Sanitation, Health and  
465 Environment. Poornima College of Engineering, Jaipur, India.

466 GNCTD (2006). Economic Survey of Delhi 2005-06. Directorate of Economics & Statistics.  
467 Government of National Capital Territory of Delhi,  
468 Delhi.[http://delhi.gov.in/wps/wcm/connect/DoIT\\_Planning/planning/economic+survey+of+dehli/](http://delhi.gov.in/wps/wcm/connect/DoIT_Planning/planning/economic+survey+of+dehli/content3/water+supply+and+sanitation)  
469 [content3/water+supply+and+sanitation](http://delhi.gov.in/wps/wcm/connect/DoIT_Planning/planning/economic+survey+of+dehli/content3/water+supply+and+sanitation). Accessed 26 September 2016

470 GNCTD (2010). Water Supply. In: State of Environment Report for Delhi, Department of  
471 Environment and Forests, Govt. of India, New Delhi.  
472 <http://www.indiaenvironmentportal.org.in/files/SoEDelhi2010.pdf>. Accessed 26 September 2016

473 GNCTD (2013). Human development report, Institute for Human Development, Government of  
474 National Capital Territory of Delhi, Delhi.  
475 [http://www.indiaenvironmentportal.org.in/files/file/delhi%20human%20development%20report%](http://www.indiaenvironmentportal.org.in/files/file/delhi%20human%20development%20report%202013.pdf)  
476 [202013.pdf](http://www.indiaenvironmentportal.org.in/files/file/delhi%20human%20development%20report%202013.pdf). Accessed 26 September 2016

477 GNCTD (2015). Economic Survey of Delhi 2014-15, Directorate of Economics & Statistics,  
478 Government of National Capital Territory of Delhi, Delhi.

479 <http://delhi.gov.in/wps/wcm/connect/16541d8048d8ebdea8e9f97a2b587979/ESD+2014-15+->  
480 [+Ch-](#)  
481 [13.pdf?MOD=AJPERES&lmod=519320373&CACHEID=16541d8048d8ebdea8e9f97a2b587979](#)  
482 . Accessed 26 September 2016

483 Govt. of Haryana (2012). Statistical abstract, Haryana 2010-11, Department of Economic and  
484 Statistical Analysis, Chandigarh, Haryana, India.[http://esaharyana.gov.in/Portals/0/statistical-](http://esaharyana.gov.in/Portals/0/statistical-abstract-2010-11.pdf)  
485 [abstract-2010-11.pdf](#). Accessed 19 September 2018

486 Habib I (1982) Agrarian economy. In: Raychaudhuri T, Irfan I (eds) The Cambridge History of  
487 India, Vol. I, Cambridge University Press, Cambridge, pp 48-75.

488 Hall PA, Taylor RCR (1996) Political science and the three new institutionalisms. Political  
489 Studies 44:936-957

490 Hardiman D (2002) Farming in the forest: the Dangs 1830-1992. In: Madan V (ed.) The village in  
491 India, Oxford readings in sociology and social anthropology, Oxford University Press, New Delhi

492 Kim YY, Lee KK, Sung I (2001) Urbanisation and the groundwater budget, Metropolitan Seoul  
493 Area, Korea. Hydrogeology Journal 9(4):401-412

494 Mann M (2007) Delhi's belly on the management of water, sewage and excreta in a changing  
495 urban environment during the nineteenth century. Studies in History 23(1):1-31.  
496 <https://doi.org/10.1177/025764300602300101>

497 Maria, A (2008) Urban water crisis in Delhi. Stakeholders responses and potential scenarios of  
498 evolution. Institut du développement durable et des relations internationales (IDDRI), France

499 Mehta VK, Goswami R, Benedict EK, Muddu S, Malghan D (2013) Social ecology of domestic  
500 water use in Bangalore. Economic and Political weekly 48(15):40-50

501 MoEF (2010). Integrated water resources management and water quality modelling of River  
502 Yamuna basin: draft final report. Yamuna action plan: phase II. National River Conservation

503 Directorate, Ministry of Environment and Forests, Government of India, New Delhi.  
504 [http://52.7.188.233/sites/default/files/DRAFT%20FINAL%20REPORT\\_YAP%20Phase%20II.pdf](http://52.7.188.233/sites/default/files/DRAFT%20FINAL%20REPORT_YAP%20Phase%20II.pdf)  
505 [f](#). Accessed 19 September 2016

506 MoUD (2013). Draft revised regional plan 2021 (Approved in 33rd Meeting of the NCR Planning  
507 Board held on 1<sup>st</sup> July 2013). National Capital Region Planning Board, Ministry of Urban  
508 Development, Govt. of India, New  
509 Delhi. [http://ncrpb.nic.in/pdf\\_files/Draft%20Revised%20Regional%20Plan%202021/4-in-1.pdf](http://ncrpb.nic.in/pdf_files/Draft%20Revised%20Regional%20Plan%202021/4-in-1.pdf).  
510 Accessed 19 October 2016

511 Newman PWG (1999) Sustainability and cities: extending the metabolism model. *Landscape and*  
512 *Urban Planning* 44(4):219-226

513 Onodera S, Saito M, Sawano M, Hosono T, Taniguchi M, Shimada J, Umezawa Y, Lubis RF,  
514 Buapeng S, Delinom R (2008). Effects of Intensive Urbanisation on the Intrusion of Shallow  
515 Groundwater into Deep Groundwater: Examples from Bangkok and Jakarta. *Science of The Total*  
516 *Environment* 404(2-3):401-410

517 Sengupta N (1985) Irrigation: traditional vs modern. *Economic and Political Weekly* 20(45/47):  
518 1919-1938.

519 Shah T (2009) Taming the anarchy: groundwater governance in South Asia. *Resources for Future*,  
520 Washington DC and International Water Management Institute, Colombo, Sri Lanka.

521 Sharma, D & Kansal A (2011). Water quality analysis of River Yamuna using water quality index  
522 in the national capital territory, India (2000–2009). *Applied Water Science* 1(3-4):147-157.

523 Shekhar S, Purohit RR, Kaushik YB (2006) Hydrogeological framework and groundwater  
524 management plan for NCT Delhi. Central Ground Water Board, New Delhi.  
525 <http://indiaenvironmentportal.org.in/files/Kaushik.pdf>. Accessed 26 September 2016

526 Sohail A, Balaban O, Doll CNH, Dreyfus M (2013) Delhi revisited. *Cities* 31:641–653  
527 <https://doi.org/10.1016/j.cities.2012.12.006>

528 Spear TGP, Gupta N, Sykes L (1994) *Delhi, its monuments and history*. Oxford University Press,  
529 New York Accessed 26 September 2016

530 Weisz H (2011) The probability of the improbable: society–nature coevolution.  
531 *Geografiska Annaler: Series B, Human Geography* 93(4):325–336. [https://doi.org/10.1111/j.1468-](https://doi.org/10.1111/j.1468-0467.2011.00386.x)  
532 [0467.2011.00386.x](https://doi.org/10.1111/j.1468-0467.2011.00386.x)

533 Wong THF, Brown RR (2009) The water sensitive city: principles for practice. *Water Science and*  
534 *Technology* 60:673-682

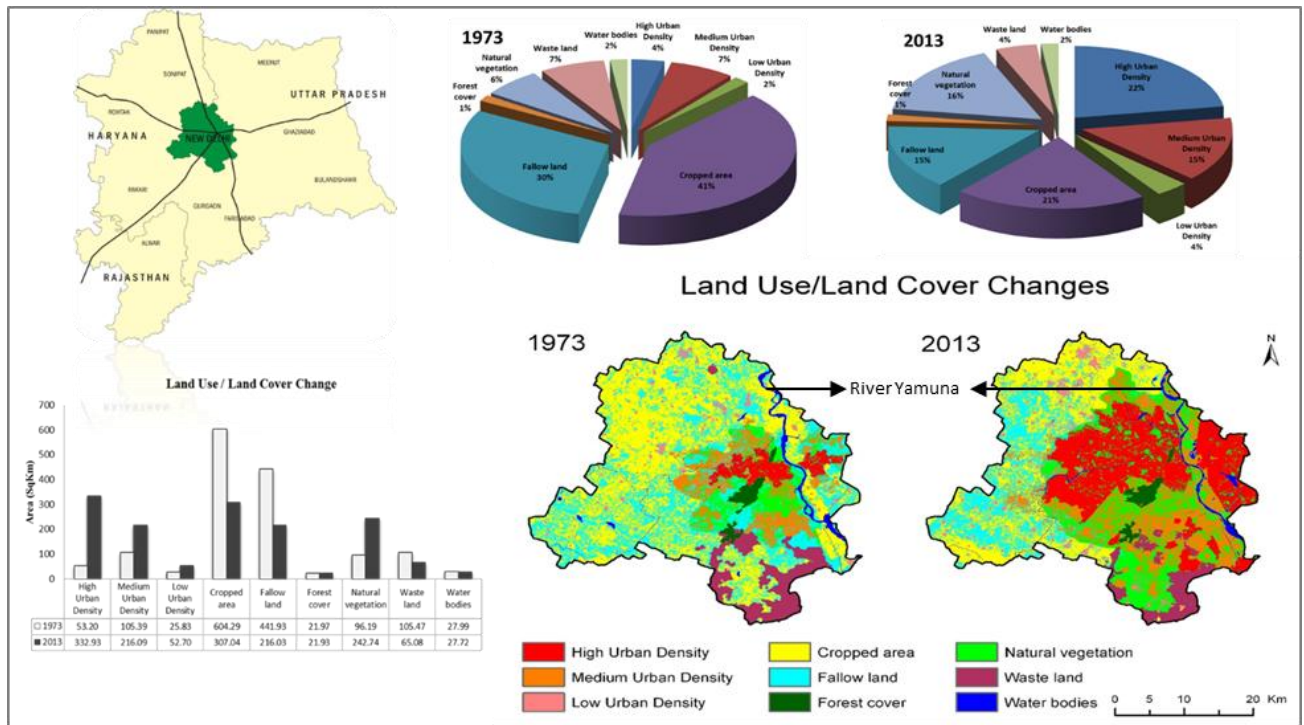
535

**Table 1 Annual groundwater development and end uses (million cubic metres) in Delhi: 2011 (CGWB 2011)**

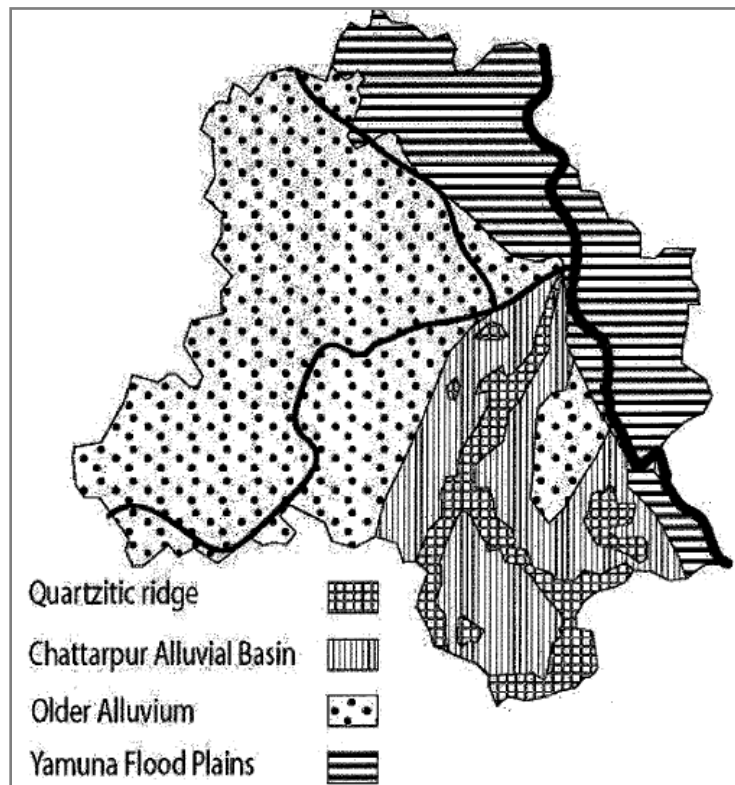
District	Recharge	Net availability	Gross Draft			Stage of development (%)
			Irrigation	Domestic and Industrial Uses	All uses	
Central	3.84	3.45	0.51	2.40	2.92	84.45
East Delhi	12.84	1.18	8.44	12.80	21.24	178.87
New Delhi	7.97	7.17	5.53	0.95	6.49	90.40
North-East	12.55	11.35	3.28	9.69	12.99	114.36
North-West	86.31	80.23	32.81	57.33	90.15	112.36
North	15.55	13.99	1.38	8.30	9.68	69.18
South-West	97.52	91.27	64.59	63.17	127.78	139.99
West	28.11	26.52	4.73	35.77	40.51	152.73
<b>Total</b>	<b>264.69</b>	<b>235.16</b>	<b>121.27</b>	<b>190.41</b>	<b>311.76</b>	—

**Table 2 Water works during the Colonial period (data compiled from archival sources)**

Year	Water works	Capacity (million litres per day)	Source	Technology	Population (million)
1890	Chandrawal	4.5	Wells sunk along the river		0.19
1912	-	15	River Yamuna	Settling tanks and slow sand filters	0.23
1921	Wazirabad raw water pumping station; water carried to Chandrawal	32	-	-	-
1948	Works gradually increasing	159	-	-	-



**Fig.1** Land-use pattern in Delhi (1973–2013) (Source: Landsat image compilation)



**Fig. 2** Main geological formations of Delhi (Source: Maria 2008)