INDIA'S WATER HUSBANDRY: DESIGN FOR CHANGE

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ABSTRACT: Changing weather patterns, combined with population growth and demographic shifts, have begun to impact the shape and structure of India's traditional water landscapes. Water scarcity as well as superabundance can be linked to natural weather events such as cloudbursts, glacial lake outburst floods (GLOFs), and drought, as well as to human causes such as development pressures. Considering as a backdrop the intertwined issues of urban development and climate change, this paper establishes a taxonomy of water management systems found in India and charts each system's capacity for change. Both traditional and current systems are identified, in an effort to better understand the varied tools and techniques used for harnessing, regulating, and conserving water in South Asia. Water management systems featured in this paper include the talaab, the ghat, the canal, bunds and tanks, the stepwell, the artificial glacier, the ice stupa and the snow barrier band. This research draws upon a combination of field study and archival document studies, conducted in India from 2012-2016. As a survey of water management strategies, this paper makes a connection between design practice and water husbandry, acknowledging the need for reference material that could support adaptive design thinking in the face of environmental change.

KEYWORDS: Water management, India, infrastructure design, landscape architecture, design for climate change adaptation.

INTRODUCTION

India is a country in South Asia known for its sheer size and diverse geography (Figure 1). The subcontinent has a long history of human-centered development, with unique site-specific approaches to irrigation infrastructure stretching back to ancient times. Because of this history, as well as the country's rich cultural and spatial influences, water management practices are both varied and time-tested (Briscoe & Malik, 2006). India's breadth of design thinking around water husbandry, as well as experience with a wide variety of design strategies, offers landscape architects and urban designers an important reference collection of proven lessons and ideas.

Figure 1: Map of India. Source: Author

This paper surveys just eight of these water management strategies, all of which are currently found in India. Included in this study are the talaab, the ghat, the stepwell, the canal, bunds and tanks, the artificial glacier, the ice stupa and the snow barrier band. In so doing, the survey provides a taxonomy of different types of designs for water management in India, links each strategy to a series of attributes and design conditions, and highlights opportunities for change or adaptation. This comparative organization helps to make the opportunities and constraints associated with these different water management approaches clear, and could potentially help designers to adopt components of such systems as they work in other contexts.

BACKGROUND

The 'improved' water management system used in Western contexts consists of a wide variety of design responses, many of which are entirely invisible to the people who rely upon that water (Kinkade-Levario 2007). By placing water catchment, drainage, and delivery mechanisms below ground, and sourcing water from enclosed or otherwise secured sites, municipalities can effectively control, maintain and regulate water resources. But this concealed infrastructure also has the concomitant effect of severing people's physical and psychological ties to their own water resources (ibid). Without a visual appreciation for the processes of water collection, purification, conveyance, and disposal, people served by underground municipal water services lack strong connections to hydrological landscapes and processes (Rossano 2015). In obscuring hydrological systems there is a missed opportunity for improved water literacy and environmental stewardship; in these situations people are more likely to overuse, undervalue, and pollute water held in the commons (Ostrom et al. 1999, Orff 2016).

The disconnect between resource stewardship and environmental visibility may even be exacerbated by the twin pressures of climate change and urban development (Sarté & Stipisic 2016). In this context, opportunities for additional co-benefits, especially, may be unrealized. According to architectural educator Ila Berman, "By insisting on the clear legibility of our infrastructural systems, while simultaneously assuming the limitlessness of the environments we have exploited, we have largely disregarded the vast impacts of these systems on a broader and more nuanced ecology" (2014). As water becomes a scarcity in some places, and a flooding threat in others, the visibility of this resource could serve as an ever-present reminder, helping humans to both mitigate and adapt to changing conditions (Clouse & Lamb, 2017). Invisible hydrological processes, on the other hand, may effectively camouflage environmental risk while decoupling human behavior from associated hydrological impacts.

In India, many villages, towns, and even cities have a vibrant physical relationship with their own water husbandry. Water in this context is a form of the commons, and the spaces of water management may also serve as valuable sites for social, cultural, and religious engagement, as well as recreation (Nawre 2013). These multifunctional spaces reveal co-benefits that help residents develop personal relationships with their hydrological landscapes, in turn potentially improving environmental awareness as well as quality of life factors (Silveirinha de Oliveira, & Ward Thompson, 2015).

By making water management processes visible, people can easily see the effects of pollution, or track drought, or recognize relative risk conditions (Ludy & Kondolf 2012, Rohrmann 1994). Also, when individuals participate in the governance of a shared space, such as water management infrastructure held in the commons, they are more likely to also assert some ownership over that space, which may benefit long-term maintenance and land stewardship (Ostrom et al. 1999). The shared water resources of a community can be held underground---invisible---or above ground---in full view---and the outcomes of this decision have far-reaching implications for both environmental health and human experience. The water management strategies explored in this paper help to demonstrate that visibility and accessibility are central features of the adaptive and multifunctional co-benefits found in Indian water spaces.

METHODS

This paper began as a survey of water management strategies in India, with expansive if not comprehensive representation of different approaches from across the subcontinent. Strategies were specifically selected because of their potential to inform the topics of climate adaptation and a multi-functional design approach. In addition, it was important to find examples that addressed both conditions of drought and flood, scarcity and surfeit. While most of the systems studied contribute primarily to agricultural irrigation, design strategies were also selected to represent other types of water use.

Field research was conducted during the course of the past four years, which included visits to many of these water management sites, and where photographs, drawings and maps helped to produce an understanding of the characteristics and working components of each system. In addition to this work, historical photographs and records relating to some of the water management strategies helped to fill in additional information, particularly for the classification structure that was developed. In this initial research phase, the tables of attributes, co-benefits, adaptive potential and operational qualities were constructed in such a way as to compare widely divergent case studies under a common system of terms, areas of impact, and features. In so doing, the composite pieces of each water management type begin to show similarities and differences in a readable and succinct format. Additional studies might address more nuanced design responses in this manner, or perhaps conduct interviews for a better understanding of human responses to these design ideas.

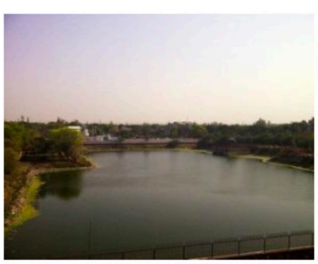
WATER MANAGEMENT STRATEGIES

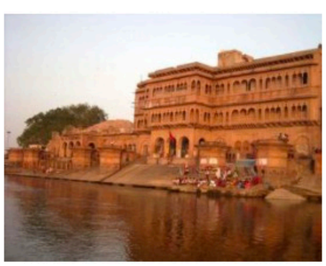
The following water management strategies highlight just eight of the many different hydrological landscapes currently in use in India. These eight examples come from several different cultural, social and environmental contexts, despite sharing the same national boundaries. In an effort to better display the different approaches and characteristics of these systems, the following table of attributes has been produced. (Table 1)

Table 1: Design Attributes for each Water Management Strategy. Source: Author

Strategy	Location	Material	Size	Cost	Scalable?	Machinery	Energy	Longevity
Talaab	Village centers with water	Stone or concrete	+/- 50,000 sf	Labor only	Yes. But one can serve a village	Digging equipment only	Passive	Permanent
Ghat	River edges	Stone or concrete	+/- 10,000 sf	>$10,000	Yes	Needed for stonework	Passive	Permanent
Stepwells	Urban centers	Stone	+/- 50,000 sf	No longer built	Yes, as individual wells	Needed for stonework	Passive	Permanent
Canals	Connecting villages and farms	Earthen banks	+/- 900 linear km	Labor only	Yes, across many farms	For digging and dredging	Passive	Semi-Permanent
Bunds & Tanks	Individual rural farms	Stone and earth	Walls up to 9' tall, any length	Labor only	Yes, across many farms	For digging only	Passive but pumps can be used in tanks	Semi-permanent
Artificial Glaciers	Between glaciers and villages	Stone and pipe	Up to 1 mile in length	$6,000 per major pool	Yes, within one watershed	Human labor	Passive but some maintenance is needed	Permanent
Ice Stupas	Between glaciers & households	Plastic Pipes	+/- 1,000 sf	<$1,000 per system	Yes	Human labor	Active effort during construction	Annual Construction
Snow Barrier Bands	High mountain passes	Stone	+/- 1,000 linear feet	Labor only	Yes	Human labor	Passive	Permanent

In addition to this table, each design strategy is described below, individually. A brief description of the type of intervention is followed by the adaptive response of each design solution.


Talaab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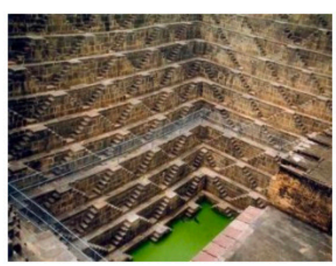
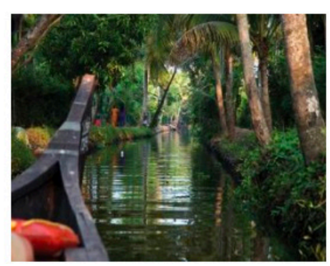

Stepwell


Canal


Bund and Tank


Artificial Glacier


Ice Stupa


Snow Barrier Band

Figures 2-9: Images of each Water Management Strategy. Source: Author

Talaab
The talaab is a human-made depression, much like a pond, meant to hold monsoonal water for use across the entire year. These communal water access points serve as multifunctional landscapes, places for people to collect water for household use, but also a space to bath, wash clothing, and commune. More than 1.3 million talaab are known to exist in India (Nawre 2013). Where water scarcity is a potential problem, talaab can help to extend water resources across the entire year. The catchment ponds hold water when it is abundant (during the monsoon) for drier times. (Figure 2)

Ghat
India's ghat line river edges, as a series of steps, to both enable human access to the water and to minimize flooding. The stepped edge of the river promotes communal space and interaction, where humans gather to perform personal tasks as well as to gather for cultural, social and religious functions. Moreover, this hardened edge also effectively holds the water in the river, minimizing flooding by creating a stepped zone that can also carry additional loads. This edge therefore acts as a dynamic edge, populated by human activities and occasional flooding events (Samant 2004). Ghat function like public parks, and each ghat may take on its own identity, defined by the activities it hosts: laundry, yoga, basketry, boat making, puja, etc. (Figure 3)

Stepwells
India's stepwells are mostly out of use, now, having been replaced by smaller wells and municipal water systems. However, many of the old stone stepwell structures still exist, where they are venerated for their craftsmanship, used as a communal meeting space, and often host active shrines. When the stepwell was used for water management, it was an elaborate, stone structure built into the earth, shaped like an inverted pyramid that enabled individuals to reach well water via a series of steps. Because these steps funnel down into the far reaches of the bottom of the well, water was made available to citizens during both high and low well levels. When not holding water, the stone steps served as space for socialization and reprieve from the heat, thanks to the shade and cooling breezes afforded by the well. (Figure 4)

Canals
The canal is used to move water throughout India, but it is most clearly expressed as a spine, edge, and movement corridor in the state of Kerala. Here more than 900 km of canals move water throughout the low-lying landscape, effectively transporting and equitably distributing water. This system enables water access more uniformly across the land, while also reducing the risk of flood and drought events. (Figure 5)

Bunds and Tanks
On the Deccan Plateau, bunds are the earthen embankments that extend across swales to trap rainwater, and tanks serve to collect that runoff (Mathur & De Cuna 2014). Bunds typically slow and retain monsoonal rainwater on a site, so that it might recharge the groundwater, or be collected to serve as irrigation later in the year. However, bunds are also used in India to manage mud and retain topsoil, as well as to deter saltwater intrusion. Combined with storage tanks, bunds can help to direct and hold rainwater for human use.

Much like the practice of contour bunding, which is a strategy typically employed in mountain or hillside agricultural contexts, India's bunds promote water retention and reduce soil erosion. Bunds are made from locally-harvested stone, which is piled up above the ground to form bermed walls. Stone bunds also typically enter into the ground, and they can be dug into the ground up to 9 feet. While bunds are challenging to build, they remain as landscape features, and continue to work passively, with minimal additional management over the years. (Figure 6)

Artificial Glaciers
In northern India, water is collected as it cascades down a mountain slope and stockpiled, as ice, for agricultural use in the spring. These formations are called artificial glaciers, as the ice masses share similar shape, form and function as the natural glaciers in this region. Artificial glaciers represent one of the many ways in which farmers have begun to extend the water resources issued from larger, parent glaciers, by trapping water in the winter months that otherwise would

move into the Indus watershed below (Clouse 2014). Artificial glaciers can extend up to a mile in length, and once built they require very little oversight, aside from the seasonal manipulation of regulator gates. (Figure 7)

Ice Stupas
Similar to the artificial glacier, ice stupas redirect and collect winter snowfield meltwater to a site located above a village, where it is stored, as ice, until the spring planting months. Ice stupas are smaller than artificial glaciers in terms of footprint, but they can grow to 60' in height. Interior pipes shoot water up into the cold air from the center of the stupa; when it freezes on the surface it builds a larger ice mass. Buddhist monks from monasteries visit and bless these stupas, connecting the process of water management to the religious fabric of Ladakh. (Figure 8)

Snow Barrier Bands
Also found in northern India are snow barrier bands: the long, linear walls that have been erected to funnel snow into drainages with village settlements. In this high-Himalayan rainshadow context, water is extremely scarce, and yet critical for subsistence agricultural purposes. By pushing water into specific drainages with farms below, snow barrier bands increase the water resources available to village farmers.

Snow barrier bands are constructed from site-harvested stone, and once built, may serve a community for many decades. A recent snow barrier band build, at Warila Pass in Ladakh, effectively enlarged and improved an existing 100-year old snow barrier band. These constructs rely on gravity and wind, and once created, can serve their purpose without human management or oversight. (Figure 9)

DISCUSSION

In India, water is a resource that is typically understood as a form of the commons. It is a shared resource, a basic human right, and a critical component of efficient and effective agricultural landscapes. The eight examples highlighted in this paper have developed over time to reflect specific site constraints, as well as physical features and social responses that connect to the place in which they perform. Still, all eight examples also feature a shared set of qualities: they are multifunctional landscapes, with deeply intertwined ecosystem services, and in many instances they also overlay social and cultural spaces. Together they suggest the breadth of ways that Indians have historically managed, regulated and conserved water for public use.

Vernacular hydrological landscapes suggest a number of important design attributes. They tend to be visible structures, with clear, decipherable organization and components. They are often built by the people who will rely upon the system, using inexpensive local materials. Such connections to the construction process enable ongoing maintenance while also allowing for low-tech, incremental adaptation. While many of these solutions are often labor intensive, in India they have been extraordinarily affordable.

In acknowledging the diverse array of attributes and contextual responses that characterize water management strategies in India, designers can better understand potential opportunities for improvement and adoption. Moreover, by distilling each water management strategy into discrete components, we can better understand each design in relation to its broader urban planning relevance. (Table 2)

Table 2: Adaptive Potential. Source: author

Strategy	Primary Use	Adaptive Application	Improves Husbandry	Downstream Impacts	Could this intervention scale up, or be applied in other contexts?
Talaab	Storage	Drought	Yes, through awareness	Possible pollution	Yes, these depressions would work in any flood-prone landscape. New Orleans, for example.
Ghat	Access	Flooding	Yes, through awareness	People access waterway, possibly polluting the river	Yes, these access points help to minimize bank erosion and improve people's connection to river edges.
Stepwells	Access	Drought	Yes, through veneration	Aquifer is drawn down	Perhaps. This is an enlarged, communal well. It could transfer to other areas without pump technology.

Canals	Movement	Flooding	NA	Water is dispersed across landscape	Yes. These canals are ubiquitous, and when combined with barrages, help to provide fresh water access in low-lying coastal areas.
Tanks and bunds	Retention and Storage	Drought	Yes, through soil retention	Less water leaves site	Yes. These are useful in places where sheet runoff removes soil, and water from farming landscapes.
Artificial Glaciers	Storage	Drought	NA	Less water volume runs into rivers	Yes. These require high mountain sites and drainages that feed communities.
Ice Stupa	Storage	GLOF reduction	Yes, through blessings	Less water volume runs into rivers	Yes. These may be used to help purge backed-up glacial lakes, while holding the water for future use.
Snow Barrier Bands	Deflection Increasing capacity	Drought	NA	Watershed on the other side of a pass is deprived of water	Yes. These bands may help to stop and funnel water into the appropriate drainages.

Finally, beyond just reviewing and assessing these seven water management systems, this study offers a starting point for a conversation around the place of design in new water management projects. In each system, the water level is on clear display, indicating abundance and scarcity so that people might adjust their use accordingly. While landscape architects have not historically been a part of the project conception and integration in these examples, the study shows areas where design thinking would be helpful and influential. According to Sarté and Stipisic, this design thinking leads to "Efficient infrastructure (that) can simultaneously create safe water supplies, support ecology, and provide structure for more resilient cities" (2016). (Figure 3)

Table 3: Co-benefits. Source: author

Strategy	Primary Benefit	Environmental Benefits	Social Benefits	Recreation Benefits	Religious Benefits	Cultural Benefits	Economic Benefits
Talaab	Storage	Water source for wildlife	Watering hole	Swimming	Shrine site	Site for community events	Affordable water distribution
Ghat	Access	Reduction of river bank erosion	Watering hole	Access to swimming	Place for riverine offerings	Site for community events	Place for entrepreneurship
Stepwells	Access	Water source for wildlife	Watering hole	NA	Temple associated	Ornate stone carvings	Shared well, Affordable water distribution
Canals	Movement	Dispersal of water across a much larger landscape	Access to others via boat	Boating	NA	NA	Enables the cultivation of additional farmland
Artificial Glaciers	Storage	Retention of water on site	Built by people together	Ice Skating	NA	NA	Enables larger crops
Ice Stupa	Storage	Retention of water on site, Emergent vegetation	Built by people together	NA	Blessed by monks and a sacred site	Site for community events	Enables larger crops
Snow Barrier Bands	Deflection Increasing capacity	Retention of water on site	Built by people together	NA	Prayer flag sites	NA	Enables larger crops

There are a number of limitations to this study. First, in scope and range, the paper broadly addresses several different water management solutions in India, and therefore cannot offer a detailed assessment of each option. While eight different design solutions for water husbandry were selected for study, many more exist in India alone, and this paper would benefit from a more exhaustive survey of water management landscapes in the future. This is particularly important in the context of the shifts to water management systems in India and abroad: in the context of both climate change and the rural-to-urban demographic shifts that have become critical development pressures impacting water resources.

Finally, the topics of climate change adaptation and shifting population pressures on water security are in and of themselves complex, multifaceted issues (Sarté & Stipisic 2016). The paper acknowledges the nuanced approaches to contending with these major challenges without fully articulating those disparities. In gaining a better understanding of extant water management practices, and gleaning insight for future development challenges, this taxonometric approach is perhaps useful. However, next steps for this research include a more comprehensive approach to data collection and interrogation, revealing more explicit research outcomes.

CONCLUSION

As climate change threatens to change many of the weather conditions that have enabled stable water resources and sustainable water management in places across the globe, change will become the new normal. Also, as global water use increases with an increasing population and with new standards for water usage, water will likely become ever scarcer or more risky (Sarté & Stipisic 2016). In this context, communities will need to adapt or improve upon their longstanding water management practices.

Designers occupy an important role in this shifting water landscape (De Waegemaeker et al. 2016). Landscape architects, planners and architects are well equipped to envision future water systems. They are skilled in managing many different stakeholders, in representation and visualization, and in problem-solving. But designers are also adept at referencing historical precedents, and integrating old wisdom and knowledge into new design schemes. It is for this reason that designers would do well to consider the vernacular water management landscapes of India.

India is an important country to reference in the study of vernacular water management strategies, because the country has a broad range of climatic and weather conditions, irrigation approaches, and intact examples. Moreover, because the country has a history of managing water for more than 2,600 years, it is a rich repository for a wide variety of approaches and time-tested solutions.

Each of these eight design strategies for water management respond to, and will be impacted by, increasing population pressures and the shifting weather patterns caused by climate change (Gosain et al. 2006, Mall et al. 2006). In this context, it is worthwhile to examine the existing components of India's water management in an effort to better understand opportunities for adaptation in the future. For instance, attributes of systems may need to adjust to continue to be effective in the face of ongoing development pressures, and a clear understanding of these disparate elements may ease that transition.

Moreover, the considerable knowledge and experience found in India's current water management landscapes may be useful for other people, places and conditions. Alternate or hybrid systems could have applications for other contexts, and components or approaches taken from these systems may be useful when applied to other areas (De Waegemaeker et al 2016). As the swift changes in climate and urban living necessitate new forms of water infrastructure, the diverse approaches explored in India could become useful and valued contributions to the design field.

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