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A Drop in the Ocean. On Writing Histories of Water Resources Management

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Abstract

This text builds on the shared focus of historians and engineers to understand how particular circumstances came to be. In their endeavours, engineers regularly turn attention to the past, many times with the explicit aim to build on the past. In this chapter, it is discussed why these water histories written by engineers are vulnerable to being less correct. Using a range of scholarship on water history and shared experiences within the International Water History Association, we discuss the core of any historical scholarship: a drive to demonstrate and understand the complexity of the past. As such, this chapter wants to warn against the engineering drive to use (water) history as a guide towards the future. Instead, we propose a perspective of history as a way of reading and understanding the complex paths we have travelled until now.

Keywords

Historiography • Grand narratives • Deserts • Colonial irrigation • Climate change

4.1 Introduction

Historians and engineers have at least one thing in common: they try to understand how particular circumstances came to be. Where historians aim for explaining how human past(s) can be understood, either on their own or in relation to the present, engineers aim for understanding particular issues or problems and providing solutions to ameliorate them for the future. Both endeavours require data of different kinds, and an engagement with processes, or perhaps more specifically, both create processes. For instance, the historian discerns processes of the past based on (always limited) archival and other sources, the engineer shapes the future based on (always limited) expectations and data. In their work for the future, more often than not, the engineering profession turns its attention to the past. Sometimes this is undertaken with the explicit aim to build on the past, while at other times, this is performed with the explicit aim that "the past is the key for the future" (Angelakis et al. 2012). According to this perspective, studying historical technologies would reveal their "apparent characteristics of durability, adaptability to the environment, and sustainability", and is often accompanied with the idea that such "technologies are the underpinning of modern achievements in water engineering and management practices" (ibid).

Without suggesting that these aims are problematic in themselves—an issue we will discuss in more detail later in the chapter—we would suggest that these water histories written by engineers are vulnerable to at least one risk. Where professional historians and archaeologists continuously discuss new findings and contrast these with existing empirical and theoretical claims—in similar ways that other scholars practice, including engineers—the historical work that engineers undertake is often based on secondary publications, ignores recent studies, and can rehearse well-worn narratives of triumphant progress. Furthermore, with engineering publications on historical issues typically focussed on descriptions of technologies—again, an issue we will return to later—it is the contextual and more socio-political material that tends to be repeated. Let us briefly review the topic of "qanats" to illustrate why this observation would be problematic—benefitting from a recent thematic issue in *Water History* on this technology (Issue 1, 2018).

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The term ‘qanat’ refers to the technology of subterranean galleries tapping groundwater, specifically in the Near East and western/central Iran. The technology is known elsewhere as “Mina de aqua”, “viajes de agua” or “galería drenante” in Spain, “khattāra” in Morocco, “foggāra” in the northern Sahara, “kārēz” in Iraq, Eastern Iran and Pakistan, “kan’erjing” in China, and “falaj” in Oman and the UAE (Charbonnier and Hopper 2018). Environments, length, depth and levels of investment of these structures are highly variable, but their purpose is always to “drain groundwater resources in their upstream section and channel the water to the surface by gravity” (Charbonnier and Hopper 2018).

Despite this diversity, one of the more persistent narratives within archaeology in the twentieth century has been that the origin of qanāts (always using that term) had to be sought in Achaemenid Persia in the sixth century BCE—modern Iran. The spread of qanats would have gone hand in hand with the expansion of the Persian Empires—and beyond, when, for example qanat technology would have moved from Spain to the Americas. Even when qanats were found in Oman that predated the Achaemenid period, this was explained by processes of technological diffusion (Potts 1990). Apparently, the option that the technology had moved from Oman to Iran was not taken seriously. Much of the claims of Persian qanat origin are based on the idea that the technology could only have been developed by particular civilizations, such as Ancient Persia. When qanats were in use elsewhere, in seemingly less developed societies, populations would only have maintained pre-existing Persian structures (Charbonnier and Hopper 2018). Such claims were also clearly suggesting that the large number of water tunnels in Iran, with their relative length and discharges, were the result of a long trajectory of development—with the assumption that this long trajectory meant that the Iranian plateau was the single region of origin.

Such a claim is not as straightforward as it appears. As Charbonnier and Hopper (2018) indicate, evidence suggests that this technology is more ancient than previously thought, and originates in many diverse environments. This new evidence brings these authors to suggest a polycentric origin of qanāt technology, mainly grounded in the observation that the societies with early examples of qanāts would not have had cultural ties. Despite this new evidence (see Yazdi and Khaneiki 2017; Boucharlat 2016 for further discussion), the popular narrative that qanats originate from (what we now call) Iran, and have been disseminated from there, remains strong. Such a narrative is problematic, as it suggests that a certain water capturing feature would be more unique than others (tunnels versus dams for example) without clear explanation why that would be the case. It is also problematic because a single origin still does not clarify why the technology could spread so successfully. Actually, the different types of groundwater tapping systems firmly indicate that the origin of the technology was more diverse than previously understood. Furthermore, although some qanat tunnels are impressive in scale, most qanats are rather short, and could have easily resulted from communities originally following a drying well into a hillside. With mining technologies also widely available among ancient human societies, the idea that qanats arose from a single origin is not as straightforward as many authors suggest.

In this chapter, we draw on a range of scholarship on water history, including our own and the manuscripts that have featured in the journal *Water History*—established in 2009—and on shared experiences within the International Water History Association to survey the field of water history. Nearly a decade of publication has introduced readers to a wide range of themes within water history, with contributions on rivers, urban water systems, irrigation, health, water quality, and state-led engineering, just to name a few. Meanwhile, case studies have focused on regions as far-flung as the southern United States, the North China Plain, Iran, and central Europe. Among the approaches to studying these relationships, there has been a particular focus on the importance of water technologies, which bring human desires, ideas, and expertise into relationships with physical possibilities and material limits. These relationships, as we show in this chapter, can be extremely complicated: it is the water historian’s task to disentangle these relationships between people and water over specific time periods.

In this regard, the water historian’s task is not unique: at the core of any historical scholarship is a drive to demonstrate and understand the complexity of the past. History is comprised of a confluence of specific contexts, causation, and contingencies that shape human relations and experiences over time. Writing history requires explicit historical analysis of the particular society, place or issue under examination, while avoiding neat and over-generalized linear trajectories of change over time. Although the past might point us in particular possible (future) directions, historians are mostly suspicious of the direct applicability of such lessons to the concerns of the present. This chapter does not make a case for water history as a “roadmap for the future” (Sabin 2010) that will show us the best way out of our current planetary predicament, but rather, a way of reading and understanding the complex paths we have travelled until now.

We continue the discussion by examining the grand narratives of water history, including those that are popular in works on water technologies and the work of one of the earliest water historians in the 1950s. We contrast this work to what had been published in the journal *Water History*, with a brief overview of the themes, periods, and regions that have been discussed. While on the one hand we argue that the grand narratives that purport to tell the story of water and society are not fit for purpose, this does not mean we think it is not possible or useful to discuss water histories in a comparative perspective. In the three sections of this chapter, we offer the reader three different historical narratives, that each show specific ways of historical actors engaging with water. We have selected three themes that will interest readers: deserts and water use, colonial irrigation, and water and climate change. We have drawn these examples from our own work on the intersections of agriculture, colonialism, and water in historical moments as varied as the ancient Hohokam culture of the American southwest to the climate anxieties of twentieth-century Australia. Finally, we conclude by reflecting on the relationships between small stories and great histories.

4.2 Grand Narratives

Water has been a key concern to human societies throughout history. Whether used for domestic, economic, or spiritual purposes, water has historically played a valuable role in processes of production, health, transport and communication (Boomgaard 2007; Collins 1990; Gill 2000; Hundley 1992; Lansing 1991; Lucero and Fash 2006; Marcus and Stanish 2005; Magnusson 2001; Pietz 2002; Rortajada 2000; Scarborough 2003; Steinberg 1991; Worster 1985). These processes depend on a reliable and predictable water supply: too much or too little water can wreak devastation, as catastrophic floods and famines have shown (Bankoff 2003; Davis 2000). In some cases, the human hand in such "natural" disasters is evident—secondary salinity, desertification, and dam failure are all consequences of water and land "management" (Reisner 1986; Davis 2007, 2016).

As a result of humans' material and spiritual dependence on water, the ways that human societies harness, access, and use water have significant implications for their organization. The importance attached to the availability of water tends to give rise to highly regulated water flows and access arrangements, which depend on particular rules, institutions, and hierarchies to mediate social relationships. Some scholars in the social sciences refer to such relationships as "hydro-social" in nature (eg. Swyngedouw 2009; Linton 2014). Whatever the concept applied, human-water relations also have implications for the ways that humans in societies make meaning out of water. For example, ideas about water often relate to its purity and transformability, which are expressed in Hindu rituals near the river Ganges, baptism rituals of Christian conversion, and ritual cleansing before Muslim prayer (Strang 2004, 2015; Morgan and Smith 2013).

The wide literature on the history of water and human societies tends to emphasise the centrality of water to the many environmental problems that face the world today—climate change, natural resource scarcity, pollution, and habitat destruction. How should water resources be developed and distributed? Who decides? Neither of these questions are new. Historicising a society's relationship to water is crucial to understanding our contemporary concerns, as it can invite more creative approaches to water management in the present. Yet we encourage water managers to be wary of certain historical accounts of the hydro-social relations of the past. 'Grand narratives' of water history often fall into one of two camps: either triumphalist stories of Western technological progress, or declensionist tales of mismanagement and ruin. In this section, we critique these approaches to water history and suggest that they fall short of helping us to understand the complexity of hydro-social relations in different cultures, places, and time periods. Their tendency towards simplification and narrative linearity misrepresents the past, and as a result, curtails their usefulness to understanding our current environmental crisis.

A significant early example of such grand narratives of the relationship between human societies and water is the work of the German-American historian Karl Wittfogel. In his book *Oriental Despotism: A Comparative Study of Total Power*, Wittfogel (1957) put forward a 'hydraulic hypothesis' to account for the development of different forms of political organisation. Absolutism, he argued, was the product of the ways that societies managed their particular hydrological endowments. In the so-called "hydraulic civilisations" of Egypt and Mesopotamia, for example, political power was in the hands of those who controlled water. The expansion of irrigation infrastructure in these arid and semi-arid climes (and the mobilisation of labour for its construction) facilitated the consolidation of the elite's power and their increased control over both people and the environment. This centralisation of power fostered what he called 'Oriental despotism', in contrast to the representative political systems that developed in the more well-watered lands of Western Europe. Wittfogel's hypothesis continues to provoke debate on the grounds of environmental determinism, the extent to which authoritarianism is inevitable in such conditions, and the Eurocentric assumptions that underlie his argument (Bichsel 2016, 359–60; see Harrower 2009, Wilkinson and Rayne 2010).

Many decades later, the association of water with political power, civilisation, and the essence of life continues. Anxieties about water scarcity and the prediction of water wars have produced a new generation of writers, who seek to navigate the history of humankind through water (eg. Scarborough 2003; Solomon 2010; Fagan 2011; Sedlak 2015). Many claim that the water crisis of today can be—and needs to be—explained in relation to global water history. Some go as far to suggest that "water is calling us to learn its lessons so that we can grow and prosper" (Priscoli 1998: 628). Certainly, the importance of water for societies from ancient Mesopotamia to twenty-first century China calls for the study of hydro-social relations through both archaeological and historical perspectives. Water history can reveal the structural foundations of material and social conditions today, such as the ongoing challenge of subsidence in Amsterdam that is the product of historic drainage works (Van Dam 2000; De Bruin and Schultz 2003). These experiences show how a particular intervention in the past continues to shape the hydro-social relations of the twenty-first century. Nevertheless, we encourage readers to approach such accounts with caution. Many authors of grand narratives appear to misconstrue the methods and aims of contemporary historical research and writing, in favour of their teleological ends.

We consider grand narrative approaches to water history to have four main failings. First, these histories often universalise the historical relationships between people and water, such that these become histories not of individuals, groups, and societies, but of humanity as a whole. Claims such as the declaration by archaeologist Fekri Hassan in his UNESCO study that the "history of water management is nothing less than the history of humankind" (Hassan 2011: 5) are symptomatic of this tendency. Second, a singular water history is depicted as a stream of linear events—a "series of stages" or "successive transformations" (Hassan 2011: 22, 23). These stages are defined as "those that have been adopted by the majority of human societies" (Hassan 2011: 24).

Third, this progressive version of water history favours the telling of ecological morality tales—of the centrality of water to the ultimate success or failure of societies. Take journalist Steven Solomon, for example, for whom the lesson is clear: "Repeatedly, leading civilizations have been those that transcended their natural water obstacles to unlock and leverage the often hidden benefits of the planet's most indispensable resource" (2010: 14). The last of the grand narrative failings is that, the progress or evolution of humankind through these stages is often depicted as logical, natural, and inevitable, overlooking the role of contingency and context in shaping the hydro-social relations of the past. The advance of a society through each stage is characterised as the result of a 'turning point' or 'breakthrough' on the march towards Western modernity (Solomon 2010). Elsewhere, Solomon describes societies as having 'failed' in their (progressive) relations with water, which seems at odds with the reality of their continued existence in the present. Similar stories of progress and decline can be found in many works on the history of engineering technology.

In Juuti et al. (2007), several historical situations concerning water and sanitation services are discussed, in order to show that history of water and sanitation is strongly linked to current and future water management and policy issues. The book is structured along a timeline of 'early systems' through a 'period of slow development' to 'modern urban infrastructure' and finally 'future challenges'. As the book does not specifically provide thematic cross-cutting discussions of the various chapters, the different cases remain relatively isolated from each other. Interestingly, the chronological structure of the book suggests a certain "order of development", but chapters dealing with comparable issues appear to be set in different timeframes. In other words, the overview does suggest a certain timeline of developments, but does not provide any further discussions of the cultural construction of this trajectory.

The historical overview of wastewater technologies provided by Laureano et al. (2014) is again interesting, as it offers evidence of human ingenuity and arrangements, and can serve as sources for inspiration. However, here the suggested chronological arrangement of the book might suggest that there is a logical order of these water-related applications. Such a claim, however, would have to be explained, at least as to how different parts of the globe would be connected over time—an issue we already encountered in the discussion on qanats, where the absence of evidence of such relationships was explicitly mobilized to refuse to acknowledge a connected and dynamic history of the technology. Fortunately, Laureano and colleagues do have something more to say about the relevance of their collection on issues of relations and chronology compared to Juuti et al. (2007).

Take, for example, their suggestion that "the history of wastewater offers the possibility to study the history of mankind from a very unique perspective" (Laureano et al. 2014). Indeed, many histories tend to ignore dirty subjects—with the possible exception of environmental history, possibly the closest to water history within the larger historical discipline. They suggest, however, that the technologies in question are direct proxies for the wealth and prosperity of a society. We would agree that investment opportunities should relate to technologies that have been applied, but we would also suggest that there are other issues to consider, such as cultural preference, climate, and political realities. As such, we do not consider that the concept of "technological improvements" should be used so loosely. Who decides what an improvement is? Applying an uncritical chronology of unrelated wastewater technologies in several regions ignores standard historical questions of power, environment, and influence. Instead, the book suggests a rather linear idea of progress of wastewater technological development, interrupted now and then by "barbaric raids and invasions" (ibid), as if without such raids there could not have been changes and interruptions. Both World Wars in the twentieth century may have been rather strong interruptions, but did not seem to have changed wastewater technologies. This uncritical idea of historical change is only highlighted by the authors' use of phrases, such as "a timeline about historical development of sanitation and wastewater management".

Another engagement with histories of water management establishes a series of stages through which a city's water management proceeds over time. According to a linear 'Urban Water Management Transitions Framework', a city's infrastructure develops from 'water supply' to sewers, drainage, waterways, and ultimately, to the water sensitive city (Brown et al. 2009). Although the original figure explicitly represented how these 'transitions' unfolded in the particular context of settler Australia (post-1788), subsequent iterations posited its stadial representation of progress towards a 'water sensitive city' as a more general depiction of how "how urban water management in cities generally transitions when moving towards sustainable urban water conditions" (Hoekstra et al. 2018, 9). Likewise, the aspirational 'water sensitive city' is the (ideal) "result of the several stages transited by the cities when looking for sustainability" (Rodriguez et al. 2014, 174). Excised from its original context, the figure has been interpreted as a means by which to "benchmark a city's progress (either forwards or backwards) at a macro scale" (Fisher-Jeffes et al. 2014, 1029). This representation of a smooth continuum from past to future states (however originally framed as not so linear in practice) flattens and erases the dynamism, agency, historical context, and material conditions that shaped the ways in which cities have historically managed water.

Using the past as a linear laboratory of technological progress suggests that particular historical developments are both normative and certainties. If there is anything that the historical discipline shows, however, it is that progress and linearity are very problematic terms. Just as current engineers deal with uncertain futures, so did our historical actors. In their times, it was not clear at all what "progress" would look like, let alone how it could be achieved. Apart from robbing historical actors of their agency, a linear idea of progress suggests not only that a single idea of progress exists, but also that that idea of progress can be found in historical and archaeological sources. However, as soon as we accept that historical actors would have had differences of opinions—just as we have in the twenty-first century—it would be strange that historical analysis could reconstruct a single timeline of development. The difficulty of doing so is highlighted by the partial nature of historical knowledge, drawn from archives that reflect the views of particular social groups.

Overviews such as the example provided by Rossi et al. (2009) offer a more careful approach to histories of water technology. Even though the term "ancient" is taken rather loosely—given that descriptions from the seventeenth, eighteenth and nineteenth century are included—the authors provide several interesting remarks about how they address concepts of historical development and progress. They start with the observation that the idea that "our generation has invented and discovered almost everything" is not correct (Rossi et al. 2009). Rather than viewing progress as "sudden unexpected spurts of individual brains", they view such change as a "limitless progression of experiments" (ibid). Without providing too much historical context, the book focuses on artefacts and the persons who first designed or described them. This is done, however, without any strong claim of linearity in the artefacts' development themselves. The authors mainly show the wide variety of technologies that all deal with the basic premise of providing water to society.

Similarly, more modest approaches in general overviews also steer away from claims of grand narratives and/or overarching chronologies. Archaeologist Steven Mithen, for instance, present a series of case studies from antiquity in his 2012 work, *Thirst: Water and Power in the Ancient World*. Although the book opens with the Hoover Dam as a symbol of the dependence on the modern world on "hydraulic engineering", this example is in this case a framing device to examine the extent to which this dynamic also characterised the hydro-social relations of the distant past. *Thirst*'s narrative is not a linear tale of technological progress, but rather a survey of the water management and hydraulic systems in the ancient world (Mithen 2012). The author also highlights a significant limitation of the study, which is relevant to the more ambitious studies we have already discussed—the difficulty of accessing "individual lives and experiences" beyond those of the elite that figure most in recorded history. The book's modest approach extends to the policy relevance of the hydro-social relations of the ancient world: *Thirst* concludes with the observation that the water challenges of the twenty-first century are unprecedented in their scale. Nevertheless, Mithen argues, "understanding the past enables us to see the present more clearly" (Mithen 2012; 296). As historians, we share this inclination toward the social and political value of water history, while cautioning against simplistic attempts to map our current sense of crisis onto those of societies past.

4.3 Towards Water Histories

The formal establishment of the International Water History Association (IWHA) in 2001 has helped to invigorate the study of water history on local, regional, and global levels. Increasing interest in water history was given further momentum in 2009 with the launch of IWHA's journal *Water History*, with the support of publishing house Springer. The new journal wanted to offer a message to its audience of readers and authors of inclusiveness—in the sense that the editors encouraged all kinds of water histories (not only those that examined European or modern contexts), and from all areas of scholarship (Tempelhoff et al. 2009). As water has been such an essential resource for human communities throughout the world, its study contributes to our understanding of economic, political, social, and environmental history, the history of science, medicine, technology, environmental sciences, and geography. Scholars from the humanities, social sciences, sciences, and engineering disciplines have all contributed to the field of water history. The coherence of water history as a subfield arises from its commitment to the disciplinary characteristics of history. Through their formulation of research questions, theoretical approaches, analytical methods, and use of sources, water historians can "transcend disciplinary boundaries" (Sewell 2005, 3) precisely when they remain true to the discipline of history, more precisely, "its careful use of archival or 'primary' sources, its insistence on meticulously accurate chronology, and its mastery of narrative" (Sewell 2005, 3).

The editors also sought complexity, in the sense of a historical narrative that delineated relations between various actors, settings and problems, which would require a high level of detail in the papers. In its 10 years' existence, *Water History* has managed to cover a diversity of topics—ranging from transportation and sanitation to water supply and issues of energy and governance. Given the multitude of possible topics, one of the policies of the journal has been to encourage the publication of thematic issues. The themes of these issues have included methodologies and interdisciplinarity, indigenous histories, Roman canals, and big dams. In addition to the thematic issues on Vienna and the Danube in 2013 and on urban cases in 2016, contributors to *Water History* have published widely on urban water histories in general. This is not unusual, given that water in cities is a major topic in current academic and policy circles. The increasing—real or perceived—water problems in urban areas, the trend of urbanization itself, and the theoretical question as to the extent to which the urban differs from the rural are topics of these historical studies—suggesting again that the history we write is strongly influenced by our own ideas, contexts, and interests.

Despite efforts from the outset to define 'water' as broadly and as inclusively as possible, *Water History* is yet to engage closely with salt water (although the thematic issue of June 2015 on writing water histories includes some articles on sea-related topics). As Rila Mukherjee argued in her 2015 paper, water history encapsulates the "connectedness" of "oceanic, riverine, deltaic and estuarine histories" (Mukherjee 2015, 172). In terms of time periods, contributions to *Water History* are predominantly about the Ancient world (that is, archaeological) and the Roman Empire, or focusing on the nineteenth and twentieth centuries. The term "Dark Ages" may no longer be in vogue among historians, but the scholarship on water history on what is generally labelled as the (European) medieval period is definitely scarce. In terms of regional focus, the majority of published articles in *Water History* discuss water issues in either Europe or Asia. This probably reflects two different realities: USA-based water historians find options to publish within the USA, and there are few water histories of Africa, given the challenges for scholars in terms of budgets, archival access, and publishing options.

The journal is not alone in these specific focus points and gaps. We find a comparable—although not completely similar—composition in terms of book and chapter titles when taking a look at the nine volumes that shape the book series *A History of Water*, which was initiated by Norwegian geographer Terje Tvedt in 2001. The first volume was published in 2006, the last in 2016. The series aims to provide "a long-term historical and comparative perspective to the understanding of the complex relationship between water and society".[1] In contrast to the monographs we discussed above, however, the series aims to analyse "history and societies' development—from the birth of civilization to the present day" by bringing "the myriad confluences between water and society into the picture". In order to do this, Tvedt and his co-editors have brought together 255 scholars from many disciplines and close to 100 countries. As such, the series may claim to provide a universal history of water, but the multitude of voices and accounts needed to do this in fact reinforce our position—that the study of the relations between water and societies requires an engagement with many empirical areas, and does not favour the imposition of a single global (or "grand") narrative.

Taken together, such published water histories provide a rich and varied set of case studies that illustrate the breadth of this growing field. This wealth of topics, time periods, and places indicate the difficulty of forming any overarching history on the relation between water and society. That does not mean, however, that we would argue that all arguments on more general issues or concepts are to be resisted. We do think that it is both possible and fruitful to discuss water histories in a comparative or general perspective. In the following sections, we will offer three of those perspectives, drawn from our own research. We chose these case studies for the mundane reason that we are familiar with our work, have easy access to it, and appreciate the opportunity to reflect on these interventions. The drawback is that we remain within most of the temporal and geographic boundaries we have identified as characteristic of the field. For instance, we discuss ancient and modern times, with little much in between, and we focus on fresh water (or lack of it), ignoring the vast tracts of salt water on planet Earth. Despite these limitations, these examples present opportunities for

[1] https://terjetvedt.w.uib.no/a-history-of-water/.

further discussion about the possibilities of water history in water resource management.

The first case study explores a landscape that seems almost the antithesis of water—the desert—and shows why deserts are relevant to water history. In the second, we focus on colonial irrigation engineers, how they altered the hydrology of landscapes, and how they constructed their professional identity in doing so. Finally, we extend our narrative about engineers into the late twentieth century, shifting to how they deal with and discuss issues of climate and climatic change.

4.4 Deserts and Irrigation

Water is often portrayed as the source of life. On the other end of the spectrum, deserts—or arid landscapes in general—are often portrayed as uninhabitable and useless, barriers instead of bridges. Just as elsewhere, human survival in arid regions depends on human ability to adapt to the natural environment. A major instrument in reshaping arid environments for human prospering is irrigation. The role of irrigation in intensifying production, allowing societies to grow and thrive, is well studied. Much of the available scholarship is produced in the light of a typical image of a full-scale, well-watered agricultural system—as if all irrigation is similar to a Chinese or Balinese terrace system. The stark binary between desert and irrigation system plays on the desire to use irrigation to transform harsh environments into an anthropogenic version of the Garden of Eden. Irrigation as the antidote for deserts has served, and perhaps still serves, the defenders of irrigation as a major symbol of civilization and progress against the marginality and backwardness of aridity. For emerging colonial societies, such images were valuable as they justified state initiatives to develop irrigation. For anthropologists, geographers, and engineers making careers in colonial circles, stressing the marginality of the arid lands to be cultivated and exploited was normal. Here, we show how this narrative of irrigation 'redeeming' the desert is indeed too simplistic (see also Davis 2007, 2016).

Certainly, dry conditions do provide societies challenges to overcome, but there have been many different ways of responding to these pressures. In some well-known irrigation-based societies such as the Hohokam in the Southwest of the United States of America, irrigation seems to have been of a supplemental nature—occasionally bringing water to fields in a growing season. Instead of meeting the demands of crops, as in rice systems where ample water is available, the Hohokam system stored moisture in the soil. Furthermore, Hohokam irrigated agriculture provided roughly 50% of food production, suggesting that exploiting the desert environment was at least as important as watering fields.

The Hohokam is an archaeological culture found along the middle Gila and Lower Salt rivers in the Phoenix basin in the Sonoran Desert—the following discussion is based on the Middle Gila area (Ertsen et al. 2014). The Hohokam culture is renowned for two things: its extensive irrigation canals, which were discovered by European colonists, and the apparent disappearance of Hohokam society after roughly 1450. The Hohokam occupied that area roughly between 0 CE and the middle of the fifteenth century CE.

Originally, as the name suggests, the Classic period (1150–1450 CE) was seen as the core period of a flourishing Hohokam civilization. However, flourishing may be an optimistic way of describing the way that Hohokam society dealt with the challenges of their environment. The Hohokam did develop monumental architecture and extensive hydraulic infrastructure, but life was likely harsh along the Salt and Gila Rivers, with overpopulation, environmental degradation, resource stress, and poor health. We can speculate that social fragmentation was a result of this. The story of the Hohokam is a popular fable for the risks that societies run when they rely on a single source of food production and when they overstress that system. However, the situation was more nuanced and complex than such accounts suggest.

First, even though irrigation was important for the Hohoham, it was not everything. Hohokam people also relied heavily on harvesting wild plants, and they hunted animals as well. At the moment, the best estimates suggest that about 50% of calorie contribution came from irrigated agriculture. The principal irrigated field crops were maize, beans, squash, and cotton. Agave was an important wild plant, used for both fiber and food, but it seems to have been grown within irrigated systems along canal banks as well. Mesquite was a very important wild plant, both for food and wood. Wild mammals were hunted, including rabbits/hares, rodents, antelopes, and mountain sheep, besides birds and fish. Second, in terms of water use, maintenance, and other tasks within the larger agenda of food production, recent research suggests that within the yearly labour and irrigation cycle, several production bottlenecks (in terms of activities to be performed) can be found, related to winter floods, summer monsoons, dry periods, maintenance, planting, harvest, gathering, hunt and the available workforce (Zoric 2015).

The largest bottleneck was in the harvest and planting transition period (late June—early August), as this overlapped with activities like gathering, canal cleaning, and irrigation. Another potential bottleneck was the period of harvesting, where winter floods might arrive to interrupt this activity. The last major bottleneck was the start of a new agricultural cycle in March/April, when floods could destroy both canals and the young crops on the fields. These floods appear to have occurred more frequently than was hitherto assumed. Flood events—very wet conditions—would have been a very critical factor for Hohokam desert agriculture.

The changes in Hohokam society in the second half of the Classic period (1150–1450 CE)—both in terms of lower population numbers and its ultimate disappearance—are often attributed to increasing aridity, but something else may have been happening. Researchers have recently found that the Hohokam area had relatively low ('apparent') water scarcity together with a low runoff variance between 750 and 1000 CE. This moderately dry and relatively calm period may have led to changing dietary contributions from gathering and sedentary (irrigated) farming, with irrigation becoming more important. Around 1150 CE (the beginning of the Early Classic era), increased water scarcity might have resulted in a larger, perhaps more hierarchical cooperative structure in the area.

The period between CE 1275 and 1350 shows the highest incidence of both droughts and floods, compared to the previous two centuries. During these same years, the Hohokam seemed to have witnessed a dispersal of the larger cooperative networks. Although it is not really possible to generalize for the whole Hohokam area, there is evidence that in wet periods people moved away from settlements; many people would have moved back in dry times. These movements might have led to the dispersal of population centers as the Hohokam sought better areas settle elsewhere. A community dependent on irrigation would need to repair the canal systems after a flood, but the higher flood frequency might have demanded more energy to keep the systems working than the gains from cooperative irrigation could sustain.

These specific interactions between humans, water and climate have made and changed the Hohokam and their irrigated landscape over time. One of the striking observations of Hohokam society could be that although the elements that support hydraulic states all appear to be present in the Salt and Gila basins—arid lands, single rivers, people—Hohokam society does not appear to have grown into such a complex state. The danger of a grand narrative approach to the Hohokam may be, however, that it aims to explain precisely why the Hohokam did not develop into a complex society, as if that is something problematic. In a way, such an approach ignores the need that all situations of state development and water need to be explained, whatever state formation process and hierarchical societies one encounters in the archaeological and/or historical record. Building a society is hard work. In the specific case of the Hohokam, recent work by Zhu et al. (2018) shows that the growing irrigation systems would have created problems that could not be solved anymore in ways that created equal options for all members of Hohokam society. With irrigation systems becoming larger, with higher numbers of people being involved, opportunities to keep the costs and benefits of irrigation disappeared. These processes of change in irrigation-based groups need to be understood in detail before one can assess its course of development. One cannot take the outcomes of processes of water-related societal development for granted just like that (Ertsen 2016).

4.5 Modern Water Knowledge: Colonial Irrigation

Irrigation was an important field for most major European colonial powers during the nineteenth and twentieth centuries, especially in areas that were considered as deserts or wasteland, such as parts of Africa, India, and Australia. Even in non-desert areas (with desert defined as arid land), like in the Netherlands East Indies, colonial powers stressed that they had to improve these territories. Engineers especially highlighted the inadequate nature of indigenous irrigation structures, and articulated the import of their own expertise to the civilizing mission in order to strengthen their position within the colonial bureaucracy. In quite a few colonial settings that heavily exploited irrigation, like in the Netherlands East Indies, French North Africa and the British Sudan, a change in colonial policy occurred in the late nineteenth century, moving from mere exploitation to a policy of productive imperialism, in which the colonies' productive capacities should be improved (Bolding 2004; see also Diemer 1990). Irrigation development in the colonies did not only serve the colonial powers, but also had to serve the needs of the colony itself, whether in terms of agricultural needs or environmental conditions.

Most irrigation systems developed by the British in British India were aiming to maximizing economic profit for the state through an increased land tax. Irrigated land was taxed higher than "dry" land, no matter the size of the harvest. The British irrigation approach employed the principle that 'water follows irrigated surface'. Especially after 1860, this policy was developed, when the British introduced the concept of protective irrigation. Protective schemes provided lower amounts of water to large numbers of acres. This water was not enough to realize maximum yields, but was assumed to be enough to produce a crop and especially save food crops during droughts—an assumption that had to be confirmed in actual practice. Water from the subcontinent's rivers was brought to large tracts of land through long canals with many outlets. In order to minimise operation costs, these schemes needed to function with a limited workforce. The schemes also needed to produce a fixed, predictable supply to the land and to be secured against human interference.

The colonial objective for an almost autonomous irrigation system required engineers to adapt to local conditions across the environmentally diverse sub-continent. In the Bombay Agency, British engineers designed structures that could discharge a constant volume independent of changes in canal flow (Bolding et al. 1995); in the Punjab, the translation was sought in an artefact delivering a fixed proportion of the canal flow (Van Halsema 2002). In 1922, engineer Crump introduced new proposals for outlets in the Punjab: The Open Flume and the Adjustable Proportional Module (APM). These basically similar structures consisted of a narrow throat with a sloping sill. Crump had designed his devices in such a way that they could deal with fluctuations in canal water levels and seasonal changes of water levels due to silting or scouring of canal beds (Van Halsema 2002). Crump's artefacts could maintain the delivery of a relatively stable water flow to fields within wide fluctuations of upstream water levels. This success was recognized: in 1944, Open Flume and APM outlets covered 67 percent of all outlets in the Punjab (Van Halsema 2002).

In West and North Africa, French engineers endeavoured to overcome what they saw as a degraded and unproductive landscape. One of their more challenging plans for irrigation had to be realized in the old inner delta of the Niger River (modern Mali). The delta region actually had been and still was an important area for the cultivation of cereals like millet and sorghum, using the soil moisture that was available after the flood season. Nevertheless, the French stressed its desolate character and compared its potential to the Nile—as early as 1899, when Emile Zola expressed the hope that the Niger could be supported in its conquest of the desert and creating a fertile valley to make the river the Nile of the French Empire. Creating the vast scheme proved difficult (Spitz 1949; Diemer 1990). In North Africa, however, French engineers had more success. There they aimed to return the region to its mythical past as the "Granary of Rome", which would cement themselves as successors to the Roman Empire (Davis 2007). Even in Northern Africa, however, the Roman ideal was initially challenged by an Egyptian image: Morocco's rivers would have to be converted into Niles, with the Sebou Plain under cotton generating as much wealth as the Nile Delta.

Around 1930, 'la politique des grands barrages' was formulated, the first irrigation development program for Morocco and indeed North Africa (Swearingen 1984). Another crucial colonial decision was a focus on high-value crops, such as citrus and other fruits, and vegetables. By this time, the rapidly developing agricultural economy of California had replaced Ancient Rome and Egypt as the model to emulate. California also inspired other countries, including Spain, South Africa, Argentina, Russia, Canada, Australia, and other French colonies such as Tunisia and Algeria.

Like their French counterparts, the agents of the Dutch empire were also interested in maximizing crop yields. As the Dutch colonial state levied taxes on actual harvests per unit of land, its aim was to maximize productivity of land. In contrast to the British in India, who tried to maximize the land area under irrigation, the Dutch colonial officials were more interested in maximizing labour inputs on agricultural land to maximize crop yields (Djuliati Suroyo 1987). For Dutch colonial irrigation water followed the irrigated crop: the appropriate amount of water should be distributed when the crop actually needed it. These ideas were translated into design requirements for water distribution structures, which resulted in very different structures compared to those devised in British India. In the Dutch East Indies, the ability to adjust and measure water flows was key. Irrigation management on Java had to be able to adjust to the different crop demands and available flows in the dry East Monsoon or the wet West Monsoon.

The cultivation of peasant crops with commercial crops was a particular issue for Dutch water managers. Peasant crops included rice, and non-irrigated crops such as *polowidjo*, while the commercial crop was sugar cane. Private sugar estates produced the sugar from the cane. They did not own the land to grow the sugar cane. Instead, they rented the land for a period of three years from the Javanese owner. In any other year, the same fields were used to grow rice in the West Monsoon or dry crops in the East Monsoon. With sugar factories renting new land and returning other land back to rice every year, each year the mosaic of fields with cane and rice changed. Furthermore, although rice and sugar cane were irrigated, their different requirements and rhythms created another complex water demand pattern. Rice needed water in the West Monsoon, but sugar cane needed its highest irrigation water gifts in the East Monsoon.

In Dutch colonial irrigation, water was distributed to rice and sugar cane through the same canal system—as the fields for both crops were the same over time—but at separate times. Sugar cane could be irrigated during the day in the East Monsoon, which meant that peasant crops had to be irrigated at night (or from late afternoon onwards). In order to assess the water delivered, which was crucial to determine whether the crop potential could be reached, water distributed for sugar cane was measured with moveable measuring weirs just before the water entered the field(s). This general description already reveals the two pillars of Dutch East Indian water management: (1) water measurement (although in the beginning only for sugar cane) and (2) the need to adjust water distribution over the years. In summary, the main difference between Dutch and British approaches regarding discharge structures in irrigation is a matter of adjustability (see Ertsen 2007, 2010 for further detail).

After World War II, the new political realities of independence for many former colonial areas caused a major shift in context for Dutch and other colonial irrigation activities. For Dutch engineers Indonesia had disappeared as secure field of practice. This new reality led many Dutch irrigation engineers to seek work in other countries, while engineers from other former colonial powers began working in independent Indonesia. These new working realities for Dutch irrigation engineers were explicitly taken into account to defend continuous attention for irrigation in Dutch engineering training programs at the universities of Delft and Wageningen. In Delft especially, irrigation engineering education continued to be an application of design prescriptions developed in the Netherlands East Indies. Until the 1980s, all irrigation professors in Delft had gained their working experience in the Netherlands East Indies. As a consequence, until the 1980s the Delft university irrigation approach reads like a collection of Netherlands East Indian design tools and artefacts. They may have been stripped from their original political, economic and even natural context, but remained firmly grounded in colonial practice. New engineers applied the well-known design practices of their respective colonial practices, which were treated as ‘the best possible method’ (Dahmen 1997).

Elsewhere, colonial irrigation practices also persist in post-colonial engineering activities (Van Halsema 2002; Mollinga 1998; Bolding et al. 1995; Pritchard 2012). Colonial British irrigation concepts, for instance, continue to influence irrigation in Pakistan and India to a large extent, while French engineers continue to build on the colonial lessons of the Maghreb. The colonial influence on irrigation methods similar informs the definition of different ‘schools’ or approaches: The Dutch in the former Netherlands East Indies, and the British in South Asia and Britain’s former African territories, the French in north-western Africa (Ertsen 2010; Dahmen 1997). Although the activities of international bodies such as the World Bank and the International Commission on Irrigation and Drainage suggest the existence of an international, homogeneous body of engineering knowledge, these separate approaches to irrigation continue to pervade the practice of water resource management (Plusquellec et al. 1994).

4.6 Water and Climate

As the Hohokam and the approaches of European empires to colonial irrigation suggest, how a society understands its climate (and the extent of climate variability) influences the ways that society manages its water resources. This understanding of climate is inherently historical, drawing directly on past experience or through information transmitted by oral and written cultures. The implication of such thinking is that humans have experienced the full range of climate extremes of a particular place, and that future conditions will not exceed these expectations. The principle of stationarity enshrines such an approach and provides the foundations for planning, designing and operating water infrastructure (Jones and Brooke 2005). It assumes that neither the prevailing extent of climatic variability nor the relationships between the major climatic variables, such as rainfall and temperature will change. Yet this basic principle of water management is being undermined by climatic change in a warming world—researchers at the US Geological Survey even declared “stationarity is dead” in 2008 (Milly et al. 2008). For water managers, the past is no longer a guide to the future. This shift indicates the extent to which historical thinking has been a part of water management over the last century (Morgan 2011a). In this section, we examine the Australian experience of coming to terms with this shift in perspective during the 1980s.

By the end of the 1980s, the increasing scientific and political concern about anthropogenic climate change and its likely impacts had begun to seriously challenge conventional approaches to environmental management. Although scientists had made significant advances in their understanding of the greenhouse effect in the 1970s and early 1980s, the potentially harmful effects of increasing atmospheric carbon dioxide levels were yet to stimulate political action. But a small group of scientists endeavoured to inform Western nations about the growing scientific knowledge of the enhanced greenhouse effect (Bodansky 2001, 27). The well-publicised Villach meetings of the mid-1980s proved to be especially influential for the ways in which scientists and policymakers imagined and planned for a greenhouse future.

At a joint meeting of the United Nations Environment Program, World Meteorological Organization (WMO), and International Council of Scientific Unions in 1985, participating scientists presented their findings on the emerging climate question. They agreed that increasing concentrations of greenhouse gases would lead to an unprecedented rise in global mean temperature in the first half of the twenty-first century. In the preface to the conference proceedings, the editors presented what is referred to as the ‘Villach Statement’. It read:

> Many important economic and social decisions are being made today on long-term projects … all based on the assumption that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption since the increasing concentrations of greenhouse gases are expected to cause a significant warming of the global climate in the next century (WMO 1985).

Climate data from the past could no longer provide a reliable guide to future conditions—the future was uncertain (Morgan 2011a, 162).

This developing climate change agenda prompted Australia’s peak scientific body, CSIRO (the Commonwealth Scientific and Industrial Research Organisation), and the federal government to convene the Greenhouse87 conference in late 1987 (Morgan 2011b, 99). Greenhouse87 was the first national meeting of scientists and resource managers to discuss the potential socioeconomic and environmental effects of anthropogenic climate change for Australia. The basis of these discussions was a CSIRO climate scenario for the year 2030, by which time the concentration of carbon dioxide in the atmosphere was expected to have doubled. The resulting changes in the atmospheric circulation would cause a decline in the rainfall of the southwest region of Western Australia, which extends from Geraldton to Esperance and is home to the overwhelming majority of the state's population (Pittock 1988, 42).

With less frequent rainfall and higher temperatures, this scenario depicted a significantly drier and warmer future for the southwest in the twenty-first century (Pittock 1988, 43). What made the prospect more alarming was that the southwest region had a reputation for having the most consistent and reliable rainfall in the nation. The rest of the continent is more susceptible to the effects of the El Nino-Southern Oscillation and other global climatic processes, which leads to extremely variable rainfall from year to year (Nicholls et al. 1997, 66). The southwest's renown for reliable rainfall had therefore played an important role in attracting colonists to the region and influenced the dryland agricultural practices that farmers had developed there since the early twentieth century (Morgan 2014). According to CSIRO's scenario, however, the region's future climate might be less suitable for prevailing practices of land and water management. Although this was not the first time that the declining rainfall of the southwest had been linked to anthropogenic climate change, Greenhouse87 altered the landscape for decision-making about the region's water resources (Morgan 2011a, 163).

Water managers from the state's water utility were invited to respond to this projection of a drier future for the southwest. The findings of the Villach meeting had resonated closely with their observations of a period of dry years since the 1970s with lower than normal winter rainfall (May, June, July). The contrast of this trend with the region's reputation for reliable rainfall had made the pattern all the more apparent to them. The local reservoirs were especially affected: at the time they provided seventy per cent of the region's potable water supplies (Mauger 1989, 16). To supplement the dams, the water utility relied increasingly on the groundwater reserves beneath the Swan Coastal Plain, but these too were susceptible to the drier conditions that were underway (Morgan 2015).

Three Western Australian water managers attended Greenhouse87 to present their utility's position on the implications of a changing climate in the southwest. Comparing the recent rainfall records to the trend identified in the Greenhouse87 scenario, they suggested that the expected drop in rainfall might have already commenced in about 1970 (Sadler et al. 1988, 299). As a result of the Greenhouse87 prediction, they assumed that the drying trend already underway would continue to the middle of the twenty-first century, leading to a twenty per cent reduction in rainfall and an even greater decline (over forty per cent) in the average streamflow of the region's rivers, due to the relationship between soils, climate and vegetation in catchment areas (Sadler et al. 1988, 299–300). With lower rainfall and streamflow, they expected that demand for potable water would surpass the available supplies more quickly than they had previously expected. This revised forecast suggested that water supplies could be insufficient by as early as 2020, rather than lasting until nearly 2040. Other sources of scheme water would have to be found and demand for water would have to be curtailed as soon as possible.

Planning for drier conditions in a warmer future required water managers to reconsider one of the very basic assumptions of water management, that of stationarity. Stationarity assumes that the climate conditions of the past will continue indefinitely. This relationship between the past, present and future was a comforting prospect for water managers who had to contend with other variables, such as water demand and water quality. But neither the drying trend since the 1970s nor the Greenhouse87 scenario suggested a stable, static or predictable climate. Instead, the local water managers saw that the southwest's climate could be variable and uncertain, with no guarantee that future climatic or hydrological conditions would reflect those of the past. They could no longer rely on the historical record alone to determine their planning for the future (Morgan 2015).

The Greenhouse87 prediction of a drier future thus led local water managers to reconsider the trends and fluctuations of rainfall and streamflow within the data set (Ludwig 2009, 80). Until the late 1980s, their planning had considered the entire meteorological record in the southwest region. But wetter conditions in the earlier half of the twentieth century had obscured the below average rainfall that had prevailed since about the drought of 1969. Restricting the historical record to the more recent past gave water managers what they believed to be a more realistic view of the future, given their new expectation of drier greenhouse conditions. Excluding the statistics from the wet 1930s and 1940s "reduce[d] the estimated yield of river resources by about 13 per cent", producing a vision of the past that was more congruent to the possibility of a drier southwest (Mauger 1989, 30). No longer were the run of dry years from the 1970s only temporary. Instead, these drier conditions were permanent and worsening as part of a broader trend of a changing global climate.

This new interpretation led water managers to dismiss an alternative climate scenario for the southwest region. At the Greenhouse88 Conference in November 1988, the Perthoffice of the Bureau of Meteorology presented a second scenario that considered the impact of a larger increase in greenhouse gas emissions than the Greenhouse87 option

(Hille 1989, 12). Higher greenhouse gas emissions, the meteorologists suggested, would affect the winter atmospheric conditions of the southwest and actually produce a slight increase in rainfall (Hille 1989, 13). But the lower rainfall levels since the 1970s suggested to water managers that an increase of rainfall in the future would be unlikely. Furthermore, the coincidence of the Greenhouse87 meeting with two winters of below average rainfall in the southwest reinforced their conviction that dry conditions could continue (WAWA 1987, 27). Their decision-making reflects the view that "environmental claims are most often honoured when they can piggyback on dramatic real-world events" (Ungar 1992, 483). Their position also reflected an adherence to the precautionary principle, which was later elucidated at the Rio conference in 1992 (Dovers and Handmer 1995, 92–93). The choice between the two scenarios was especially significant, as the different futures they presented would require very different planning strategies and investment in water infrastructure. If the water utility invested in infrastructure for lower winter rainfall but the predictions were not fulfilled, the consequences would be less disastrous than if they had invested for higher winter rainfall but received less.

The prediction for the future also altered the way water managers interpreted the past: no longer were the dry years of the 1970s and 1980s a temporary drought, but rather part of a long term, permanent and worsening trend, which required accelerated development of other sources of water supply for the thirsty region. This new understanding changed the way the historical data was incorporated into planning decisions Instead of utilising the entire historical record, the water managers took a much shorter excerpt of more recent data, which excluded earlier periods that did not conform to the emerging pattern of a drying region. Their pragmatic approach to the past suggests that both water managers and historians have a shared interest in exploring how the past can shed light on the circumstances of the present and the future.

4.7 Drop in the Ocean…

Whether drawing on the knowledge of past climates, emulating ancient civilisations, or perpetuating colonial irrigation methods, these case studies suggest that historical thinking has long permeated water management. Implicitly or otherwise, water managers turn to the ways that other peoples have addressed their own water challenges—challenges that are inherently about the relationships between society, water, and the environment more generally. We have critiqued grand narratives of water history especially for this reason. Grand narratives overlook how water histories are neither universal nor stable and neutral entities. Instead, water histories are mobilized for many different visions of the relationships between people and place.

As we have shown, European colonial powers portrayed themselves as the successors of earlier empires—if not Roman then certainly Mesopotamian or Egyptian. But they were not the first to position themselves in this way—the Assyrian empire likewise stressed the benevolent role of the imperial state in converting arid desert to irrigated paradise. Indeed, many early civilizations seem to have used irrigation agriculture to feed their (growing) population, including Mesopotamia, Egypt, the Indus Valley, China, Mexico and Peru. These ancient examples have encouraged scholars to interpret irrigation as fundamental to the growth of urban elites, forming the basis for grand narratives such as Wittfogel's model of hydraulic civilizations.

When the first issue of *Water History* was in preparation, the editors faced the task of identifying an appropriate symbol or image to encapsulate its vision. The editors sought to represent the field's unity and unique identity, without suggesting the existence of a single, overarching narrative, nor the impossibility of bringing different voices together (Tempelhoff et al. 2009). What would be a suitable picture for the first issue of a new journal? From the start, the editors agreed that an image that would reflect the grand narratives of water—like an aqueduct, huge canal or impressive dam—would be less desirable. Eventually, the editors selected a tide mill from Île de Bréhat in western France, constructed in the first half of the seventeenth century. As the name suggests, such structures generated energy from the tide.

> Often referred to in the past as 'salt mills', 'salt water mills' or 'sea mills', tide mills worked, on the simple principle of impounding water at high tide behind a barrier (or dam) on the foreshore. As the tide rose, water entered a tidal millpond through a sluice gate in the dam which closed at high water. When the tide dropped sufficiently to leave the waterwheel free of the water that would impede its rotation, the impounded water in the millpond was released to turn the wheel to allow milling to start. Milling ceased when the rising tide reached the waterwheel again or when the millpond was empty (McErlean and Crothers 2008, 16).

Selecting a tide mill for the journal's cover, the editors hoped, would encourage readers to reflect on *Water History*'s aims, the historical analysis of the material and cultural uses of water, and the meanings attached water in particular places. Tide mills operate in particular physical contexts, in terms of location, flows, and rhythms. The ideal location of a tide mill is on coasts with sufficient tidal range, preferably with small inlets or estuaries that can be easily blocked with a dam to provide the mill with its pond. In this sense, the cover image served an important purpose—to remind readers that seas and saltwater were as relevant to water history as freshwater. Studying a map of Europe reveals a concentration of mills in southeast England, the French west coast (where the Île de Bréhat example is located), Belgium, the Netherlands, north and southwest Spain, and southwest Portugal (McErlean and Crothers 2008; Minchinton 1979; Charlier et al. 2004; Van der Veur and Van Wijk 1999). From Western Europe the technology was exported to the Americas (Newman and Holton 2006) and Australia (Preston 2001). The discovery of seventh-century tide mills in Northern Ireland and a Roman tide mill on London's Fleet River in the past two decades suggests that tide mills have been in use in Europe for centuries (McErlean and Crothers 2008; Spain 2002).

The analysis of a tide mill also requires attention to its social position and the many ways relations were built with other agents in the wide society. Why would people be prepared to invest considerable amounts of labor and material to build and maintain such a structure? What forces drove the industries supported by the mill? Perhaps using the tide was their only choice, but it could also have been the best option for certain groups. The tide mill typically operates in salt water environments and only under particular conditions (such as storm swells, etc.). There is also a temporal dimension to the operation of the mill: as the tidal sequence shifts in time, milling operation times shift as well. Occasionally, mill operators had to work during the night to sustain production. How was the labor needed to maintain the mill organized? Who was responsible for organizing and managing this labor? Keeping the mill working was a clearly challenge, but the yields must have warranted the effort. Which products were made in the mill? How was the production transported to consumers or users, and over what distance?

The tide mill's technical features also require analysis. These include the tidal range, the resulting forces on the mill, and the energy required and delivered for particular uses. The engineering aspect of these structures is intriguing, as Spain's (2002) study of the possible Roman tide mill near London suggests. Studying such a structure, or finding one, also raises new questions about the social context in which it functioned. The discovery of the remains of two tide mills at the site of Nendrum Monastery (Northern Ireland) has stimulated reinterpretations of earlier ideas about the development of the monastery (McErlean and Crothers 2008). Excavations have shown that the reservoir that was once thought to be a fish pond, was in fact a mill pond for a tide mill. The monastery's resources, including its capacity for food production, the availability of labour and timber, and its willingness to invest these in the mill, had to be reconsidered.

All societies know spirituality, liberty, rationality, history, but in different ways that are continuously negotiated and contested over time. As such, all water histories are local and constructed, crafted in response to the changing relationships between people and water. Consequently, we encourage closer methodological attention to the agency of historical actors and to the specificity of the historical and environmental contexts. The wealth of water histories available points to the opportunities for more diverse and comparative studies of how people have understood and managed water in the past. Further still, they show how water histories are fundamental to the practice of water management, then, now and in the future.

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