



Delhi Sultanate Waterworks

Ancient network of water harvesting
structures in Delhi, India.

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Figure 1 Typical Baoli stepwell atmosphere.

Context.

Delhi is located in the Northern part of India between 28.7041 N latitudes and 77.1025 E longitude. It occupies an area of 1,484 sq. km. and is continuously inhabited since the 6th century BCE. Through most of its history Delhi has served as capital of various kingdoms, most notably the Delhi Sultanate and Maughal empire.

Two prominent features of the geography of Delhi are the Yamuna floodplains and the Delhi ridge. The ridge is the northern extension of the ancient Aravalli range covering an area of about 35 km and reaching height of 318 m (1,043 ft), it is a dominant feature of the region.

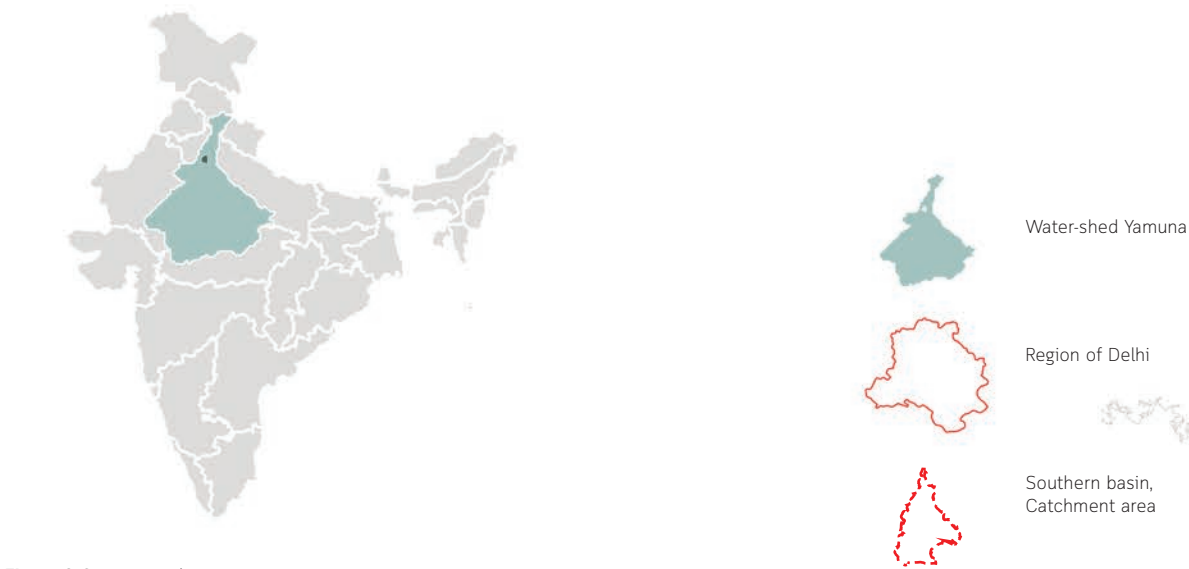


Figure 2 Country scale map

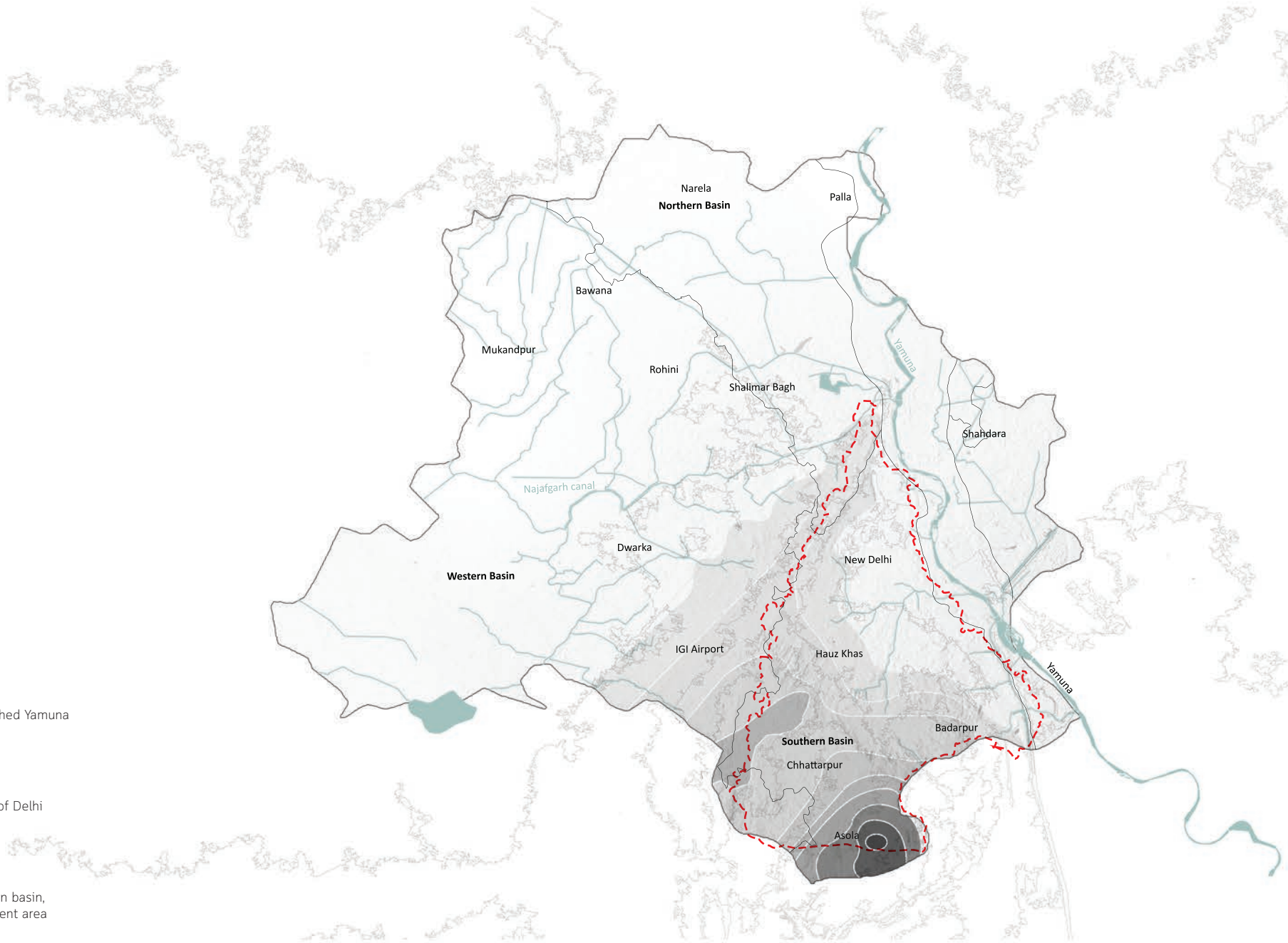


Figure 3 City scale map: the traditional water system of the bund baoli and hauz starting from the Delhi sultanate is chosen for study.

Sultanate Waterworks.

Delhi's urban waterworks developed in early thirteenth century. They took the following main forms of Hauz (water tank), baoli (stepwell) and bund (embankment). Collectively these small structures served the sultanate capitals of South Western Delhi. As with other ancient and medieval water systems, they were incremental and coordinated.

Urban lakes, tanks and reservoirs were sited in gently sloping areas adjacent to hillside water control structures.

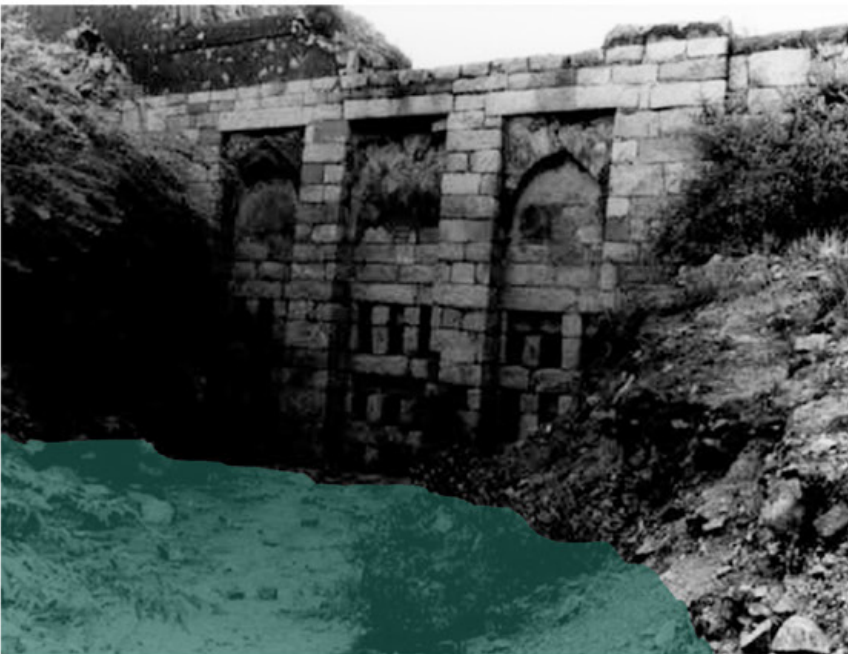
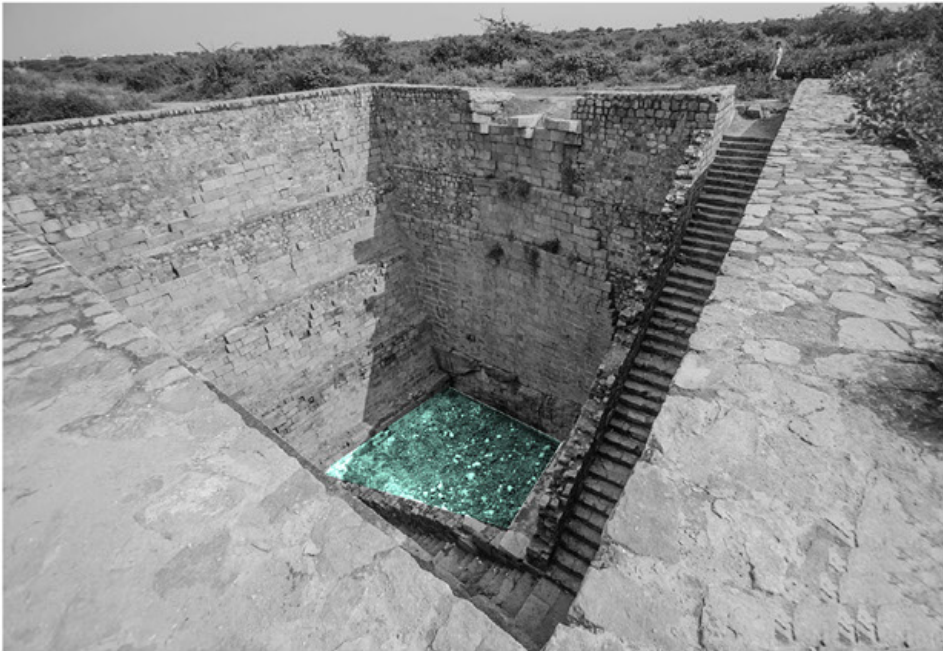


Figure 4 Historical photo of Satpulla embankment or bund.
Figure 5 Historical photo of Baoli at Tughlaqabad.
Figure 6 Historical photo of Hauz-i-khas lake (water tank).
Figure 7 Historical photo of Sluice gate at Tughlaqabad.

Climate.

Climate zone: Overlap of Humid Sub-tropical & Semi-arid

Sub climate: humid, dry & semi-dry

Climate and weather averages

High t°: 45°C
Low t°: 6°C
Mean t°: 29°C
Precipitation: 47.5 mm
Humidity: 63 %
Dew Point: 17.C
Wind: 6 km/hr
Pressure: 1008 mbar
Annual rainfall: 693 mm

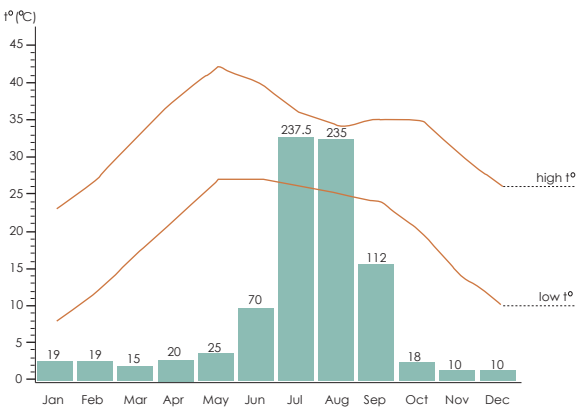


Figure 8 Temperature and precipitation graph.

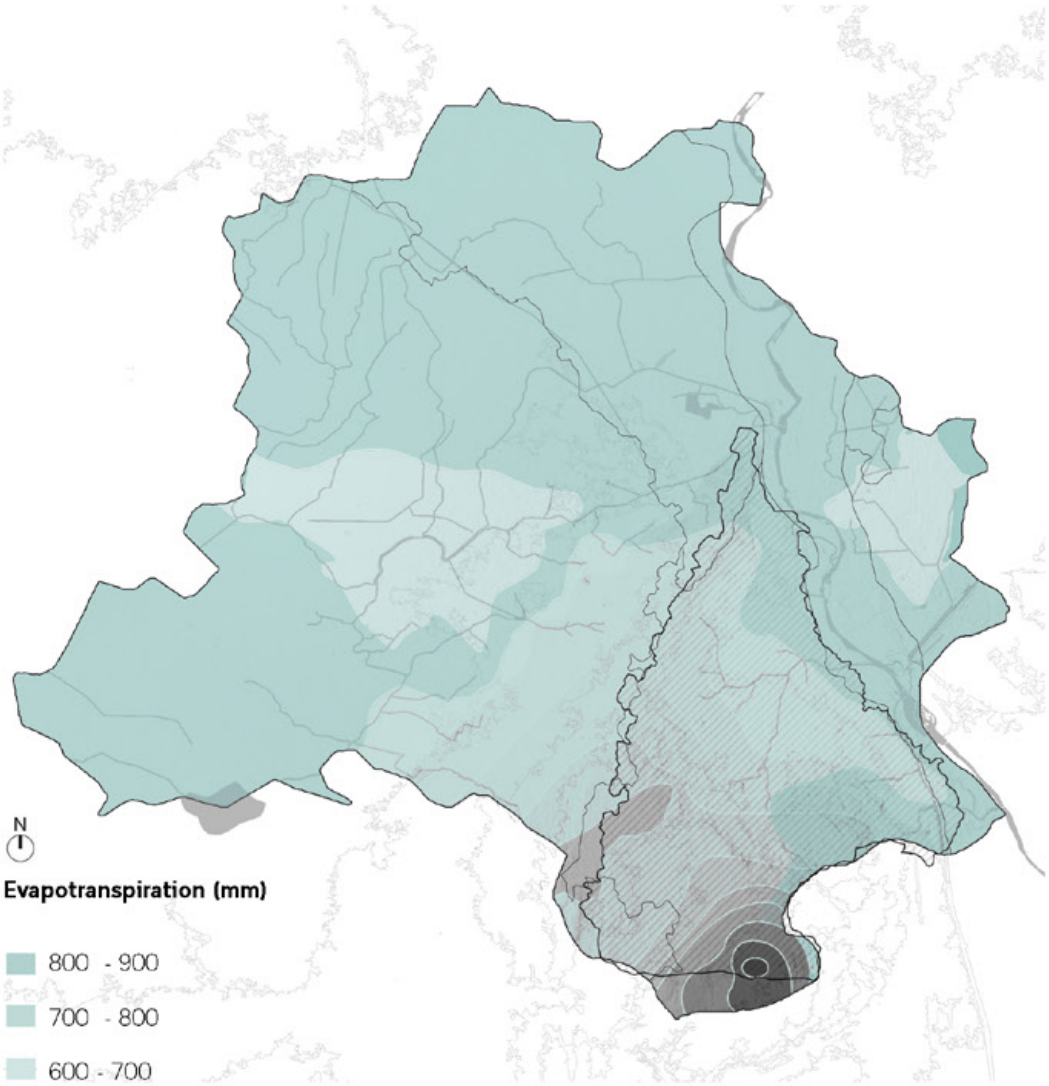


Figure 9 Evapotranspiration map

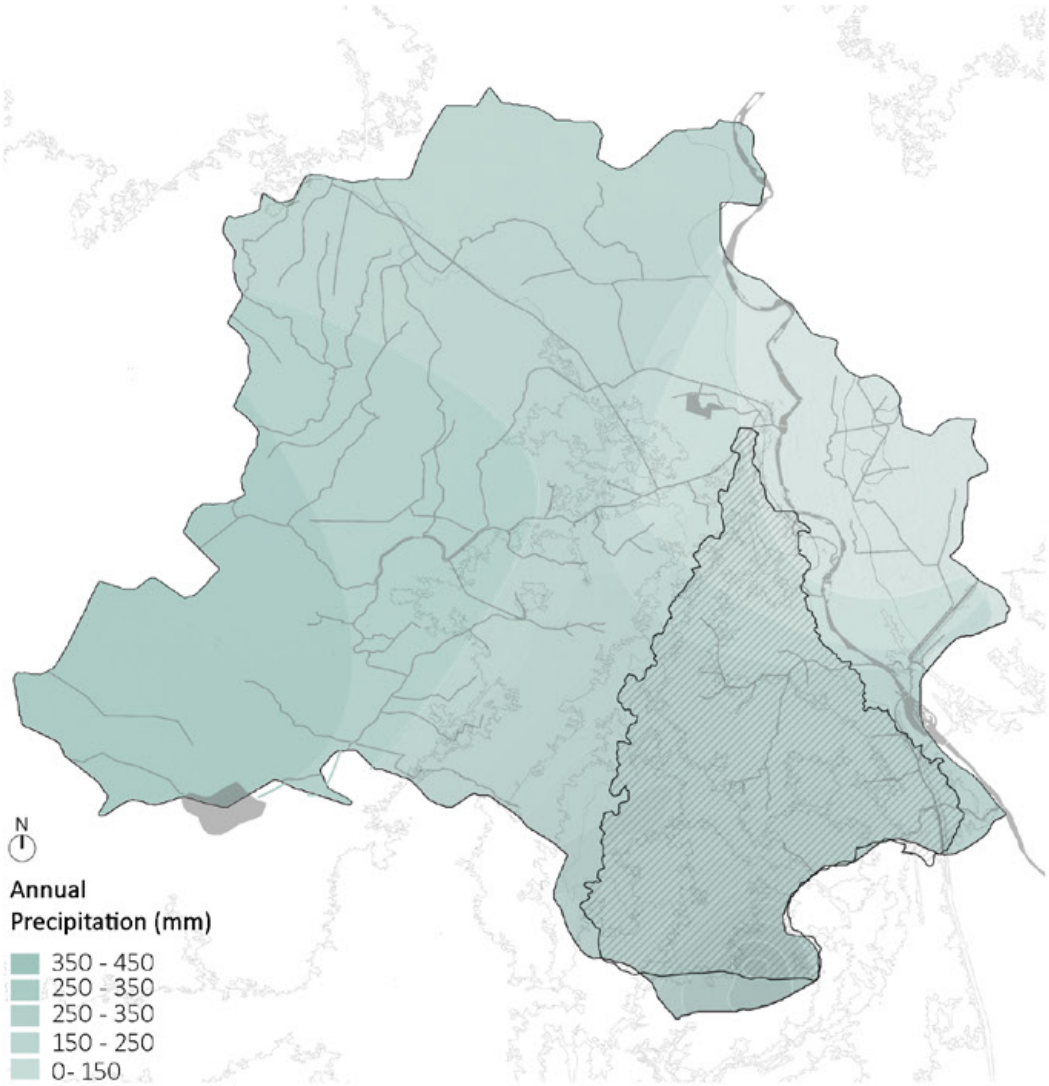


Figure 10 Annual Precipitation map

Catchment Area.

The contours of the physical landscape of Delhi as we see today, including its flora and fauna are very different from what they were thousands of years ago. The Delhi ridge as shown in the figure constitute the Northernmost extensions of the Aravalli hills, the oldest mountains in India formed hundreds of million years ago. They enter Delhi from the South-West running through the city in a North-east direction. Today the height of the rocky Delhi ridge ranges between 2.5 m to 90 m above floodplain in North and South Delhi, in ancient times it would have been much higher (S. Upinder, 2006).

Most Sultanate cities and waterworks aligned themselves along this ridge to capture its runoff. The junction between the central and the Southern ridge became the preferred location for Sultanate urbanization and water control. Delhi sultanate waterworks developed during the early 13th century. They took three main forms - the bund network (embankment), hauz (water tank), and baoli (stepwell). These reflect the main strategies of the Delhi Sultanate water works - the bund network helps in directing and capturing the runoff from the ridge, the hauz stores the surplus monsoon surface water runoff and recharges ground water while the baolis tap into the shallow ground water along with storing rainwater.

The bunds define a network of 25 water structures along 40 miles of the ridge as shown in the figure. They harnessed rain fed rivulets or sheet drainage along the slopes of Delhi ridge to create perennial reservoirs, for use in the dry winter months.

Thus, the first bund sequence on either side of the ridge entrapped rain runoff and the second sequence controlled and channeled water to city reservoirs, defense moats and irrigation canals. This 40 mile network with over 15 rivulets and 60 miles of running water was in continuous use for over two centuries.

Delhi's Streams or Nallahs

In the triangle created or the ridge, Delhi's alluvial plain is watered by a number of seasonal or perennial nallahs (canals). These *nallahs* flow down the Aravalli hills (ridge) slope through eroded gullies into the Yamuna river.

East flowing streams were tapped to feed large, lined lakes such as Anangtal, Hauz-i-Shamsi, Hauz-i-rani, and hauz-i-khas which sustained the cities of Anangpur, Mehrauli, Jahanpanah and Siri. Despite the presence of river Yamuna most of Delhi's population depended on underground or stored water until the arrival of piped water supply in the late nineteenth century. Water tables recharged by *nallahs* allowed a number of baolis (large stepwells built with several levels).

The quality of groundwater shows wide variations with depth, at most locations water quality deteriorates with depth. Canals and streams play an important role in sustaining fresh water aquifers in Delhi's upper strata of water-bearing soil.

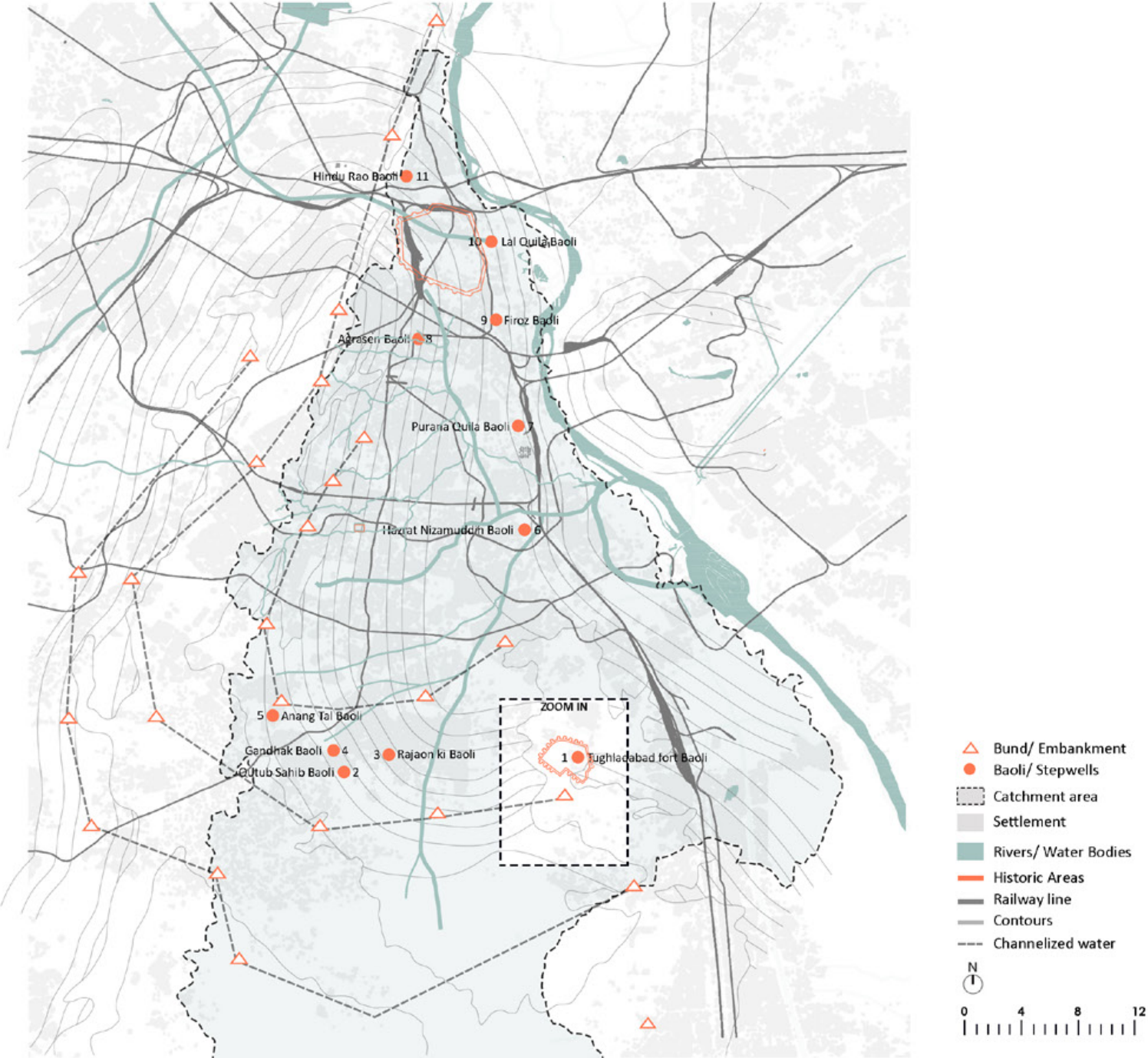


Figure 11 Bund network along Ridge.

Tughlaqabad Fort Water system.

Stepwells, water channels, embankments and canals.

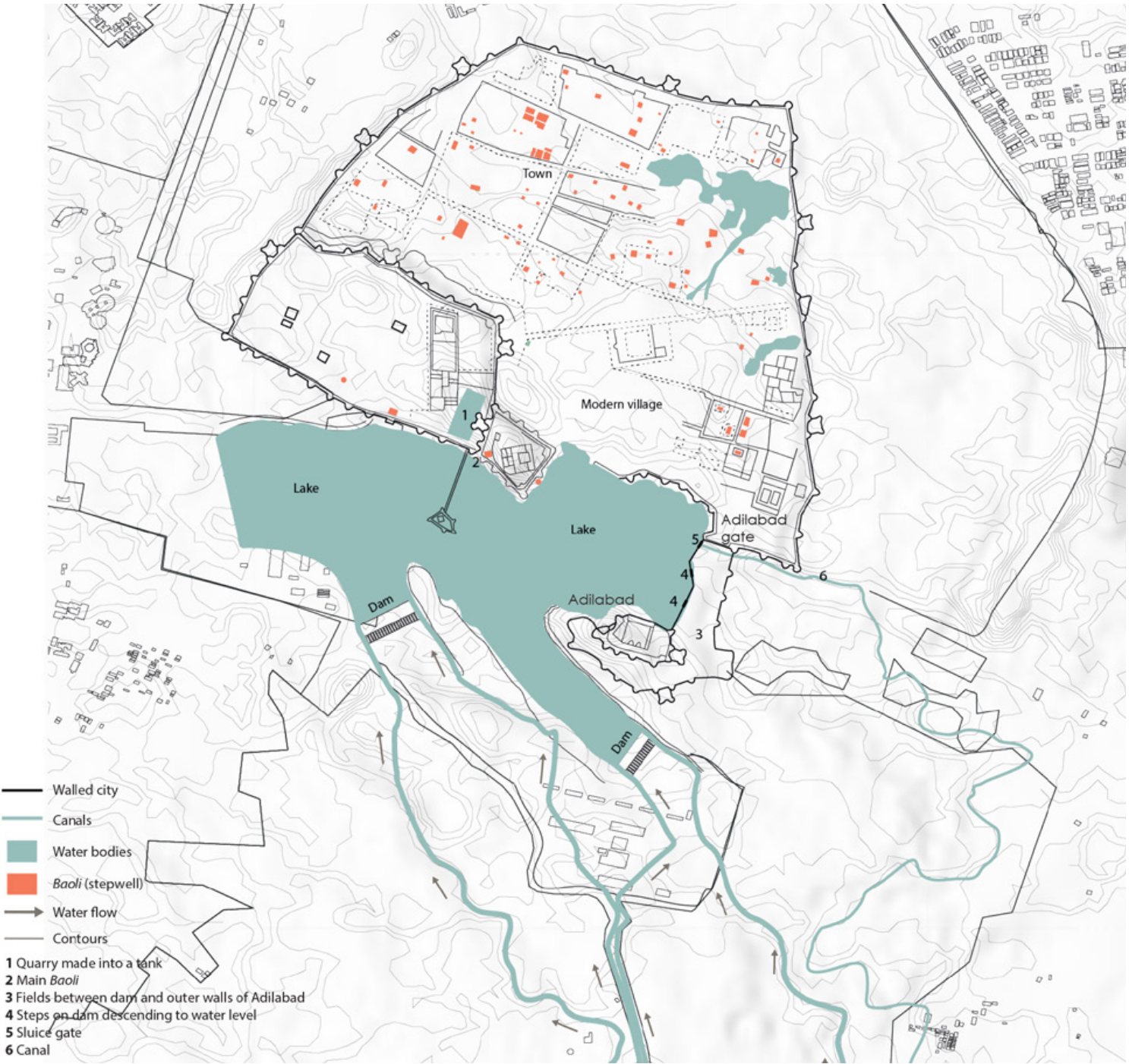
During the period of Delhi Sultanate, new cities were founded at strategic locations where water was the most important factor in their siting - its collection, storage and distribution predominated the settlement pattern. Tughlaqabad fort was built by Ghiyas-ud-din Tughlaq, located on a hill surrounded by a basin.

The fort was planned based on the contours of the site to form an irregular trapezium. The palace was quarried from the site itself and the quarries were subsequently used as moats and reservoirs. The surroundings of Tughlaqabad was transformed into a large lake with the help of waterworks (bunds) which collected water from the ridge. Tughlaqabad had 3 huge baolis and several wells for water supply as highlighted in the illustration.

Creating a lake at the South of the Tughlaqabad fort was a challenge since the site was not close to river Yamuna and in order to bring the river water up to the hilltop where the fort was located, water had to be pumped up by means of a canal which was considered impractical. The lake was therefore dependent on local streams and monsoon floodwater which was channeled into a depression at the south of the town where the water was regulated by means of several dams and a sluice gate controlling the outlet which flowed into a canal. The dams are constructed as simple earth embankments lined on the lake side with blocks of stone. This stretch is around 200m long and runs between Adilabad and Tughlaqabad.



Figure 12 View of Southern end of retaining wall of the dam between Adilabad and Tughlaqabad seen from lakeside showing steps leading to water.
Figure 13 View of Tughlaqabad lake surrounding tomb of Ghiyas-ud-din Tughlaq.
Figure 14 Tughlaqabad town water system plan.



Tughlaqabad Fort Baoli.

Stepwells, water channels and embankments.

A main water feature in the Tughlaqabad fort is a deep stepped reservoir (*baoli*). The baoli is roughly rectangular about 20 x 18 m. Towards the east side we see the remains of the steps which gave access to the water, the baoli is approximately over 16m deep. Towards the North we see the stone brackets for wheel or pulley are preserved, extending over the water. This apparatus was used for withdrawing large quantities of water for irrigation and it is likely that this baoli was a major source of water for farmlands, while drinking water was provided elsewhere.

It was a usual practice during this period to construct forts on rocky hillsides to excavate wells down to the water table to ensure permanent supply of potable water.

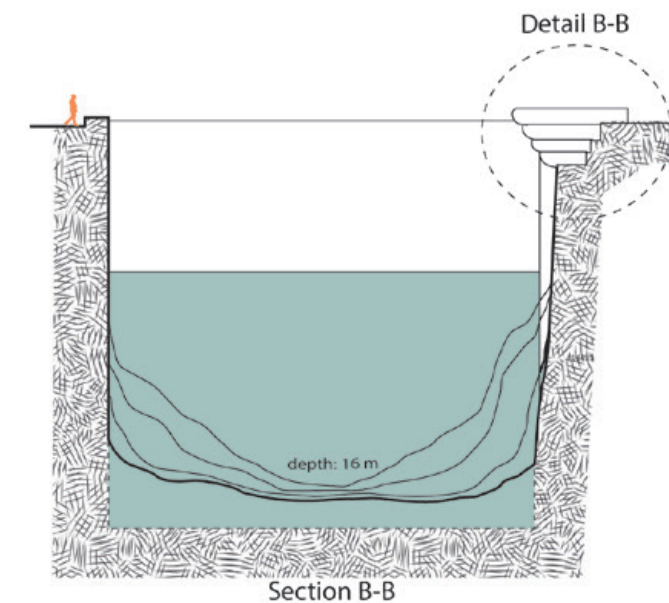
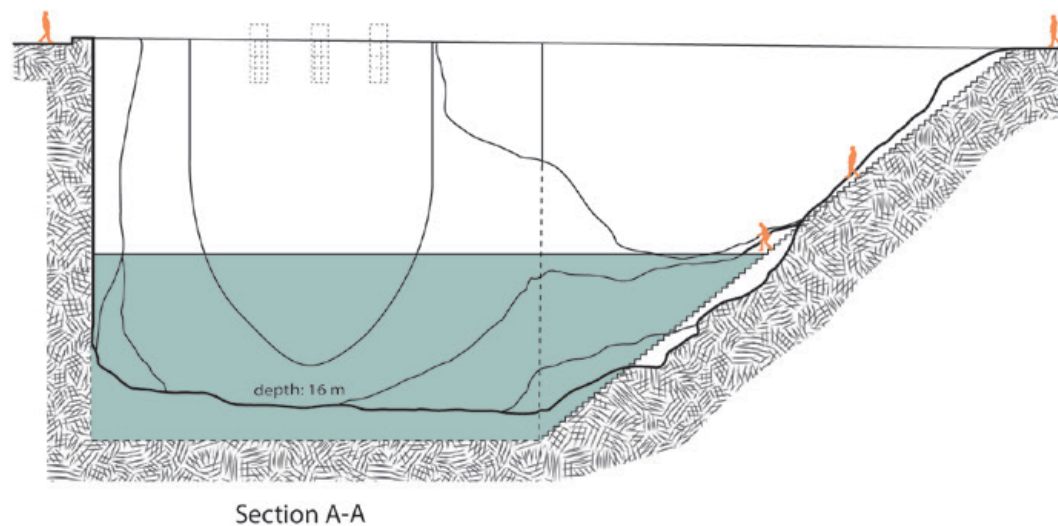
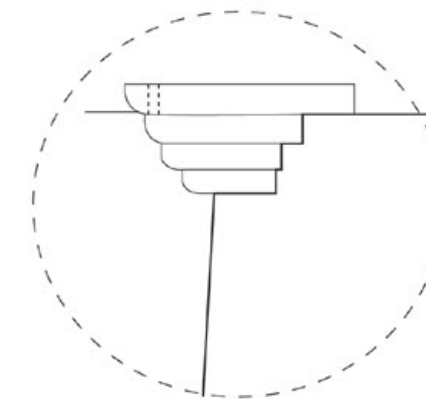
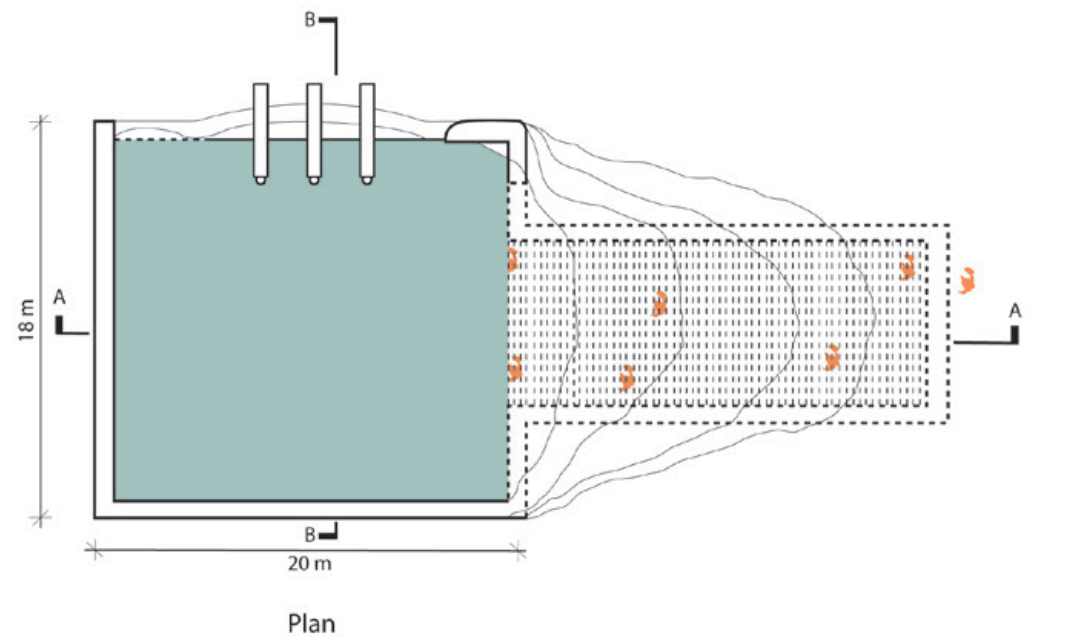


Figure 15 Baoli typology analysis and details. Key plan (above).

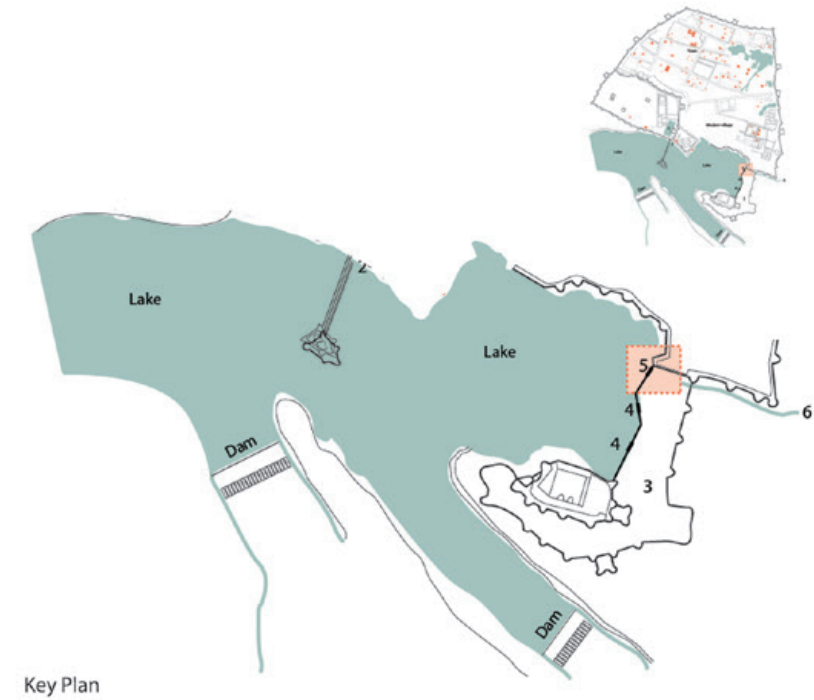
Tughlaqabad Fort bund.

Stepwells, water channels and embankments.

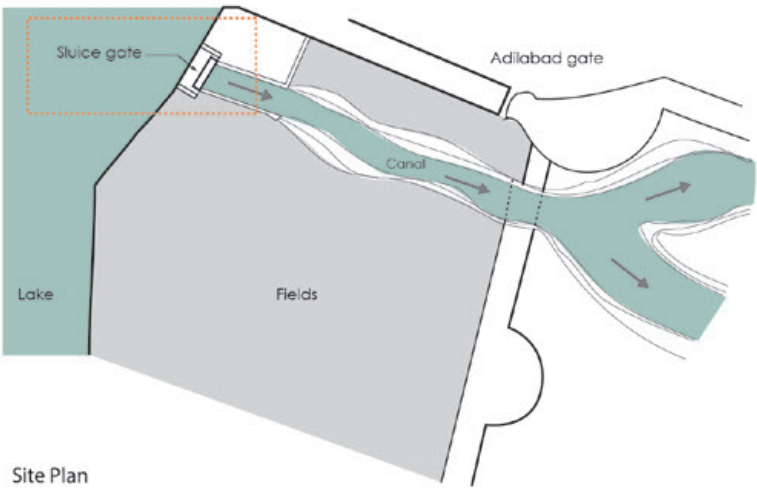
Another example of the ingenious water structure is the sluice gate, controlling the level of water in the lake water south of the town of Tughlaqabad. The water work was a simple device which could be operated by an unskilled person - an uncomplicated structure with a sophisticated design.

The structure opens to a canal with stone lined walls which runs between the dam and the outer fortification walls of Adilabad. The canal was further divided into two branches, one taking the water to the irrigated fields and the other leading to moat around town wall.

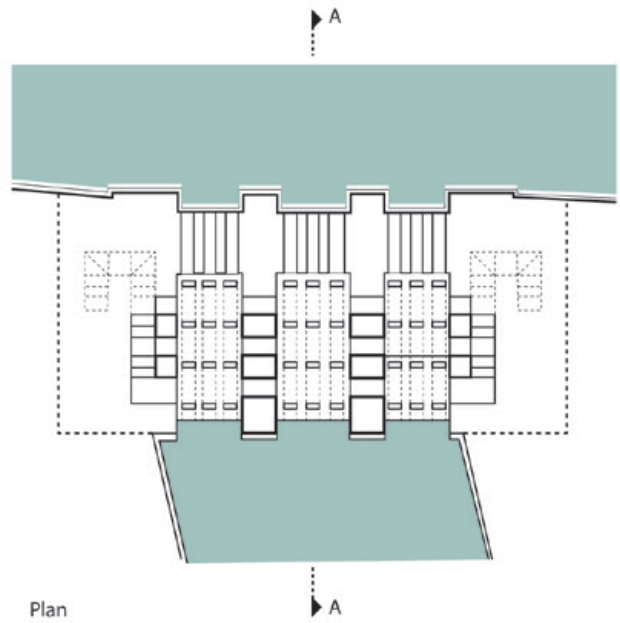
The sluice gate itself consists of three arches, each containing twelve small sluices at four levels, three sluices at each level. The western side of the arch facing the lake is walled up with massive stones and the inlet of the sluices are small rectangular canals, which appear as small apertures on lake side. Inside the arches, the four levels of sluices are stacked in a step form with eight steps. The lower step is for standing on and the upper one has the slots. Each slot measured 35x10 cm wide and 75 cm deep to house wooden shutters which controlled the flow of water. Access to these steps is provided via two sets of stairs built into the piers at either end of the structure.



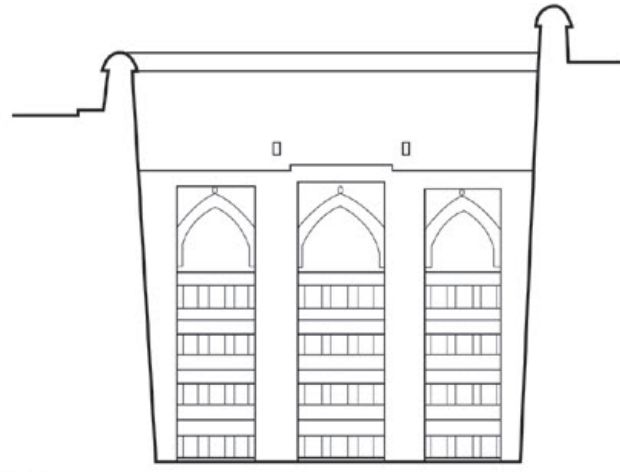
Key Plan



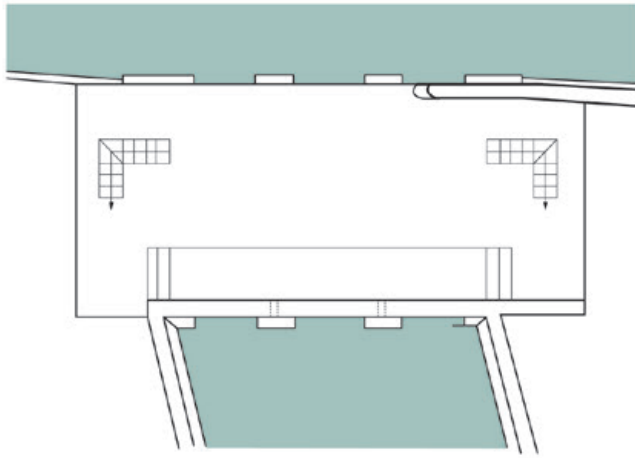
Site Plan



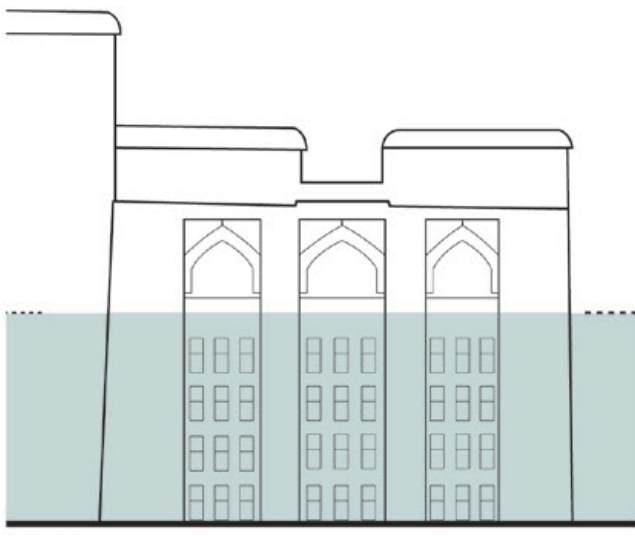
Plan



Elevation A



Roof level plan



Elevation B

Figure 16 The sluice gate and Dam south of Tughlaqabad.
Figure 17 Sluice gate site plan.
Figure 18 Sluice gate plan.
Figure 19 Sluice gate plan at roof level.
Figure 20 Sluice gate view from lake looking Eastwards.
Figure 21 Sluice gate elevation lake side looking eastwards.

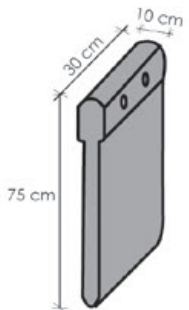
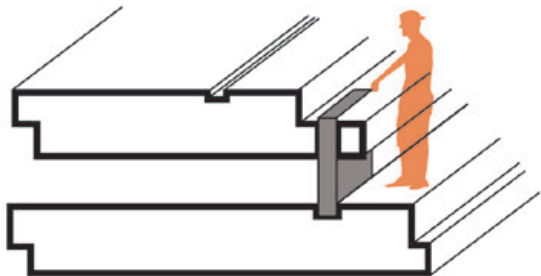
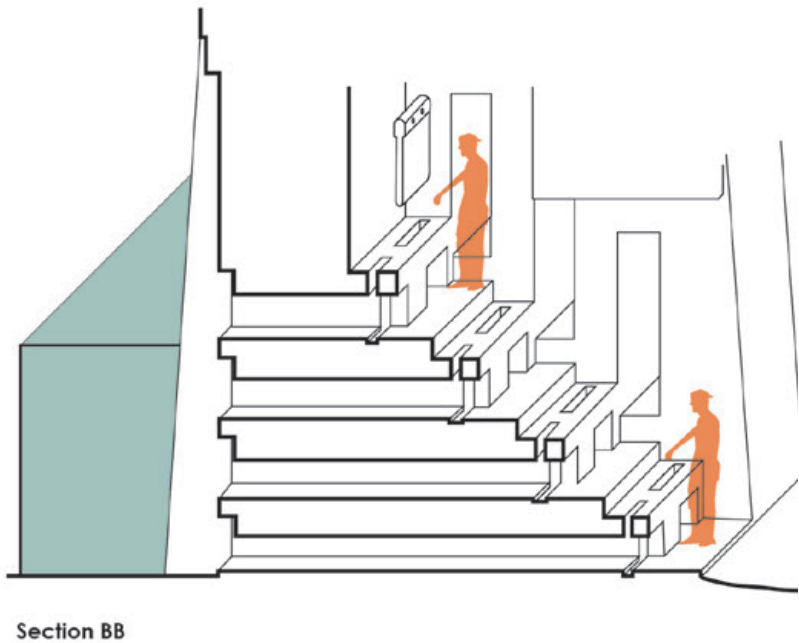
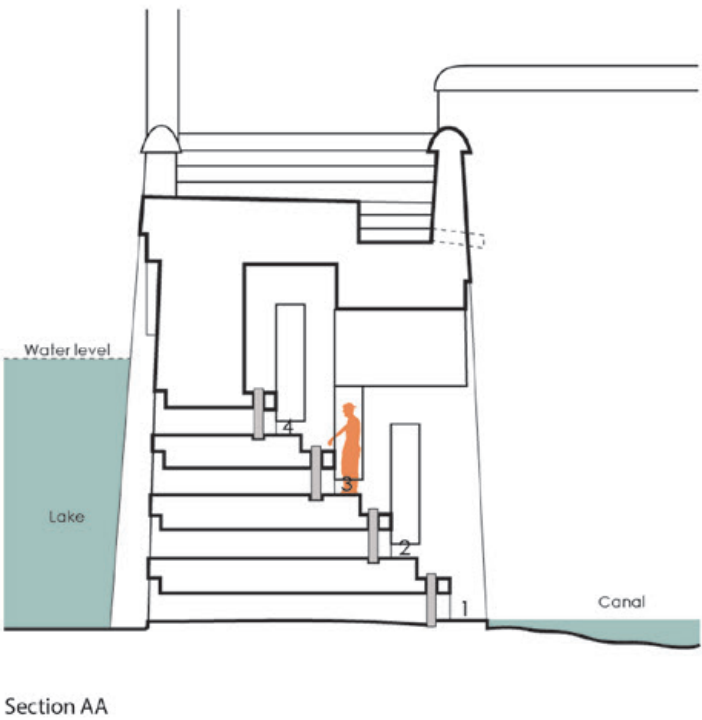
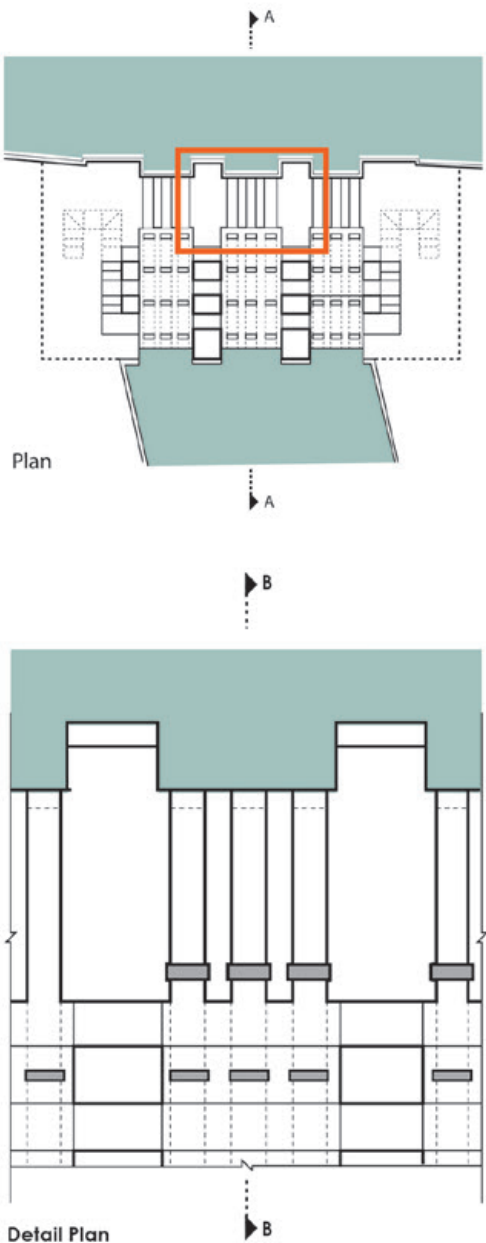
Functioning

The operation of the sluice gate was simple and could be carried out by a single person, who first went down to the lowest level to insert small shutters into slots of the lowest nine canals. The water of the lake would then rise up to the next level and the same process would be repeated at this level. In the case of heavy monsoon, a single person would remove the shutter of the upper level and excess water would gush out as small waterfall through the arches into the canal.

The site of the lake is now used for cultivation. The design concept of this sluice gate, to retain and control the water of a relatively large lake by a very simple method and no use of power was a great achievement of its time.



Figure 22 Sluice gate elevation dam side looking westwards
Figure 23 Sluice gate plan
Figure 24 Detail plan of central slots
Figure 25 Section AA through central arch showing four levels of sluices and highest water level
Figure 26 Perspective section showing sluice functioning
Figure 27 Showing function of sluice with help of wooden shutter
Figure 28 Wooden shutter detail



Circularity.

Delhi Sultanate waterworks or harvesting structures were well coordinated with one another, each structure supporting the existence of the other. The bunds helped in controlling the rainwater runoff from the ridge which was further directed to feed large lakes or royal tanks called hauz. The baoli were recharged by the rainwater and helped in tapping the inaccessible ground water with the help of steps. These water storage structures aided water evaporation and condensation into the atmosphere which again would be captured in the ridge landscape during monsoon.

Today, these water structures lie in a dilapidated state with some having been restored for heritage and tourism purposes. Thus, it is important to learn from past methods of harvesting water to overcome the hydrological problems Delhi is facing today, despite having a combination of river and ridge landscape as part of its natural terrain.

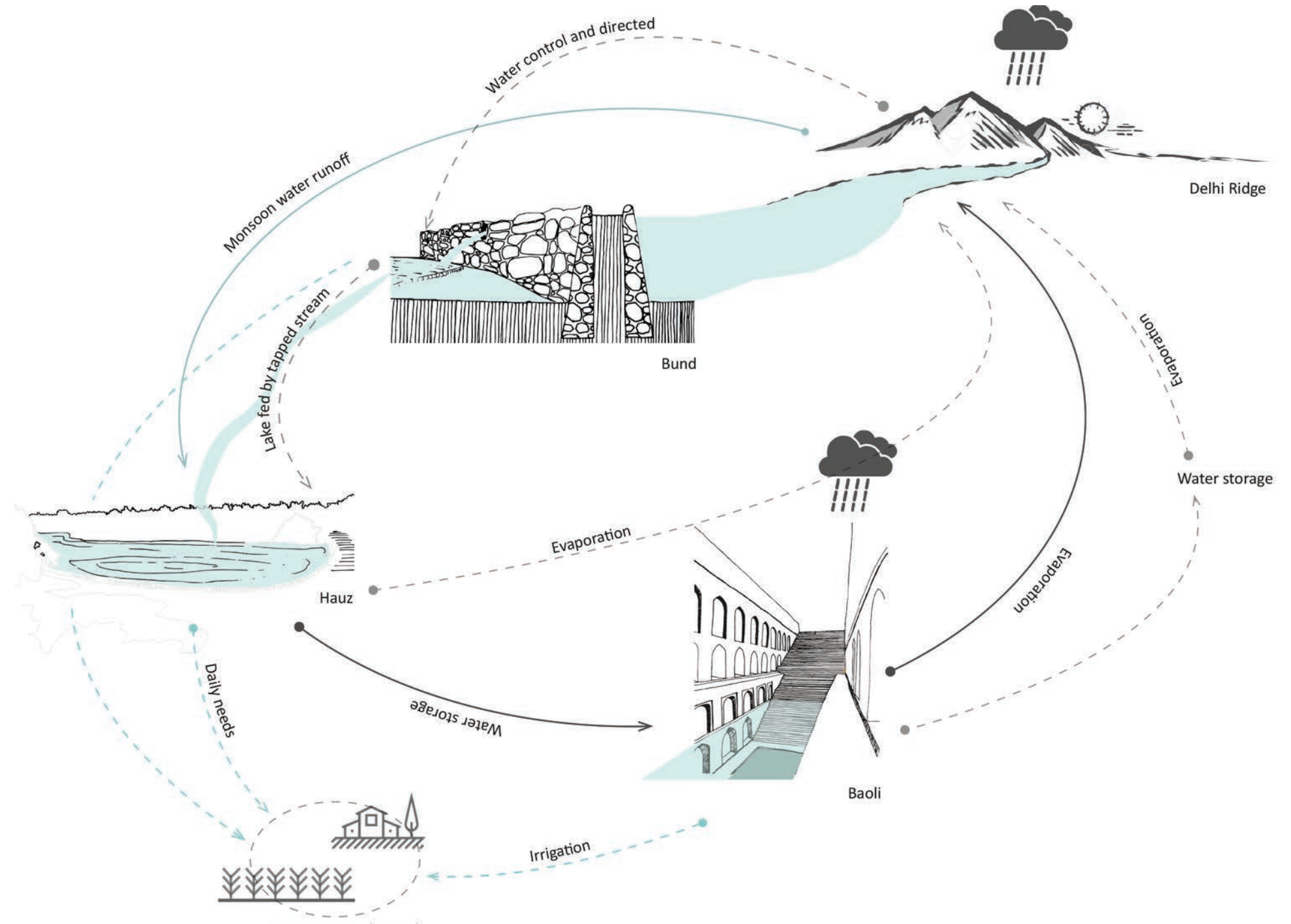


Figure 29 Circularity of the system.

Conclusion.

The purpose of this research is to study the ancient or medieval water management system during the period of Sultanate Delhi and their understanding of the region's terrain to harvest water through various water work structures. The study focuses on the urban water management of Sultanate Delhi, where most of the cities were located on Delhi's hilly ridge terrain from where rain water was controlled and channelized. Being in a humid sub tropical and semi arid zone, the frequency of water shortages and droughts is high. However 'Ancient civilizations grasped the complex reciprocities of natural systems and created an infrastructure that was modeled on, and worked in tandem with those reciprocities' (Brown and Stigge, 2017).

The Delhi watershed comprised of ridge,river and plains, its constellation of channels, canals, bridges and tanks served all important for conserving the city. Delhi Sultanate waterworks influenced subsequent eras of urban development and conservation.

The historical water works of Sultanate Delhi have urban-scale significance. With efforts to recover the dying wisdom of traditional water harvesting systems which have expanding meaning and utility. Many of these urban historical waterworks are at a risk of further deterioration along with the degraded canals of the city. However, their imposing architecture continue to persist in the city's landscape.

Architectural values - The structural elements and materials used in the system came from the knowledge of traditional or vernacular construction techniques which adapt to the climate and lithology of the region. The smaller bunds or embankments were constructed of Earth, however large dams were built of rubble masonry or wood which were easily available local materials.

Strategic values - During this period Delhi's terrain was used smartly to gain maximum profit with the minimum resources by taking advantage of Delhi's hilly ridge landscape where most of the waterworks were situated. This landscape provided all resources like maximum rain, groundwater in order to harvest water efficiently without using any source of energy or power.

Values of Sustainability - The project shows the sustainability of the water system, the natural and human resources have been carefully used such as taking advantage of the natural flow of water from higher terrain to lower. This water captured was used for both the purpose of meeting the drinking water needs of Delhi and also the irrigation needs for agriculture. These also served the purpose of rainwater storage or rainwater harvesting. Most of the elements performed more than double the function.

Ethnographic and Identity values - The Sultanate period is known for its famous tank system (hauz), another very important structure of water management the period is known for its the network of stepwells or baolis. Most of Sultanate waterworks were of secular character whereby anyone could draw water from them and were mainly used for common people's water needs and requirements.

Landscape values - Water played an important role in the location of most of Sultanate cities and settlements. This whole system of tank, baolis and wells manages water supply to whole complex of settlements during medieval history period of Delhi. Moreover, the system was planned to function as a decentralized runoff harvesting such that silting of a tank at one location did not affect the others. The homogeneity of the system avoided all post-harvesting social problems of water management that are involved in water management.

Lessons to learn - The study shows that Delhi was not always short of water. It was ensured that Delhi had enough water from its wells, baolis, water tanks, canals, ridge and the Yamuna. The ancient rulers of Delhi had an intricately worked out water conservation and distribution system along the Southern ridge ,the tail end of the Aravalli hills. They realized the importance of water security and made an elaborate system of bunds across gullies to capture water off this rocky landscape.

In present times, these water structures lie in a dilapidated state, some have been restored to their past glory but only for heritage purposes. Most of these sites have been taken over by the powerful and the rich to make their houses and other urban infrastructure, decimating the cities water resources.

Today, most of the water needs of the citizens of Delhi are met by exploiting its ground water resource by continuous extraction of ground water through private tube-wells. If these dilapidated water structures of Delhi are restored and protected they can still contribute to some of the city's water requirements. Thus, it is important to learn how Delhi's historical rulers made use of its terrain of ridge and river landscape to ensure supply of water to its citizens without exploiting and wasting its resources.



Figure 30 Conserved baoli in Delhi, India

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Project 5 - Delhi Sultanate Waterworks

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Figure 5 [Image] Retrieved from https://commons.m.wikimedia.org/wiki/File:Tuglagbad_Baoli_1.jpg

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Figure 10 Annual Precipitation map [Figure]. Drawn by Author

Figure 11 Bund Network along Ridge [Figure]. Drawn by author. Retrieved from <https://dspace.mit.edu/handle/1721.1/28802>

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Figure 29 Circularity of the system [Figure] Drawn by Author

Figure 30 Conserved baoli in Delhi, India [Image] Retrieved from <https://archnet.org/sites/6400>

