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WATER AND URBANIZATION

EDITED BY
TERJE TVEDT AND
TERJE OESTIGAARD

I.B.TAURIS

Water and Urbanization

History of Water Series

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A History of Water

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Edited by

Terje Tvedt *and* **Terje Oestigaard**

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Urban Water Systems—A Conceptual Framework

Terje Tvedt and Terje Oestigaard

There can be no doubt that the dominant tradition in urban studies has given scant attention to the universal and structural importance of water in urbanization processes. Peter Hall, in his acclaimed *Cities in Civilization* (1998), does discuss the role of water in the development of Rome, Paris and London, but this volume on cities in civilization has a register with no general entries on either sewage, water supply system, rivers, canals, or aqueducts. In the same author's book on the future of cities from 2002, the water issue is of marginal interest (Hall, 2002). A summary of the content of all the volumes of the journal *Urban Studies* between 2006 and 2012 shows that out of 14,363 pages, only 86 pages were devoted to the water issue. These pages were not concerned with the physical or man-made environment impacting city development and affected by city development, or with its role in shaping patterns of social activities, power, or control. The few articles dealt with water as a case in studies of political–economic issues, mainly and not surprisingly the water-pricing issue. There were altogether four articles that dealt with such issues. None analyzed the interaction between water systems and cities, and how these impacted the social and economic life of the people in the cities. The book with the all-including title *Understanding the City* (Eade and Mele, 2002) does not give the water issue any attention whatsoever. A textbook in sociology in an influential series on sociology in the twenty-first century, *The World of Cities*, are only dealing with social aspects of urbanization, although it claims to be broad and comprehensive in its outlook. The book promises to "take a journey across time and space, over the urban landscape and to be historical and comparative in perspective" (Orum and Xiangming Chen, 2003: xi). It has, however, no discussion on the relationship between cities and water whatsoever, and carries not one reference to either water, rivers, sewage or waterways and canals (Orum and Xiangming Chen, 2003). Theoretical books on urban politics are neither concerned with the urban/water issue and how it frames and shapes both power relations in cities and makes footprints in the water landscape (see, for example, Parker, 2003; and Davies and Imbroscio, 2009). This volume and article takes as a starting point that modern urban studies have persistently tended to neglect the water issue and the interlinkages between city development and water. The new "cultural geography" or human geography, concerned with unmasking the meaning of cities, landscapes or buildings, unpacking it as a text, have in general not been interested in unpacking the meaning of urban water landscapes. Since one of the most important urban infrastructures, the water supply and sewage system, is a truly hidden, not visible structure in a strict material sense because they are underground and not a part of the "built landscape", this aspect of the confluence between city and water has naturally been difficult to unpack as text.

We will here show how a focus on water/urban relationships can further our knowledge of city developments, and how urban studies can deepen our understanding of the role of water in societies. The basic premises for this proposal are two facts of huge importance for understanding the history and development of the city; the universal needs of water and the actual, physical waterscape at a given place. All urban dwellers[1]—from the first few people who settled around a natural spring in a desert in Jericho and built a wall around it almost 10,000 years ago, to the Incas living in the royal city Machu Picchu on a mountain top in the Andes, to stock traders relaxing in spacious apartments in a skyscraper on Manhattan, and to the party officials assembled for one of their meetings in a grand conference hall in Beijing—share the need for one resource: water. The theoretical and empirical importance of this state of affairs can hardly be overestimated: these people all need water to survive, and as long as they live in cities, it has to be provided in one way or another. Water is the only universal urban resource that in this sense is a must and that can be controlled in this strict understanding of the word.[2]

For theoretical and empirical reasons, it is also very important for urban studies to acknowledge the natural fact that the hydraulic systems that envelop and underpin the city as climate and weather always vary, from place to place, and also from time to time at the same place. The character of the actual water system helps to define a sense of place in a fundamental way—for example, whether it is its relative humidity, the average number of rainy days, whether it receives snow and for how many months a year, or if it is situated in a desert. The urban dwellers' interactions with and their patterns of activities in relation to their water will also reflect the local hydrological cycle's particular characteristics, how their water has been modified locally in the past, and how they and their predecessors have conceived of their water and how it should be managed.

All urban places are tied up in this continuous web of relationships with water's simultaneous universalism and particularism. The geography and history of all cities in the world are therefore written in water, and in the most varied ways and manners.

There are two very different, though interrelated questions to be answered: first, how can a focus on water/urban relationships help our understanding of cities' developments; and second, how can urban studies broaden our knowledge of the role of water in societies? The possibilities of approaching these questions will be explored by a water systems perspective. It is argued here that urban studies will benefit from new theoretical and conceptual approaches and a focus on water, since all cities at any time and in all places have been forced to respond to this resource in order to grow. But how to uncover and map the complex urban/water relationships? How to interpret the way this broad multidimensional relationship has impacted and changed urban history and landscapes? How to analyze the process and history by which city developments change and impact water landscapes? And how can the flows of water in urban places be used to study flows of capital, power, labor, and ideas in cities?

The recognition of this range of phenomena requires some unifying approach, but an approach that at the same time can offer open and non-reductionist frameworks within which the various elements and their relationships can be analyzed.

Analyses of urban/water relationships should study the water system in its multidimensionality as an "open and multifunctional water system" (Tvedt, 2010a, 2010b). They should take into consideration the three layers of all cities' water systems: the physical, natural waterscape; the humanly modified water systems; and the ideas and managerial assumptions about water. The way "system" is used here is different from how systems theoreticians use it. It is a descriptive term, denoting three different aspects or layers of water in connection with its social importance that are best understood in relation to each other. When the words "first", "second", and "third" layer of the water system are used, these should not be regarded as signifying a static hierarchical ordering. Instead, they denote separate, distinctive, and related layers that also may differ in explanatory importance according to what aspect of urban development one primarily focuses on. Although specific cities in this volume are used to exemplify these layers, it is important to stress that all of these layers are present at all times, in all cities in the world—and any city could have been used to exemplify the three layers.

THE FIRST LAYER OF WATER SYSTEMS: THE NATURAL WATERSCAPE

The first layer is water's physical form and behavior. This covers precipitation and evaporation patterns, river discharges and velocity measurements, and aquifers and their behavioral characteristics (i.e. the natural waterscape or hydraulic system with relevance in the area where the city in question is located). This layer should be seen as an exogenous, physical factor, with certain particular characteristics, although these are always in a state of flux. This physical aspect of the water system should not be regarded as a separate "watery" ecosystem in nature, but as constituting a central, distinguishable aspect of all ecosystems reflecting and bringing with it traces or the meaning of the enveloping landscape. To understand how H_2O runs through nature and urban societies, we need natural science data such as rainfall variations, rivers' sediment loads, evaporation patterns, hydrological data series, aquifer developments, etc. All of these are important, although they are of different importance to different urban places.

This focus on the physical water system and its importance for city development does not suggest a one-to-one relationship between a certain waterscape and city development. Moreover, the task of analyzing the role of the physical water context should not be seen as a simple descriptive exercise, because although water will always play a very important role in cities' location process, there is no simple causal relationship between the physical character of the water system and city locations. It is true that some places do exhibit such clear-cut causal connections, but even when there are such correlations, levels two and three of the water systems approach are equally important (see discussion below).

Everyone who has visited Jericho, the oldest urban settlement in the world, and already between 8500 and 7500 BC encircled by a defensive stone wall, knows this. In the beginning of the third millennium BCE, Jericho became a flourishing city, located around the 'Ain es-Sultan. This spring, which in the Bible is known as Prophet Elisha's Spring, provided 4,000–5,000 liters of fresh water each minute. Importantly, this happened without any human action needed, and the water was easily distributed by gravity and canals. The water is still coming up from the ground, as if it is an ongoing miracle—but there are specific hydraulic reasons for it. From the earliest habitation up to the Ottoman period, this spring was the focal point for urban development and it decided the location of the city.[3] In other cases, cities are located along large rivers. Babylon, situated along the Euphrates on the Mesopotamian flood plain in today's Iraq, is often associated with the Hanging Gardens, although this has proven difficult to establish archaeologically. At the time of Nebuchadnezzar II (604–562 BC), Babylon was the leading metropolis in the world, measuring about 4.5 km^2 at the beginning of his reign. Canals from the river were built for extensive irrigation, and some of the most impressive water canals were built within the city itself. The Inner City and the Western City were both surrounded by city walls and moats. By the end of Nebuchadnezzar's reign, the eastern parts of the city were also protected by city walls and mounts, covering an area of about 9 km^2.[4] Babylon could not have developed where it did had not the Euphrates crossed the flood plain, but human modifications of the water landscape was necessary to develop and sustain it.

Rain-harvesting offers yet other possibilities. Mohenjo-Daro in present-day Pakistan was built on artificial wells and developed a sophisticated water system both for supply and sewage. It was a part of the Indus civilization and one of the largest cities in the world of the third millennium. In the city, it is estimated that there were more than 700 wells and perhaps as many as 2,000—the highest density in the world. Each of these wells had an average catchment area radius of only 17 meters, making the density unparalleled in the history of water supply. The most spectacular and well-known water structure in Mohenjo-Daro is the "Great Bath", a tank 12 m by 7 m, and 2.4 m deep. However, the use and (ritual) function of this bath has been more difficult to establish. Another noteworthy development in the city is that it seems that almost every household had a separate "bathroom".[5] But the most intriguing aspect of the city is perhaps the system for sewage removal. The foundation for this water system was the fact that the water table on the Indus Plain was very close to the ground, so accessing the waters by wells was comparatively very easy.

Often a city will be dependent, of course, upon utilization of different water resources, and it is these different resources in combination that form the particular water landscape a city develops within. Aksum was the capital of the Ethiopian civilization with the rise of the kingdom of Aksum (50 BC–AD 800). The centralized state emerged in the second century AD, reaching its maximum expansion by the mid-millennium. Rainfall, surface water, and groundwater were the basis for the rural population. In the city itself, there were several springs and cisterns receiving runoff water from the surrounding hills. The largest and the most celebrated one was originally about 65 meters in diameter and 5 meters deep. This is seen as a rain-harvesting cistern, and together with the other wells it would have supplied a sufficient amount of water to the estimated several thousand inhabitants in the city's heyday. The name Aksum itself indicates the importance of the local water resources; it may be derived from "water"—"*ak-*" may derive from the Cushitic root for "water" and the Semitic term for "chief" is "*šum*". Another hypothesis is that the name comes from the western Agaw word "*akuəsəm*", meaning "water reservoir".[6]

Athens is a case that undermines the notion that water's impact on city location has a necessary, predictable pattern. Classical Athens was not located where it was because of an abundance of water. According to mythology, there was a competition between Athena and Poseidon regarding who could give the best gift to the city. Athena had wisdom and knowledge of arts and crafts, and Poseidon, as the god of waters, offered the Athenians a well at the Acropolis. The Athenians voted for wisdom instead of abundance of water.[7]

In the highlands of Ethiopia, one can study an example of yet another locational relationship between city and water. Here, rainfall is usually heavy but also strongly erratic and seasonal. The location of the country's capital is related to water, but not as a dire necessity. Addis Ababa has the curing and healing aspects and capacity of bathing as the point of origin. The queen of Ethiopia, Taytu Betul (*c*.1851–1918), had spent much time at thermal springs and requested her husband, King Menelik I, to build a house by a specific spring in the highlands; he complied. Soon the area developed into a royal settlement to which Taytu Betul gave the name Addis Ababa, meaning "New Flower". The king himself, aware of the curative powers of the waters, and troubled by rheumatism, established a royal enclosure, a palace, and an audience hall, paving the way for further city expansion.[8] One can still see the remnants today on a hilltop outside the center of the city.

Cities have been established not only where there is limited water availability or only one source of water, but also where there is too much water. One city with an overabundance of water is Rotterdam. Any visitor taking a boat ride around Rotterdam's river and canals will realize that this is a city where water is everywhere. The fight against too much water made this city possible, as the latter part of the name indicates. Rotterdam is a polder city (enclosed by dikes), created by man in a fight against the water. Changes in sea level and river discharges have forced the city to employ different policies throughout its history. The city has undergone several phases with regards to managing the changing water: natural water management (until 1000); defensive water management (1000–1500); anticipative water management (1500–1800); offensive water management (1800–90); manipulative water management (1890–1990); and adaptive manipulative water management (1990 until today).[9]

The physical layer of this water system approach includes not only the absence and presence of water at a given place, but also the very form and nature it takes throughout the seasons. It makes it possible to integrate in the analysis how non-cultural and non-social facts affect how water must be controlled and has to be distributed horizontally. Such non-social variables influence the technology that can be chosen, the type of equipment that must be used or can be used, the size and complexity of the water distribution system, and how it is operated, etc. Northern countries with freezing waters may be a case in point. In Finland, the winter may last for up to 200 days in northern Lapland and 100 days in the southern areas. The temperature varies from −45° to −50° at the coldest in the north to 35° in the summer in the south. The water infrastructure therefore needs to handle variations of at least 70°, and because the soil freezes in the city of Tampere (in southern Finland) to a depth of about 2 m during the winter, all water and sewage pipes have to be placed at a depth of 2.5 m in order to function in extreme conditions.[10] It is obvious that a city like Tampere (subject to extreme seasonal fluctuations) will necessarily be organized and physically constructed in a different way than, for example, cities like Dhaka (flood plain) or Mecca (desert) because of differences in their respective water systems. But these natural facts are still overlooked, although they continue to produce and re-produce different possibilities and conditions for organized urban life.

Although almost all capitals and big cities are located on riverbanks (though there are important exceptions), there are, as shown above, no laws or fixed pattern governing the relationship between physical water systems and city locations. A focus on water/urban relationships will, however, make possible a better understanding of how fundamental physical structures of water systems impact different cities' development. While most citizens have increasing mobility and the "flow" of people between countries and cities, and between rural areas and urban spaces, is increasing, cities remain quite fixed geographically. Indeed, one of the clear features of history is that people are stuck with the location of their cities—but at the same time they have gradually altered the original waterscape, due to improvements in technology and organizational skills.

Cities can and must change; they must be retrofitted and repurposed in relation to their water resources. Indeed, they always have been—by urban governance and citizenry; by the hydraulic engineer; and by the architect and the urban designer. Cities' relations to their water systems will become more and more challenging, because the uncertainty about future waterscapes due to global warming scenarios will become more and more important, and cities and their populations' expectations of and demand for water will continue to increase and diversify.

Another reason why understanding the relation between the first layer and cities' location and development should not be seen as simply a useful descriptive exercise is that the physical character of the water system is changing over time (although very slowly in some cases, reflecting the water source in question). Changing water systems will therefore impact urban location and development in various ways over time. Xi'an, which became the greatest ancient city in Chinese history with a population up to 1 million and an urban area covering 83.1 km^2, was surrounded by eight rivers. The name itself, Chang'an in Chinese, perhaps hints at this particular water situation, as it means "long-lasting safety and prosperity". Still, due to both the nature of the rivers and human attempts at modifying them, the city experienced water problems. Throughout the different Chinese dynasties, the city was moved to more optimal places.[11] But everyone seeing the city's surroundings today will realize that the name is still a fitting one—rivers are the arteries of the city.

SECOND LAYER OF WATER SYSTEMS: HUMAN MODIFICATIONS OF THE WATERSCAPE

A water system that is of relevance to a city's development will always—with specific but complex consequences—be modified in one way or another by urban action. The basic reason for this is that the physical water system underpinning a certain city's location in the first place will be "appropriated" for different demands and reasons at different points in its history. This is because the need for water will always be there and will also change over time, not only because of increases in urban population, but also because changing economic and social activities will put greater stress on the water resources. Other actors in the watershed and their efforts at using and controlling the waters must also be analyzed in order to understand the character of a particular city's water system. The human modifications will also in themselves have varying scales and histories. Most cities today are therefore enveloped by both an engineered waterscape and a waterscape that is still mirroring, to different degrees, the local character of how the hydrological cycle manifests itself in the landscape.

Specific types of modified waterscapes have been the very symbol of urbanized life, distinguishing it from the natural haphazard dominating rural life (i.e. the dependency of erratic rainfall patterns for rainfed agriculture). Fountains, in general placed at the very heart of cities, have had many functions, but one of them has been to symbolize man's control over nature—cultures' appropriation of the forces of nature. Here the unruly, treacherous water element is completely controlled, to serve human needs for aesthetic beauty.

Classical Rome was known as the city of fountains and baths, because what made the imperial capital possible was not the Pantheon or Colosseum: it was the human modifications of the waterscape. The initial localization of Rome was both mythical and practical. According to mythology, Rome was founded in *c*.753 BC by the Tiber River, "the river closest to god". The foundation myth starts with a flood, when Romulus and Remus washed ashore at the foot of the Palatine Hill. Springs, streams, and marshes were central in the early city building, and streams were channeled in order to dry saturated land. But as the city expanded, the numerous freshwater sources were insufficient to meet the city's water demands. Rome's first aqueduct, the Aqua Appia of 312 BC, ran mostly underground, and between 312 BC and AD 226, 11 aqueducts were constructed. Rome's history is one of many cases where the control of water was a main strategy for attaining power and demonstrating power.[12] A telling expression of this can still be seen: in the middle of the Four Rivers fountain by Bernini from the sixteenth century, standing in the center of Piazza Navona, there is an obelisk, and on top of that, the Pope who restored the water system in Rome had placed his personal symbol.

Byzantine Constantinople developed and was dependent upon a network of long-distance channels and reservoirs feeding the city with water. By AD 373, an estimated 130 new bridges and the first line of channels from major springs had been completed, measuring 268 km in total. Within the city, the Aqueduct of Valens had 87 arches and was 971 m long, one of the longest in the Roman world. The channel system was continuously expanded and developed, and the single length of one of the channels was 227 km. If a supplemented line from the late fourth century is included, the total length was 268 km. But this was still not enough for the city's water supply and, around AD 400, the system was extended to new springs almost 130 km from the city. When the second phase of the water supply was completed, about AD 450, the aqueduct channels had a total length of 494 km.[13]

Machu Picchu was the royal city in the Inca civilization, located in a mountaintop location. The city was established in AD 1450 and abandoned in AD 1572, but most likely ceased operation by AD 1540. Despite the importance of the city and its amazing architecture, the size and population was rather modest. Machu Picchu could support a resident population of about 300 people and up to 1,000 when the royal entourage visited the city. The annual rainfall is nearly 2,000 mm and the location of the city would not have been possible if a reliable source of groundwater had not been available. Water from the main spring was transported in a 749 m canal to the city center, which was distributed by 16 fountains still operating today.[14]

Building canals and aqueducts was not only important for cities in the past; it has also been intrinsic to many cities' development today. Los Angeles, although initially a small city with sufficient natural water resources, soon became a "desert city" because of its rapid population increase. From having around 1,500 inhabitants in 1850, the population rose to more than 100,000 in 1900, and only four years later it was 200,000. The solution to the water crisis this caused was to build an almost 360 km aqueduct from the Owens Valley in the early twentieth century, turning Los Angeles into a "hydraulic society". Yet already in the 1920s this was not enough, and the aqueduct system had to expand due to an increased population of 1.2 million in 1930, causing displacement and environmental degradation in the areas from where the water was withdrawn.[15]

One of the central issues that the water system approach aims to handle is that water is both an external, physical factor and creates one of the most interconnecting structures in cities in the form of socially appropriated, manmade water systems. In modern cities, all citizens and units—from the smallest apartments to the largest malls and factories—are physically, institutionally, and politically connected through water supply and sewage systems. In many cities, one reservoir is the main source of all the water for the entire population, and one major sewage treatment plant treats the waste water—connecting each and every person in the city through the whole process as the water is used. Thus, the physical character of water and the structures of the manmade water infrastructure are linked, and as such they create both social cohesion and social hierarchies, and these again reflect place specific forms and are continuously changing throughout history.

Dar es Salaam is one of the many cities in Africa where the well-being and health of its citizens have been hampered by incomplete and unreliable water supply and sanitation services. Today, only 10 percent have flushing toilets, while the majority is dependent upon pit latrines, which causes increased pollution, jeopardizing health conditions. Rapid urban growth, lack of investments, and unsatisfactory maintenance of the water systems, in addition to a large informal sector (without a centralized and governmental planning), have been a hindrance to poverty reduction, and the unsatisfactory water structures are inevitably and directly linked to the prevailing poverty.[16] In this case, water has a direct impact on the formation of social structures. Alteration in urban water thus has huge social implications for social relations and formations in general.

Manchester was the world's first industrial city and it was crucial in the Industrial Revolution. Manufacturing of cotton from 1770 led to exceptional economic growth. In the first half of the nineteenth century, the city had the world's highest concentration of cotton factories. Along with the industry, the population grew as well; in 1841, the city had 300,000 inhabitants and was the second largest city in Britain. A crucial aspect in the Industrial Revolution was the development of the water transport system. In addition to the natural watercourses, 250 km of year-round and ice-free canals, rivers, and streams were constructed within 15 km of Manchester city center. The transport system was manmade but reflected at the same time the specific character of the natural water landscape; the fact that it was raining throughout the year made supply of water for the canals much more easy here than in China or in southern France (Canal du Midi), and it was comparatively easy in the Manchester area to link canals to rivers because the rivers were running very close to each other, etc. The canals provided navigable routes to the major trading regions not only nationally but also globally. Importantly, the new manmade transport system also facilitated transportation of coal for industry on water instead of on land.[17]

New York is another example of how important it is to study this second layer of the water system on a grand scale, all the time interconnected with the first and third layers. New York started as a modest settlement in 1626; it was named New Amsterdam, and located on an island at the mouth of the Hudson River. It was thus a classical river town, established at the interface of running fresh water and salt water, of river and ocean. There can be no doubt that the Erie Canal, which connected the Hudson to the Great Lakes, opened in 1825, is one major reason why New York and not Boston became the economic capital of the USA. It married the two seas, as Governor Clinton said when the canal was opened. The city became a densely populated metropolis by the mid-nineteenth century, and local water sources were insufficient to meet the rising water demands. The history of New York's waterworks is therefore among other things a history of how far into the hinterland, away from its original core, a city may go to secure a reliable water supply. New York is dependent upon water from other watersheds, thus challenging the water interests of other states. The Hudson, although it may have the look of a natural river, is not a natural river any more, but largely controlled by man.[18]

Mexico City, considered by many to be the most populous city in the world, is not located on a riverbank, but has managed to grow due to (among other things) massive investment in water transfer projects. The city is located in a basin, which is a naturally enclosed depression, at around 2,200 m above sea level. If one flies over this megacity at night, this is one of its clearest markers: there are lights everywhere and no dark thread reflecting a river that runs through the city. The Mexico Valley basin has a large number of springs in the mountains and the foothills, providing water to the lakes and the aquifers, which still supply almost 70 percent of the water requirements for the city's now 20.5 million inhabitants. However, the city has been overexploiting its water resources for years, and the lake at which it was originally located is not there anymore, except as a bleak, small shadow of itself compared to how it was during the times of the Aztecs. This has caused the groundwater table to lower considerably, as much as 1–1.5 meters annually. "The city is sinking while people are drinking," goes the local saying. This is undermining the foundations of buildings and structures, and the area is becoming more prone to earthquakes and flooding. But since the city is located where it is, catering for a dramatic inflow of people, this means politicians and engineers have to look for water further and further away from the city.[19]

Another example, Las Vegas—one of the fastest-growing cities in the USA—never had enough water locally, since it is located in the middle of a desert. The city relies primarily on water pumped from the Colorado River, and this is stored in Lake Mead. But the amount of water the city is allowed to withdraw from the reservoir is not sufficient. One strategy has been to pump groundwater from eastern Nevada, but this has caused conflict with the interests of Los Angeles. Conservation and recycling processes are in place, but still there are huge challenges in meeting the increasing water requirements. When driving down the main street in Las Vegas, the city's water infrastructure "lies". It is difficult to maintain the impression that this is a desert city, because there are cascading waters everywhere—up from gigantic fountains and down from huge artificial waterfalls. The city architecture defies its location, and is—from one point of view—a celebration of the ability to modify the physical waterscape. The gamble on water is, however, still the biggest gamble in the city's history, and the authorities have to fetch it from water resources far away from where this city was established, originally intended as a resting place for treks through the desert.[20]

The presence of water—in some cases too little water and in other cases too much water, like Rotterdam—always has to be modified. Boston is surrounded by lakes and receives a substantial amount of rain each year. The city itself owes its topography to the way water runs in the landscape. Boston was founded as an English colony in 1630. There were 25,000 people in 1800, growing to 140,000 by the mid-century and then to over 500,000 by 1900. As the city expanded, the water world had to be successively altered. The very nature of the water topography shaped the development of the city. In order to facilitate this urbanization, in the nineteenth century, Boston became a hydrological machine, controlling and developing its water world. Canals were built, water and sewer systems were created, gigantic water reservoirs were constructed, rivers were dammed, lakes and harbors were dredged, and marshlands were filled. Thus, the very development of Boston was a series of interdependent technologies to collect, channel, deepen, preserve, reroute, and discard—and control and supervise—all of the water.[21]

Overabundance of water might be a challenge, but on the other hand, even absence of water can and has been managed, although the changes to the natural waterscape may be marginal. The stone towns of the East African coast are part of the Swahili culture that flourished during the fourteenth, fifteenth, and sixteenth centuries. Two of these sites, Songo Mnara in the Kilwa archipelago of Tanzania, and Gede on the southern coast of Kenya, are located in an area where the waterscape is characterized by dryness. Songo Mnara is located on an island, and has no source of fresh water. The inhabitants had to use brackish water from wells dug into the coral. In other coastal islands, all the fresh water had to be transported from the mainland. City development has therefore been intrinsic to overcoming water scarcity by maximizing the resources available and minimizing water usage.[22]

All cities, of course, have developed artificial water storage in some way or another, and in some locations they need to be bigger and more costly than in other areas. This is not only because the cities vary, but because the physical water systems enveloping particular cities vary. Extreme fluctuations and inequalities in the natural discharge curves of rivers or rains are therefore important aspects of urban development and different cities' efforts at controlling their waters. This is one reason why it is fruitful to think in terms of different but interrelated layers of a water system. In order to understand the manmade water system one should also study how it is reflecting the character of the natural water system, and the water system that envelops a city at any point in its development is a product of both natural and social factors. Moreover, the physical water system, which was once more than sufficient for a particular city's water needs and development, can over time become insufficient because of growing populations or changing economies, in spite of (or because of) physical or manmade changes in the water system. It is this dynamic that ahistorical theories of urbanization processes that only focus on social variables will ignore.

This notion of a second "modified" layer as part of a much wider water system can be made clearer by being contrasted with notions about the "built environment", usually defined as being only a reflection of culture or being a socially constructed environment. The notion may also be clarified by being compared to talk about a "factitiously separated and *imagined* [italics added] 'natural' environment".[23] The second layer of the water system will encourage investigations of a city's "water machine" or water technological setup as an effort to solve the water question in a context where both the first layer (the physical and hydrological) and the third layer (ideas and practices about water management) must be analyzed. Analytically it will not neglect but include changes in the way the water runs or flows through the urban landscape: as river embankments and canals, dams and reservoirs, pipes beneath the city and into the houses, bottles of water and transportation of them, etc. The water system approach is open and not reductionist: it will include in the analytical picture everything humans have done to bring natural water to the city—in all sorts of sectors and for all sorts of purposes. It thus enables a description and understanding of the water system that is an integral part of any city's planning environment at any point in time. The notion underlines that any existing water system impacts possibilities, limitations and patterns of action, as it also reflects the cities' economy and technological competence, etc. These two layers guarantee that the water system approach is neither nature-centric nor anthropocentric, but allow analyses that can capture and combine the dynamic and dialectic development between the two as factors of relevance and importance in urban development.

This concept underlines that urban places and nature should not be perceived as geographic opposites, where cities are manufactured social creations, and nature being outside of human construction. Water and the city are in this perspective fully intertwined, since cities integrate and use water at every level of development and activity. The flow of water through urban space that has played a pivotal role in freeing cities from disease, squalor, and human misery is water that flows both as a natural and a social element at the same time in the same form. Water provides a link between the material experience of physical and social space and the abstract dynamics of urbanization.

As shown, this hydrological dynamic is not restricted to the modern city: archaeological and historical evidence abounds of complex water engineering projects in the past. Urban configurations have impacted on resource flows across a range of scales. Physical and human modified water systems, always in flux and always particular, also exhibit a diversity of response to urbanization, so the same urbanization processes may have a different impact on the water system, because the water systems differ. The waste output of even a small city has overtaxed the absorptive capacity of local aquatic systems in some cases. Also, this aspect will be intrinsically related to the first layer; its effect is contingent upon the physical character of the water system. What should be studied and understood is therefore the relationship between the built environment or the man-modified water system (which is never the result only of human activity, but also of the water system's physical properties), and the response of water ecosystems in a diversity of climate, landscape, economic, and cultural settings. This human-modified water system in its turn changes the physical water system in an everlasting process of mutual interaction. These modifications have fundamentally defined the structural but changeable context in which cities develop. The impact of the urbanization process on the water system is an aspect of this layer. The concept of "open and multifunctional water systems" encourages analyses of the urban place or city and their confluences with water. This is because the form and level of any city's alteration of the water landscape it interacts with will mirror technological traditions and managerial ideas. In some cases, it will also echo broader technological and cultural patterns in the particular society in question. Moreover, no urban water landscape is completely natural or controlled, because urban development presupposes modification of the natural waterscape. However, in the long term, all hydraulic structures are vulnerable to climatic changes—whether human or natural, the water world is always changing.

Urbanization processes have a direct and indirect impact on the enveloping water system due to human modifications. Cities in themselves impact on precipitation patterns due to their impact on local climate. Existing water systems thus reflect not only natural and geographical conditions, but also societies' ability or determination to manipulate their water in the form of damming, draining, canalizing, embanking, storage, piping, or recycling the water found in nature. Human modifications have changed the way water flows through and under the city, where it flows, to whom, and how. And in changing the waterscape and controlling water, the urban population and the urban settlements have also changed themselves.

The second layer of an open and multifunctional water system covers those changes that human beings have made to their natural water landscape. These will of course vary over time, and have to be studied accordingly. The modifications will cover everything from stream alterations and river embankments when cities were first established, to tunneling water across great distances through mountains and deserts, to weather modifications by chemical bombardment. An example of this is what the Israelis do and what the Chinese did with success during the 2008 Olympics in Beijing. One question will within this approach be to what extent the modifications are passive adaptations to the natural water landscape or to what extent they represent an effort to overcome the limitations afforded by the existing water system. This leads naturally to the third level: all modifications are done by human agents, and their acts are by necessity influenced and structured by ideas that it must be possible to reconstruct and identify.

THE THIRD LAYER OF WATER SYSTEMS: IDEAS AND MANAGERIAL CONCEPTS OF WATER

The third layer of the water system constitutes the cultural, institutional and conceptual dimensions. This includes the management practices and "habits of thought" or ideas about water and water control, its religious or spiritual significance, including notions about purity, and other conceptualizations of water that have developed over time in different urban contexts. This concept will also encompass the importance and permanence of water management practices in all urban places, and how these practices and habits of thought have been influenced over the centuries to different degrees by the physical and hydrological context (layer one), and the historical water control context (layer two) in which the actors operate. This concept then does not ignore the ways in which nature or water is socially constructed. The way water is conceived in different cities shows the endurance and the instability of meaning, and the coherence and fragmentation of habits of thoughts when it comes to water and water control. It also places this production of cultural metaphors in a water system context.

The water system that at any given time envelops a city or is part of the infrastructure and linkages of the city is not necessary or deterministic. A city could have developed in other directions, given the limitations and possibilities of the actual waterscape (level one) and the means available for modification (level two). The human modifications will vary according to technological level, economic strengths, and organizational capabilities. But they will definitely also reflect the ideas of individual community leaders in the past who, for religious or other reasons, wanted to do something with their water. They will also reflect the visions of individual entrepreneurs of modern times who might have been championing huge water control projects that the majority opposed for a long time. The human element—the agent of change—must not be left out, and one way of securing this is to talk not about "material structures", but about physical and manmade structures creating what is at any point in time the existing material context. A focus on water/urban relationships definitely does not imply a view on human beings as agents through whom an active nature constantly works.[24] This focus does not imply a history without subjects or a history opposed to narration and chronology, because water is also constructed discursively and materially, and it is undoubtedly implicated in the exercise of social power. Not only that; it is also part of religion and cosmology as a whole.

Take the case of Motya—a little island of 45 ha located 1 km from the coast of Sicily. The urban settlement was structured around a sacred compound named the Temple of the Kothon. The temple was erected close to a freshwater spring. This was an underground water source from where a small lake naturally emerged. The location of the temple and the city in relation to the water suggests that the water was put under control of a divine authority, and most likely that it was holy. A water deity was apparently the focal core in the urbanization process.[25] The first Phoenician settlement occurred in the first half of the eighth century BCE, and it was a flourishing city from the end of that century to the beginning of the fourth century BCE.

Varanasi in India, located along the Ganges, is the most sacred pilgrimage site for Hindus and is believed to be the oldest city in the world that is still inhabited. The continuous arrival of pilgrims is due to the religious ideas of about the deity Ganga, and these religious ideas of water have more than anything influenced the history of the city. The constructions of ghats where people can burn their relatives, before they throw the ashes to the river in order to escape the eternal cycle, have fundamentally shaped the urban topography and the cultural construction of the city itself. Today, the ghats form a monumental and continuous riverfront more than 6 km long. They create continuity between the city and the river, materializing a particular space and cosmology.[26]

Religion and cosmology are in some cities the most important structuring mechanisms, but if one moves from the pure to the impure—from holiness to pollution—changing ideas of sanitation and sewage have been one of the key drivers in urban water developments. When in England in 1829, Paul Pry's cartoon showed the organisms that a microscope could reveal—an image of how little beasties populated the water—it was part of a changing understanding of water, which had great implications. His caption reads: "Monster Soup commonly called Thames Water." When London later was hit by cholera epidemics, it was understood that pathogenic organisms—bacteria, worms, viruses, and fungi—were responsible for outbreaks of waterborne diseases, and the water system underpinning London's growth was changed. The management of water now became the management of the city's health, and this idea had far-reaching consequences for urban development all over the globe.

In fact, developments in many cities' infrastructure were because of sanitation rather than need for increased water supply. By the end of the eighteenth century, Paris, with more than 500,000 inhabitants, was three times more densely populated than London. Around 1850, the city had passed 1 million people. Especially after the cholera epidemic of 1832, the sewer network in Paris was expanded, and in that year there were 78 bathing facilities in the city. Paris was the most important river port in France and the river became severely polluted. Due to increased urbanization and industrialization, it was only in the 1960s that the first plans and policies to rehabilitate the river and its banks were developed, and the actual projects were implemented in the 1980s. Deindustrialization along the river front, together with the "polluter pays" principle and large investments in the sanitation sector (especially from the 1980s), have since then significantly improved the water quality.[27]

In Vienna, the development of the sanitation system can be described in three different phases, but only the latter made a watershed. In the first phase, called *Amphibious Sanitation*, which lasted from Roman to early modern times, sanitation practices were local in scale where the inhabitants adopted and made use of natural water resources. In the second phase, called *Patchworked Sanitation*, which lasted from the 1700s to the 1860s, the Habsburg authorities drew attention to sanitary issues, providing punctual solutions at specific sites throughout the city. In the third phase, called *Integrated Sanitation*, approximately from the 1860s to 1910, sanitation was actively included in urban planning. Thus, Vienna's waterscape was subject to major undertakings as the city grew, providing for this change in its metabolism.[28]

In other cases, there are examples that it was the need for neither safe water supply nor improved sanitation that triggered urban water developments. Bergen is the city in the western hemisphere that receives the most rain, with an average of 2,250 mm a year. However, the city has also on numerous occasions experienced water scarcity, and the general abundance of water has required specific developments to be made regarding water supply and sewage systems. In relation to Norway's capital Oslo in the nineteenth century, Bergen as a former capital lagged behind, and it was internal national rivalry between the cities which prompted development in the water sector in Bergen, rather than combating diseases and desire for public good and health. Moreover, development in water supplies was not followed by sewage systems to the same extent. The new health regulations from 1865 banned homemade WCs and forced citizens to erect outhouses with buckets, which ideally should result in waste product being able to be used in agriculture. However, due to the rainy weather in Bergen, the manure could not be dried and the plan failed. It was only in the beginning of the twentieth century that the idea of the WC won through and was implemented on a larger scale.[29]

Yet another reason for development in urban water systems was the problem of a different kind that cities faced: fire. Houston was a city with a population of only 1,500 people in 1837, but grew rapidly to become the fourth largest city in the USA and today it contains more than 2 million people. The city is the regional and commercial center commonly known as the "energy capital of the world". All this is possible because of the water infrastructure, but this was built rather late. The first public water supply was built in the 1870s, when the city had emerged as a city center. One of the major reasons for constructing a public water system was the need for fire protection. Thus, it was not the public health with regards to waterborne diseases and a safe water supply that was the first and main driver,[30] but all of these developments were eventually made possible by political decisions.

Policies and managerial practices are thus crucial for a city's development, for better or worse. Water deficit may also be manmade due to a number of reasons. Damascus was renowned for its abundant water resources and variously described as "bride of cities", "the grain of beauty on the world's cheek", and "a lover's torment", and indeed was seen as the biblical Garden of Eden. The city's strategic location by the Barada River and as a crossroads from India, Persia, the Arabian Peninsula, East Africa, and Anatolia made it an economic, cultural, and religious center. Today, it is a city characterized by decline, uncontrolled urbanism, and acute water scarcity. All of these factors are to a large extent the consequences of neglect and bad policies for decades. High population growth, pollution, over-utilization of water resources, unsustainable groundwater extraction, and lack of technical capacity and political will, in addition to limited capacity to enforce water management strategy, have all led to a deteriorating situation.[31]

On the other hand, Singapore is a success story when it comes to development and water. Four decades ago, the country and city suffered from slums, poverty, and waterborne diseases. From this position, Singapore has become a rising star. Given the minimal available water resources present, advanced rain-harvesting techniques collect all the rainwater. Treated waste water is used for drinking and all water is recycled and reused. Thus, Singapore has been able to overcome water shortages and insecurity by being at the forefront of developing sustainable practices. However, Singapore still has to import water from Malaysia. The water import started as early as 1927 and has caused tensions between the two countries. An agreement was signed in 1962, providing Singapore with water until 2061, but Malaysia has threatened to turn off the tap if Singapore's policies were to be prejudicial to Malaysia's interests.[32] Thus, the availability of water resources is often a source of contestation within a city as well as in a country and between nations. This is also evident in the conflicts and challenges rising from privatization of water. The water supply and sanitation services in Manila metropole in the Philippines were privatized in 1997. Concession contracts involved in such processes present a fine line between flexibility and accountability. In practice, this is a difficult balance and the regulator's role often becomes extended to an unintended degree. This includes confusion about responsibilities, inconsistency in regulatory decisions, and opportunistic choices and implementations.[33]

Thus, the third layer of a water system often represents the decisive factor in the actual physical layout of a city's water structure and the water use by whom and at what time. It impacts on how the natural waterscape (level one) is understood and modified for different purposes (level two), like building a canal to supply a city with water (whether it is pipes from Malaysia to Singapore or aqueducts in Rome, Constantinople, or Los Angeles). It is the waterscape (absence of water) which sets the premises. Canals and aqueducts modify the waterscape, and this is only possible because of ideas, managerial plans, laws, and regulations constituting the practices for developing these water structures. It is precisely, therefore, that these three levels should be seen most fruitfully as analytical categories which are best understood in relation to each other. All cities are outcomes of how these three levels influence each other and none of these levels can work in isolation from each other.

CONCLUSION

Urbanization is one of the most dominant forces in the world of today. Nature, peoples, and cities are woven together in an inseparable dialectic of destruction and creation, changing the face of the earth. Water and the concept of an open and multifunctional water system as an analytical approach is a vehicle for understanding this development. The city—an attraction that has fascinated writers and researchers from a variety of disciplines—is in practice incomprehensible to individuals, both researchers and planners, due to its totality and complexity. Analytical approaches should therefore be seen as complementary, since the strength of one might be the weakness of the other and vice versa. A focus on water should also be seen as helpful to understanding other flows and interlinked developments and processes in history; as that of technology, labor, and people, and how cities produce urban realities and landscapes.

From this perspective, a water system approach should be able to encourage a much broader type of research on urban development—multidimensional and multidisciplinary in approach—because such an approach will be helpful in order to gain a better understanding of the urban world. Theoretically, it is important to highlight the role of water, because it is important to learn to look at and to think about urban space not just as culture, as a reservoir of collective memory and imagination, or as an engineering relation, but also as nature, and on how these factors are interconnected. The aim with this volume is to summarize some of the case studies that have been carried out, and to present some historic-geographical illustrations of how the role of water in urban history can be studied and understood. By proposing an open inclusive, and non-reductionist approach to urban studies, it will hopefully also stimulate, and be part of, a new and broader research agenda on cities in general, and on water and urbanism in particular.

NOTES

1 There are of course a number of definitions of towns, cities, and urban centers, and there is no general agreement on one definition. Max Weber argued in his *The City* that a full urban settlement must display the following features: fortification; market; a court of its own and at least partially autonomous law; a related form of association and partial autonomy and voting rights, see Weber (1958). This definition now looks very outdated and Western-biased. Ira S. Lowry in “World Urbanizationin Perspective” argued that “Rules of classification vary between nations, but it will do for now to define an ‘urban place’ as any permanent settlement containing at least 2,000 people who are not engaged in agriculture and who live within easy walking distance of one another, and a city as a similar dense settlement with at least 100,000 inhabitants” (1990: 148). This definition is too present-oriented and

has a non-Western bias, since a great number of the classical cities in Europe (and elsewhere) will fall outside the definition of a city. Here, urban places, cities, and towns are used interchangeably.

2 As the ancients were well aware, water was not the only essential element. Without air, death will happen in about five minutes. Without water, it takes a thousand times longer: three to four days. But the important thing in a historical and social perspective is that air cannot be tamed, piped, controlled, or diverted (although practically, it is done for a number of specific purposes, such as for scuba diving, submarines, firefighting, space travel, etc.). But in a city, there is never too much air, and it is not in a constant flux in the same way as water. So the parallel to water is, from the point of view of urban development, not very interesting, except when it carries "alien" matter and becomes a major pollution problem as it did in "smoggy" London in the early twentieth century, and in Beijing in the early twenty-first century.

3 See Nigro, this volume.
4 See Pedersén, this volume.
5 See Jansen, this volume.
6 See Sula, this volume.
7 See Koutsoyiannis and Patrikiou, this volume.
8 See Finneran, this volume.
9 See Hooimeijer and Meyer, this volume.
10 See Katko and Juuti, this volume.
11 See Wang and Chen, this volume.
12 See Rinne, this volume.
13 See Crow, this volume.
14 See Wright, this volume.
15 See Klaver and Frith, this volume.
16 See Kjellén and Kyessi, this volume.
17 See Maw, this volume.
18 See McCully, this volume.
19 See Romero-Lankao and Gnatz, this volume.
20 See Wilds, this volume.
21 See Rawson, this volume.
22 See Wynne-Jones and Fleisher, this volume.
23 See Harvey, D. (1996).
24 For this viewpoint, see Sauers, C. O. (1970).
25 See Spagnoli, this volume.
26 See Jalais, this volume.
27 See Barles and Guillerme, this volume.
28 See Neundlinger, Gierlinger, Pollack, and Krausmann, this volume.
29 See Hammerborg and Byrkjeland, this volume.
30 See Melosi, this volume.
31 See de Châtel, this volume.
32 See Araral and Ching, this volume.
33 See Ching and Wu, this volume.

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