United Nations
Educational, Scientific and
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International
Hydrological Programme

# WATER
## HISTORY FOR OUR TIMES

**IHP ESSAYS ON WATER HISTORY #02**

FEKRI HASSAN

International Hydrological Programme

**WATER** HISTORY FOR OUR TIMES

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# PREFACE

The history of water management is nothing less than the history of humankind in its attempts to eke out a living and, whenever possible, satisfy its desires. For human beings water was not merely a substance that sustained life. It was above all an elemental ingredient in the way people conceived of the world and a principal component in the expression of their thoughts and emotions.

For millions of years, hunters and gatherers depended on the wild plants and animals sustained by rainfall, which varied significantly from one place to another, but was on the whole insufficient to provide food for large, dense, settled populations. Around 10,000 years ago, the structure and dynamics of human societies were radically transformed due to the development of food production in favourable habitats all around the world. Communities that settled along the banks of great rivers and those that had access to abundant groundwater were faced with frequent food shortages to which they responded with novel social mechanisms. Since then, the reciprocal relationships between water supply, arable land, food production and social organization have led to significant transformations in the configurations and structural dynamics of human societies. In general, the management of water on both local and regional levels has undergone a series of historical transformations in association with significant developments in social organization.

These transformations included the invention and widespread use of irrigation and drainage methods, water-lifting devices, long-distance water transport technologies and storage facilities. In part, these transformations were stimulated by the emergence of urban centres and the growing demand for water as cities expanded and the spectrum of water-demanding activities broadened. Successful water management leading to greater food production was accompanied by a sustained increase in the size of the human population.

The world population rose rapidly after the advent of industry in the 1800s. Cities, once inhabited by a few thousand people, have mushroomed and multiplied in number. The acceleration of the pace of industry and a new set of services have created a new demand for water that was once primarily allocated to agriculture and food production. This extraordinary increase in the demand for water has been matched by an attack on the purity of water resources caused by industrial and urban pollutants. Over the last two decades, the realization that water shortages pose a serious threat to humanity has triggered a plethora of efforts by concerned individuals, scholars, organizations and institutions.

In 1977 the emerging problems related to water scarcity led to the United Nations Water Conference (Mar del Plata, Argentina). This was the first intergovernmental conference devoted exclusively to an attempt to find solutions to water problems and apply them at national, regional and international level in order to improve the social conditions of humankind, especially in developing countries. In 1980 the UN General Assembly proclaimed the Declaration of the International Drinking Water Supply and Sanitation Decade.

In 1992 the United Nations International Conference on Water and the Environment was organized in Dublin and the Conference on Environment and Development (the 'Earth Summit') was held in Rio de Janeiro, Brazil. Attended by 100 heads of state, the summit addressed urgent problems of water, the environment and socio-economic development. The assembled leaders signed the Convention on Climate Change and the Convention on Biological Diversity, endorsed the Rio Declaration and the Forest Principles, and adopted Agenda 21, a 300-page plan for achieving sustainable development in the twenty-first century.

Realizing the importance of understanding the social dimension of water management, the International Hydrological Programme (IHP), under its Secretary András Szöllösi-Nagy, began actively to develop various areas for action. One of the initiatives in the fifth phase of the programme (1996–2001) was an investigation into the history of water and civilization. I prepared a document entitled 'Water and Civilization' in collaboration with Jerry Delli Priscoli in 1997. IHP's efforts were paralleled by an initiative that led in 1996 to the establishment of the World Water Council (WWC) by renowned water specialists and international organizations, in response to increasing concern from the global community about world water issues. From 1 to 6 September 1997, the First Meeting of the General Assembly of members of the WWC was held in Montreal, Canada, during the Ninth World Water Congress of the International Water Resources Association (IWRA). I presented a paper entitled 'Water and Civilization: An Archaeological Perspective on Management and Development of Water Resources' during this meeting.

With the continued commitment to a further exploration of the social dimension, IHP organized a meeting to launch a book series entitled the *History of Water and Civilization* (HWC) and encouraged the establishment in 2001 of the International Water History Association (IWHA). As a founding member of the preparatory meeting for the UNESCO-IHP book series, I was appointed editor-in-chief of this long-term project in 2007, and served as President of IWHA from 2005 to 2007, promoting contributions from a broad spectrum of scholars on various aspects of water history.

From the initial survey and synthesis of water history and civilization at the Montreal meeting in 1997, it became clear that there is a need to re-conceptualize human history within a new theoretical formulation – one that would enable us to mine historical sources for a deeper understanding of the forces and dynamics that have shaped and steered human societies, in different habitats and with different historical trajectories, towards the contemporary world order with its myriad problems and potentialities. This prompted me to prepare a working document for the potential editors and authors of the HWC entitled 'Rewriting Water History'. Realizing that this piece might be of some benefit not only to historians of water, but to all those who are concerned with the social and historical dimensions of water management, I was asked by IHP to rework it so that it would also provide a summary of the key developments in the history of water and civilization. I have done this within an explanatory framework that emphasizes social dynamics in a continually changing world.

## ACKNOWLEDGMENTS

First and foremost, I wish to acknowledge my immense debt to András Szöllösi-Nagy, currently Rector of the UNESCO-IHE Institute for Water Education, for his unwavering support and deep commitment to an exploration of the relationships between society and water. I am also grateful for the many fruitful discussions with Jerry Delli Priscoli, currently editor-in-chief of *Water Policy*, with whom I undertook my first venture into the history of water and civilization. Over the years, further discussions in London, Paris, Montreal, Washington, D.C. and many other cities have not dimmed the spark generated by Jerry's insightful mind. I should also like to express my thanks to all the officers of IWHA who have, since its inception, provided the opportunity for scholars from all over the world to come together to rewrite water history. Those scholars have immensely enriched our knowledge of all aspects of water history, from ancient civilization to our recent past. I have also benefited enormously from discussions with distinguished members of the editorial board and editors of the IHP *History of Water and Civilization* series. Special thanks are due to Alexander Otte, who has been indispensable in coordinating this series. In addition, I am grateful to Lazlo Hyde, who organizes and participates in a short course at IHE on the history of water management. Exchanges among the students as well as the visiting lecturers have been invaluable. This essay is a token of my appreciation of all those whose ideas and actions have been such a source of inspiration.

# FOREWORD

**by Andras Szöllösi-Nagy**

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**and**

**J. Alberto Tejada-Guibert**

Director a.i. of the Division of Water Sciences
Secretary of the International Hydrological Programme

It is our great pleasure to see this exceptionally timely essay appear. When UNESCO started exploring water history over fifteen years ago, the idea was born out of the insight that we needed to understand better what had brought about the critical water situation the world was facing then. Although the situation has evolved, many difficulties and dramatic problems remain: the lack of access to water and sanitation, the impact of extreme events, climate change and pollution, to name but a few. It also remains as important as before to share the available water in a peaceful manner, and to build up our capacities to do so, in particular, skills and mutual understanding for cooperation. Only a sound and systematic look into our common, global history could do this. Fekri Hassan was among the first to advocate this approach, and represents as such a group of important scholars that unveiled a hitherto often forgotten part of the hydrological cycle: societies and cultures.

Water has always played an essential role in the history of humankind, but we did not always deal with it in the same way, in various places, cultures and times. Today's views and actions, the scientific hydrological approach and technological sophistication, and the traditional knowledge systems and practices, illustrate the tremendous human experience in dealing with water for over ten thousand years. This essay delivers a first attempt by one of the most accomplished scholars in water history to systematize how this wealth of knowledge and practices developed across the globe, and why certain strands of it spread over time, geographical and cultural space and our minds.

We are glad that Fekri Hassan is today the Editor-in-chief of the forthcoming UNESCO benchmark reference series History of Water and Civilization (HWC). This current book is the second IHP essay on water history. It draws on and accompanies the first volume of the HWC series that will appear in autumn 2011, Water History and Humanity, edited by Vernon Scarborough. Drawing from that volume's more than forty outstanding chapters, extensive references, including from conferences of the International Water History Association and from his lifelong intellectual and academic commitment to water history, Fekri Hassan has formulated the co-evolutionary theory of the historical transformations of water management that he describes in this truly remarkable essay.

We are convinced that this is not only an important contribution to a better understanding of the interaction of civilizations with water today, but will also help to guide our actions toward the future.

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# SECTION I

## INTRODUCTION

A history of water management is also a history of humankind. From the inception of our species, coping with the availability – or unavailability – of water resources has been an essential element of human beings' strategies for survival and well-being. Throughout history human ingenuity was manifest in the means by which water was procured, transported and allocated to various uses. The quality, distribution, seasonality and amount of water have been key determinants of subsistence, health and settlement potentials.

Today, humanity faces a serious challenge as perceptions of current water shortage and the ominous prospect of global droughts and changes in weather conditions are prompting policy-makers to seek out political solutions, and water professionals to find managerial and technical solutions to water scarcity. In this context a study of water history becomes more than an idle intellectual pursuit. It may be argued that conditions today are so different from those in the past that a study of water history is irrelevant. But such an argument would be overlooking the important transcultural structures, continuities and principles that inform human actions. Even within today's technologically and scientifically dominated water management systems, a hydrologist operates within a socially constituted tradition, shaped by an overall scientific and engineering paradigm, and historically accumulated and legitimized canons and 'facts'. Such a paradigm is in turn situated within a scientific paradigm, shaped and structured within the intellectual heritage of the Enlightenment. Placing this currently dominant approach in a wider historical context can help us to improve contemporary actions and consider their consequences from new angles.

It is not difficult to justify why we have, at a time of crisis, to draw attention to water, which I do in the first section of this essay. What was more difficult, but nonetheless essential, was the formulation of a new way to construe and write about water history. This effort demanded a re-examination of the target 'units' (community, society, culture and civilization) of historical investigation, and development of a transformational theory of water history based on a model of social dynamics. In this theory, different water communities are connected to each other by a web of dynamic relations, as affected by individual mobility, population movements, conquest, trade or marriage. These communities are often studied within the fixed framework of modern nation-states or regions, but this is misleading since the number, identity and borders of political units have always been in flux. What matters when applying a more transformational theory is that key innovations in water management appear in one or more regions within a particular socio-political system and a given ecological setting. Canals and drains, for example, appeared simultaneously and independently in the earliest riverside agrarian societies in different parts of the world.

By contrast, the Archimedes screw was invented in Alexandria during the third century Before the Common Era (BCE). From there it spread to far regions of the world. The spread, diffusion and transmission of innovations are not instantaneous or haphazard. Rather, they are often a function of the perceived utility of the innovation to the recipient group, the routes and means of communication, and the compatibility of the innovation with the host cultural system. Key innovations are those that have caused humanity to take a new turn, altering its previous direction. This has been the case with water-lifting devices, water mills and hydropower. An innovation has significant impact if it can be seen to go through stages of incubation, spread and development that lead to a specific state of water management; then another key innovation appears in turn, and it too begins to alter the prevailing state.

In an attempt to gain a better understanding of the relationship between water and society, I propose here a model of cultural dynamics based on how people who participate in instituting and managing social organization influence the allocation of labour, capital and energy, as well as the invention or appropriation of knowledge and technologies for water extraction, transport, lifting, distribution and treatment. Social organization interacts dynamically with strategies for producing food, basic and luxury goods, and the systems of capital formation, modes of economic transactions, and trade with other societies.

The course of human history, as presented below, has been shaped by the combined efforts of communities in many parts of the world who used their mental and physical faculties to survive in a variety of different environments. In doing so, they were acting, as we still do today, on the basis of their perceptions of the world and people around them. These perceptions are shaped at certain times, under certain circumstances, in a particular environmental setting. Water has been one of the most fundamental elements in our perception of the world because it is vital for life, and essential for the survival of vegetation and the creatures of the ecological chain.

From the dawn of prehistory until agriculture was widely adopted, the focus was on mobility as a means of tracking the seasonal rhythm of rainfall. By the time settled agriculture became the dominant mode, water management strategies included modest technological modifications of the landscape such as the digging of wells and canals, or the draining of swamps. They required intensive labour input and local organizational institutions. During a long period spanning the beginning of agriculture (from 10,000 years ago in some localities to several millennia later in others) until the first millennium BCE, the rise of complex social organizations led, in many instances, to the emergence of urban centres and an elite who resorted to a variety of strategies (including religion and coercion) to induce farmers to produce more than was required for their own needs so that the elite could collect it to support themselves and their functionaries. The urban, powerful elite, in addition, used *corvée* labour or slaves, and supported artists, artisans, seers, entertainers, and on occasions individuals who showed a talent for metaphysical speculation, historical narration, geographical exploration, medical treatment, astronomical observation and engineering. These individuals generated the ferment of an invisible global scientific community, learning from each other through travel, oral transmission or manuscripts. Their knowledge was passed on from one generation to the next as a stream that cascaded through the ages, growing in size and force as time passed.

The sustainability of scientific advances in Europe was in tandem with the transformation from merchant capitalism to imperialism and industrialization. At this stage of water management, financial capital became extremely important, as it is still today for the achievement of huge and technologically sophisticated hydraulic projects. Such projects have also benefited and contributed to new sources of energy generated from steam (water and the burning of fossil fuels), electricity (from fossil fuels and hydropower), and more recently nuclear energy. Today, the impact of human activities on the water cycle is tremendous and has begun to substantially influence its function.

From this perspective of evolving interdependencies we may wish to view human history in terms of a series of transformational stages.

The evolution of water management may thus be envisioned as a series of turns from one system to another. This transformational history is provided in **Section II**, which provides a brief explanation of the dynamics of the origins and consequences of history-bending developments in water history.

**Section III** explores a set of transhistorical paradigms that flow from the past into the present. They are transmitted through the processes of socialization and enculturation because they are bound to values and norms of profound importance to those who propagate them. They range from deeply ingrained notions of the spiritual and religious 'essence' of water to calculations of the economic cost and value of water, which have contributed to a recent historical paradigm.

In linking the past to the present, it was therefore important in **Section IV** to focus on one of the key historical issues that has perplexed and captured the attention of sociologists, historians and archaeologists, namely 'hydropolitics'. This issue has become popular among engineers and managers in the form of a theory developed by Karl Wittfogel in the 1950s. It was necessary to revisit this topic in order to draw attention to its complexity and the lack of empirical support for Wittfogel's theoretical foray.

Hydropolitics leads us to a consideration of the recent emphasis on water governance (**Section V**), and thus provides more evidence of how the future is being shaped by recent developments within and among nations.

Water governance, as we learn from history, is not separable from the domain of 'water ethics'. Hence it was essential to cap this essay with a metahistorical narrative which shifts from the strict confines of historical knowledge to an exploration of 'water wisdom' as may be gleaned from lessons learned from experience. This is the point at which history and human affairs come together as a basis for future human action (**Section VI**).

The essay concludes with an emphasis on the importance of tangible and intangible water heritage for providing palpable, vivid and thought-provoking traces of human ingenuity, creativity and values across the ages (**Section VII**). Terraced fields and water gardens; dams and grand canals; water wheels and water mills; *hamams* and ritual bathing; water songs and water art: these are only a few examples of a rich water heritage that can inform us beyond the written words of a dry text of a history that still shapes who we are, and influences what we will do.

## WHY WATER HISTORY?

Studying water history will not only inform us about why we opt for certain solutions, such as big dams versus traditional water technologies, and why we might approach a water crisis from the standpoint of a certain economic theory, but will also guide us in assessing the long-term consequences of specific managerial strategies. History can inform us how we got to be in this particular predicament, and may indeed provide us with means by which we can make informed choices concerning our future. We can only ignore history at our peril.

Historical studies also provide us with an understanding of the deeply rooted symbolic values of water, which play an essential role in how people today perceive water shortage and the solutions proposed to alleviate it.

Water history is important at a time of debates on the forces that are shaping our present (such as the so-called 'clash of civilizations'). Clearly a world history of water reveals how ideas and practices have spread in different directions at different times in a series of transcultural transmissions back and forth, with additions, modifications and improvements that link humanity as a single water community. We need only consider the history of water-lifting devices like the *saqiya* (see below), its transformation into the water mill and its transmission from the Arab world to Europe, or the influence of European hydraulic engineering on countries such as India and Egypt.

Water history may also unearth ancient water materials and technologies that could be suitable as durable and inexpensive substitutes for imported versions, such as ancient Egyptian and Roman mortars, and underground *qanats.* Thus, oral history and ethnographic research can be combined with traditional historical methods to expand our knowledge of such traditional and more remote historical water management systems.

Water history also clarifies how water management policies, practices and technologies are dynamically interrelated with political, ideological and economic forces in society, as well as to society's impact on and responses to external climatic and environmental events.

For example, droughts in England are not simply a matter of a reduction in rainfall, but a complex phenomenon that has to do with leaking pipes, profits, privatization, car washing, green lawns, toilets and showers, and swimming pools, among other things. In another example, conflict over water in the Nile Basin is an outcome of political suspicions precipitated from a colonial past, an explosion in population size and consumer demands, the economic interests advocated by the World Bank, and a persisting mental structure that regards agriculture and self-sufficiency as self-evident categories of thought. In fact, many Egyptians are totally unaware that their historical views of the bounty of the Nile are hardly compatible with their current share of Nile water.

# SECTION II

## HISTORICAL TRANSFORMATIONS OF WATER MANAGEMENT: A PUNCTUATED, CO-EVOLUTIONARY THEORY

One of the key notions in this work is that although societies vary immensely in their media of communication, manners and customs, dress codes, songs, festivals and architecture (Wylson, 1986), just to mention a few examples, they share basic structural dynamics bound with certain regularities imposed by a common biological and psychological inheritance, as well as common experiences conditioned by our life cycle from birth to death. Among the most common experiences is our relationship with water, on both the biological and psychological levels.

It is also based on the premise that social organization and water management technologies and strategies have co-evolved through a series of stages marked by long-term gradual, cumulative change, and relatively short-term episodes characterized by rapid and quantum leaps. This mode of cultural evolution shares some elements with the theory of punctuated equilibrium (Eldredge and Gould, 1972), but it places more emphasis on punctuated evolutionary dynamics that do not emphasize the notion of equilibrium. Also, instead of focusing on peripheral isolates, this theory of culture change emphasizes regional differentiation and regional interactive pools, as well as critical climatic transitions.

It is important at this point to emphasize that the course of cultural evolution involved a progressive increase in the number of interconnected communities and individuals which expanded the size of innovators and hence the number of innovations. The expansion of population into a diversity of ecological habitats also provided humanity with a broad spectrum of resources.

Throughout this evolutionary climb (to higher population numbers, greater food production and greater complexity), the role of relatively isolated or marginalized communities as hotbeds of innovation was complemented by the eventual diffusion of innovations to other world communities. Such groups included foragers who lived in precarious semi-arid habitats; the Greeks and Persians on the outskirts of the greater world civilizations in Egypt and Mesopotamia; the Arabs on the margins of the Byzantine and Sassanid empires; the Spanish and Portuguese on the southern periphery of the dominions of France, Germany and Austria; then the British and the Dutch, and finally the people of the United States. It has to be emphasized that the peoples of these areas were not isolated cultural islands. They were often at the edge of large cultural entities, and were interconnected through trade or other means of exchange.

The main elements of the theory presented here include geography/ecology/climate, population and knowledge. Advances in knowledge were linked to the size of the pool of interconnected innovators, the instrumentalities that promoted and speeded communication among innovators, the media of information transfer and processing, and access to previous bodies of knowledge. No single nation or region was ever totally isolated for long periods of time from others, but the rise and fall of empires led to shifts in regional centres of power (which often attracted talented artisans and savants from far away), turning cultural peripheries into cultural centres before they surrendered power to other regions. Today, the rise of China, India and Brazil may usher in a new phase in the arrangement of world powers.

This theoretical prelude allows us to begin an examination of water's role in human history in terms of a series of successive transformations that may be used heuristically to refer to 'ages'. For lack of a better term, 'ages' designates a set of cultural parameters that have a historical time range, over a large or influential area of the world, but are neither static historical stages nor marked by sharp time boundaries, of the same time value everywhere. These transformations mark structural changes in the relationship between water management and the principal forces that structure the dynamics of a society.

This transformational theory is based on a sequence of history-bending developments, each leading to a new, hitherto unforeseen destination, but firmly grounded in the path travelled before. At each node between one leg and another there are options and multiple directions possible. Certain options are generally deemed more favourable than others given the short-term prospects and the interests of those in charge of making decisions. The directions that have shaped the trajectory of the human journey are those that have been adopted by the majority of human societies.

The first history-bending transformation followed the invention and spread of cultivated agriculture and the herding of animals for food production, after a long prelude of foraging, hunting, fowling and fishing. This period lasted from the dawn of humankind until about 10,000 years ago, when some societies adopted agriculture as a means of subsistence, which was rapidly followed by digging canals, drains and wells. In the context of agriculture and with the rise of cities, the development of water-lifting devices was a prerequisite for further developments, particularly in the modification of the water wheel (*saqiya* or *noria*) into a water mill, which helped accelerate the transition into an age of industrial production.

These transformations are related to key structural changes in human societies. The invention and spread of artificial irrigation techniques was a result of rural community initiatives. The rise of state societies subsumed and overshadowed the efforts of local communities. It also created opportunities for occasional regional hydraulic projects either to supply cities with water or to dig canals for trade or warfare.

The earliest states evolved into militaristic empires that rose and fell in succession in many parts of the world. By the end of the Roman Empire, changing conditions in

Europe and later the spread of Islam created a different world order, which capitalized on the accumulated knowledge in water management, especially the technology of irrigation in arid lands, the abstraction of groundwater, and the use of water-lifting devices. At that time, the earlier invention of the water wheel (*saqiya* or *noria*) proved to be revolutionary. The water wheel was modified for industrial purposes in combination with trade in the context of merchant capitalism.

The social, political, financial and economic dynamics in Europe associated with merchant capitalism in medieval times led to the promotion of water sciences and technologies. For the first time, Europe became the seat of a significant and history-bending development – the steam engine. The transformation of water into steam led to a new age of water sciences and technology. In rapid sequence, water technologies evolved into the use of turbines for the generation of hydropower, continuing the legacy of the water wheels. By the end of the twentieth century, the building of huge dams and reservoirs coupled with investments by the private sector and governments marked a transition to river basin management and transboundary institutional organizations, which today are transforming the way water is managed on a local and a global scale.

## Early Artificial Irrigation

The earliest artificial irrigation civilizations emerged along the banks of the Nile, the Euphrates, the Indus and the Yellow rivers. The great civilizations of Mesoamerica, however, depended on harvesting surface runoff, small rivers, lakes and groundwater.

**The River Nile in Egypt.** Fed by rainfall in Equatorial Africa and Ethiopia, the Nile helped develop a narrow, fertile floodplain where farmers became attuned to an annual cycle dominated by summer floods. In the beginning water flowed into the natural basins of the floodplain (Hassan, 1993). However, the floodplain was constantly changing as the Nile shifted its course. In addition, high and low floods posed a severe threat to the farming villages and adjacent fields. Protective embankments were constructed, and drains were used to get rid of excess water. In times of drought, canals were extended to bring water to outlying grounds. Eventually a system of cross-dykes transversal to the floodplain was constructed, allowing floodwater and soil moisture to be retained before the water was allowed to flow to farmers downstream. Communities collaborated in digging canals, dykes and embankments.

Although agriculture was introduced to Egypt 7,000 years ago, a state-level organization unifying the communities of the whole country did not emerge until nearly 2,000 years later. The state was ruled by a king who was believed to be of divine descent, and had a government that was in charge of collecting taxes and overseeing the royal funerary and temple projects. There is no concrete evidence that the state was involved in developing or maintaining large-scale irrigation projects until about 1880 BCE (3,880 years before the present, BP) during the Middle Kingdom. At an earlier time, a dam (Sadd El-Kafara), the oldest of its kind in the world, was constructed about 4,500 years ago across a desert wadi known as Wadi Garawi. It was destroyed by a flash flood before it was completed. It is not clear why it was built, but it might have been an unsuccessful experiment in dam construction, using pyramid-building technologies. By contrast, the Middle Kingdom kings were responding to a severe drought (4,200 years ago) which contributed to the collapse of centralized government. The Middle Kingdom project (1880–1800 BCE) controlled water flow from a branch of the Nile River into a depression in the Faiyum and creating a rich agricultural royal estate not too far from the capital at Memphis. The dam, however, did not withstand the test of time and was destroyed by violent floods, only to be reconstructed by the Ptolemies (305–30 BCE). It has since been rehabilitated several times, and is now a part of the centralized system of water management that depends on high dams, barrages, and a network of canals and drains.

**Mesopotamia.** In Mesopotamia (Postgate, 1992; Wilkinson, 2003), where agriculture preceded that of the Nile Valley, the volume of flood discharge from the Tigris and Euphrates is significantly variable. Furthermore floods in the lower reaches of the Tigris are extremely erratic and dangerous. The interannual variability in flood discharge and frequent decadal variability (30–50 year intervals) were among the primary stimuli for both social cooperation and early irrigation works. Rivers in Mesopotamia are also more likely to silt up. Canals appear to have been one of the earliest inventions developed to ensure sufficient water supply. The oldest evidence of canals indicates they were dug by removing silt from clogged channels; these date back to 8600 BP, well before the rise of the state in 5400 BP. Over three millennia, canals achieved sufficient length to irrigate tracts of up to 25 sq. km.

**The Indus civilization.** Other civilizations nurtured by great rivers include the Indus civilization (Possehl, 2002). Covering a vast area of 125,000 sq. km, the Indus system, fed by monsoonal rainfall, is at least four times greater than that of Egypt (cultivated area 32,469 sq. km). Unlike Egypt, the Indus Valley benefited, within a distance similar to that from Aswan to Cairo, from the existence of numerous tributaries which prevented control of the whole valley by any single group. In Egypt, the Nile above the Delta is linear and navigable over its whole length north of Aswan. This makes it possible to control and administer all the villages and towns along its banks, which are only a few kilometres from the channel and are bounded east and west by a barren desert landscape.

The emergence of urban centres such as Mohenjo-Daro and Harappa in the Indus Valley was probably related to their involvement in trade or their function as community religious centres which spread notions of equality, health, purity, cooperation and ascetic attitudes to life. The success of their teachings is perhaps manifest in the homogeneity of Harappan society over such an extensive territory, lack of variability in house sizes and forms, and the absence of nutritional stress. In the following centuries, India made numerous contributions to hydraulics and water management (Mate, 1998, and below).

**China.** In China, rice growing and planting was practised in the southern part of the Yangtze River Basin and dates back 6,000 years, but it is believed by some that rice was cultivated earlier. Ancient paddy fields were discovered and found to have existed more than 6,000 years ago in Jiangshu Province as well as in Hunan Province. The paddy fields were associated with irrigation canals, ditches, wells and ponds.

According to the legend of ‘Combating the Waters by the Great Yu’, transferring and draining water as a flood control technique goes back more than 4,000 years:

> *an irrigation system made up of main canals, branch canals, and field ditches have been found near the capital of the Shang Dynasty (1766/1600–1122/1040 BCE). It comprises a network of irrigation canals subdividing the land into several rectangular farms with water head drop between canals and farms. This shows that the planning of small-scale, on-farm irrigation systems involved an advanced level of irrigation technology. However, it was not until 255 BCE that large-scale construction of major irrigation projects in the Qin and Han dynasties was attempted.* (Gu et al., in press)

One of China’s ancient systems of dams, dykes and sluices has helped control water and irrigate the Chengdu Basin of central Sichuan, a UNESCO World Heritage site, since the third century BCE. The system included dividing and channelling the Minjiang River.

In China canals were used for military operations during the Warring States Period (471–221 BCE), and for trade in the fifth century BCE. The construction of a grand canal began from 618 and 609 CE with a labour force of 5 million. Segments were added to the canal by 735 during the Tang Dynasty. Locks were used to facilitate navigation. Additions to the Grand Canal from 960 to 1279 made it 1,800 km long. The canal was renovated in 1411–1415.

**The Americas.** In the Americas, cultivation of domestic squash, peanuts, cotton and coca using irrigation as a part of an individual family activity may have started about 7,000 years ago, as indicated by small earthen canals found in the Central Andean Cordillera on the banks of the Rio Nanchoc. Between 6,000 and 4,500 years ago, superimposed contour canals were known (Dillehay et al., 2005). On the coast, small irrigation canals allowed farming during wet and dry seasons 4,500 years ago. The irrigation-based civilization was characterized by monumental flat-topped platform mounds with large summit buildings (Moseley, in press).

The oldest canals in North America date to approximately 1200 BCE, like the valley bottom perennial stream canal system in Tucson, Arizona, and the canal near Zuni Pueblo, New Mexico dating back to around 1000 BCE. Canals in Mesoamerica also go back to around that time, but larger and more complex systems were developed near the end of the Classical Period (200 to 800 CE). The earliest use of ditches was for drainage to reclaim wetlands (Neely and Doolittle, 2004).

In Mesoamerica, water wells in the village of San Marcos in the Tehuacán Valley date to a time between 7900 and 4000 BCE. Drains, canals, dams, terraces and reservoirs are also known from about the same period in Tlaxcala, Morelos and Oaxaca, but occur later elsewhere in highland Mesoamerica (Neely, 2005).

One of the particularly elaborate ways of growing crops in the lake region and swamps of the Basin of Mexico was the invention of a method to create artificial farming plots, through a combination of drainage and piling-up of mud, known as *chinampas* (Nichols and Frederick, 1993; Nichols et al., 2006).

In general, *chinampas* are rectangular fields 2 to 4 m wide and 20 to 40 m long, surrounded on three or four sides by canals wide enough to allow a canoe to pass. *Chinampa* farmers fence an area with wattle, and then pile up layers of lake-bottom mud, decayed vegetation or dirt to raise the field surface to about 1 m above the water level. The proximity of the soil to the water table provides adequate moisture for crops. In addition, irrigation water is readily available from the canals. Water also raises night-time temperatures, reducing the chance of frosts. Soil fertility is maintained by periodically adding vegetation, household refuse, and organic-rich silt dredged up from the canals to the field surface. Among their labour-intensive practices, *chinampa* farmers plant seeds in specially prepared seedbeds, later transplanting the seedlings into the fields. In its most intensive form, cultivation is year-round (Frederick, 2007).

Farmers cultivated maize, beans, squash, amaranth, tomatoes and chilli peppers. *Chinampa* agriculture may have begun as early as the Formative Period, around 1400 BCE, or about 200 BCE, but no fields have been securely dated prior to the Early Aztec/Middle Post-classic period (1150–1350 CE).

*Chinampas* provided the agrarian basis for the Aztec Empire. The Aztecs were people of Central Mexico who transformed city-states into an empire. By the thirteenth century, the Valley of Mexico became the core area of the Aztecs, with their capital Tenochtitlan built on Lake Texcoco. The capital was ringed with *chinampas*. The Aztecs conducted campaigns to control surrounding regions and led efforts to increase the extent of *chinampas* (Evans, 2008).

By the time of the Spanish conquest of Mexico, more than 1000 sq. km of shallow lakes in the Basin of Mexico had been converted into *chinampas.* With the destruction of the dams and sluice gates during the conquest, many *chinampa* fields were abandoned. Today, a few pockets of *chinampa* agriculture survive, including the popular tourist attraction, the Floating Gardens of Xochimilco.

Irrigation in lowland Mesoamerica, where the Maya civilization developed (400 BCE–900 CE), depended on surface runoff, considering that rainfall varies from 1,350 to 2,000 mm/year, in contrast with the arid and semi-arid regions where irrigation began earlier, as in Egypt, Mesopotamia and China. The Maya modified naturally occurring depressions into shallow lakes and wetlands, locally known as *bajos*, for year-round water storage. Farming was based on a *milpa* system. Most of the time, a *milpa* is a field recently cleared, where farmers cultivate maize, avocados, squash and bean, melon, tomatoes, chilli peppers and sweet potato. However, the Maya farmers had to contend with the hazards of excessive flooding, devastating hurricanes, murky waters, massive erosion, land and mud slides, and the accumulation of debris which clogged rivers and made them unsuitable for navigation. Farmers also suffered from crop damage during the rainy season. To make matters worse, the beginning of the rainy season was unpredictable, which made it difficult to schedule farming activities. If the rain came earlier than usual, seeds would not germinate, and farmers could not burn the wet vegetation in *milpas*; if the rainy season began later than usual, seeds could rot. During the dry season when water was scarce and of poor quality, farmers fetched water from natural wells (*aguadas*) and artificial wells (*cenotes*), as well as from low-lying rivers and lakes (Lucero, 2006; Lucero and Fash, 2006 for information in this section).

Unlike in the valleys of great rivers, arable soil was patchy in distribution, and dispersed in a variety of landforms such as hills and escarpments. In this environment, small-scale water management strategies included *aguadas*, dams, canals and terracing. Large centres, as in Tikal, which could support communities when water was not naturally available, had large reservoirs.

***Qanats***. In the Old World, by the first millennium BCE the development of artificial irrigation included a novel method to make use of groundwater in desert regions. The new method, commonly called *qanat*, *keriz*, *foggara* or *khettara*, depended on the development of tunnelling technology, well-digging and land surveying. In this ingenious hydraulic structure, groundwater was abstracted from a mother-well and transferred via underground tunnels over long distances to irrigate fields and supply towns in some of the most arid places in the world (Lightfoot, 1997).

The invention of *qanats* has long been thought to have taken place in Iran, but recent evidence suggests that the oldest documentation of *qanats* is in south-east Arabia around 3100–3000 BP. By 2300 BP, *qanat* technology had spread rapidly in the arid zone extending from Pakistan to the Egyptian desert. It spread later as far as China and Spain (Kobori, 1973).

About the time *qanats* were being developed, large reservoirs were also being excavated in India (2700 BP). In the New World, raised fields were being exploited in highland Mesoamerica (ca. 2500 BP). These independent inventions were probably a response to a global climatic event of increasing aridity that occurred around 2700–2500 BP. Coincident with these innovations was the use of deep wells in the Mediterranean (2800 BP) and the use of water in military operations during the

Warring States period in China (2700–2500 BP). The *qanats* represent the first genre of large-scale water works requiring sophisticated engineering. The link between engineering and water works began also with the invention of the *shaduf* water-lifting device, presumably in Mesopotamia around 4400–4200 BP. Could it also be related to the 4200 BP droughts?

**Early artificial irrigation in social context.** Almost invariably, the rise of a great civilization was a function of large tracts of fertile land, ample sources of water, great rivers as in Egypt, Mesopotamia, India and China, or abundant rainfall, as in Mesoamerica. Irrigation agriculture is inherently unstable because of the unpredictability of rain and frequent crop failures for other reasons. Accordingly one of the main strategies that led to the rise of state-level social organization was cooperation and collaboration among neighbouring farming settlements to form incipient regional water communities, strengthened and supported by religious rituals and myths. This was often associated with the construction of temples as centres of religious, ceremonial and ritual activities, which contributed not only to social solidarity, but also to the alleviation of anxiety, and fleeting but memorable moments of artistic, spiritual and recreational extravaganzas. Elements of this are still seen in *maulids* and saints' festivals in the Islamic and Christian worlds respectively.

Another development that accompanied early state societies and is still with us today was the institution of warfare. Initially the reasons for war were conquest to annex more land and secure labour to satisfy the needs of a growing body of state officials and managers, who developed religion into a state institution and transformed collaborative state societies into tributary state societies and eventually through warfare into tributary empires.

One of the main contributions of the state to water history was its support of innovations in water sciences and technologies. Early civilizations characterized by low-tech, labour-intensive artificial irrigation societies may thus be considered as the formative basis for the age of water industry during the medieval period, which paved the way for our own modern civilization. The Egyptians, for example, developed a scientific method of gauging the height of floods using a standardized unit of measurement. They also pioneered bid dam construction. But some of the outstanding mechanical inventions were developed in Mesopotamia and Persia, leading to the age of water-lifting technology.

## The Age of Water-Lifting Technology

This period began with the widespread use of water-lifting devices such as the *shaduf*, the *saqiya/noria* and the Archimedean screw (4,400 to 2,200 years ago). Water-lifting techniques refined during the first millennium BCE were often associated with urban water supply, irrigation of gardens and orchards, digging canals for transport, or on occasions with ambitious irrigation works such as elaborate aqueducts, subterranean water abstraction and delivery tunnels (*qanats*). This mid-level technological leap also entailed a move to the use of water, wind and animals as sources of energy (Fraenkel, 1986; Fraenkel and Thake, 2007).

**The *shaduf*.** Among the earliest water-lifting devices was the *shaduf* (Bazza, 2006; Mays, 2008), which depends on the principle of gravity to lift water from one level to another. In order to achieve this, a long branch is used as a pole, suspended asymmetrically so that it can swing as a lever on an upright support frame built from mud. The shorter section (about one-fifth of the length of the pole) has a weighty stone or a lump of mud attached to its outer end. The longer section of the pole is attached by a rope to a bucket or a waterproofed basket. The rope is pulled down so that the bucket or basket dips below the water level in a canal or well. When the rope is released the stone or mud weight pulls the other end of the pole down and sends the water-filled bucket upwards. The pole is then swung round and the bucket is emptied into a water channel at a higher level, which carries the water to the field plot. Sometimes two or more *shadufs* are used in sequence to lift water to a much higher level. The *shaduf*, so characteristic of the rural landscape in Egypt, was originally developed in Mesopotamia. It appears on a seal dating to 2000 BCE. It spread from Mesopotamia to many countries including Greece, and made its way into Europe. It was used until recently in Finland, where a model is installed in one of the streets of Tampere. The *shaduf* normally lifts water from a depth of 3 m, with a range from 2 to 6 m, and can deliver as much as 500 to 2,500 litres per day.

**The *saqiya*.** Another relatively elaborate early water device is the *noria* or *saqiya* (water wheel). The *noria* is a vertical water wheel, normally a few metres in diameter, although some wheels of very large dimensions were developed later. These wheels were initially turned by animals, although a later version used direct water power. The *noria* was the first known device that used a system of gears to transfer energy from one spatial dimension to another (horizontal to vertical). Buckets or pots made of wood, bamboo or pottery were attached by chains or ropes to the rim of the wheel, which was set to be partly above and partly below the water level in the source well or stream. As the machine rotated, each bucket in turn would dip below the water level and fill with water. When a full bucket reached the top of the rotation, it would be emptied into a trough, then return empty to the bottom of the wheel to repeat the process. In the water-driven wheel, radial blades or paddles which were pushed by the flowing water when the turning wheel immersed them were used to rotate the wheel.

It is not clear where the *noria* was invented. A hint that it was in operation comes from the time of the Achaemenid Persian conquest of the Indus Valley (518 BCE). Indian texts dating from around 350 BCE suggest that it was already known there at that time. It must have reached the Mediterranean world following the encounters between Greeks and Persians (in the fourth century BCE) and the emergence of Rome (in the third century BCE). It is likely to have been transmitted from Persia to Greece during the third century. It perhaps spread to Rome from Persia, as it was introduced to Egypt during the Persian conquest (525–404 and 343–332 BCE). Among the wheels described during the late third and early second century BCE is what appears to be a vertical undershot water wheel used for hoisting water. The important citation of water wheels in the writings of Vitruvius suggests that they spread from Greece to Rome in the first century BCE, and they were apparently diffused to China during the second century CE.

**The Archimedean screw.** The other revolutionary invention of this era was the Archimedean (also called the Alexandrian or Egyptian) screw, dating to the third century BCE. It was first used in Egypt. Diodorus Siculus described the Egyptian screw, and how it was used by Roman slaves to draw out water from Spanish mines. He marvelled at this ingenious invention, which moved enormous amounts of water with minimal labour (*Bibliotheca*, Book V, 37.3–4, c. first century BCE).

The Egyptian screw has proved of paramount importance for reclaiming land and the creation of polders from below sea level in the Netherlands since the fifteenth century. Instead of turning the screw by hand, windmills were used to provide the energy needed, combining two ingenious inventions. Windmills are probably another Persian invention, adding to its rich repertoire of water machines developed at a time when expansion into drylands to make use of groundwater was a part of Achaemenid public policy. An Archimedean screw pump was reported still to be in use at the Viinikanlahti wastewater treatment plant in Finland in 2007 (Katko and Juuti, 2007).

The earliest polders were formed by enclosing a piece of foreshore by a dyke with a sluice gate, which was opened at low tide. Polders discharged into river or the sea through intermediary collecting basins (*boezems*). Initially human bucket chains were used to drain polders because animal power was not available. Windmill-driven scoop wheels were then introduced in the early fifteenth century. The spiral scoop wheel had been developed in the Islamic world and was popular in Egypt. It is designed to raise large quantities of water over relatively small distances with a high degree of efficiency. A twelfth-century miniature from Baghdad shows a spiral scoop wheel driven by two oxen.

Later the polders were drained by the use of two or more scoop wheels in series, and this was followed by the use of the Archimedean screw, which allowed lifts of up to 3 to 5 m, compared with 1 to 2 m by scoop wheel. The water wheel probably spread northward to the Netherlands from Spain, where it had been was introduced in the eleventh century CE from North Africa, which it had reached earlier through contact with the Muslim world.

## The Age of Water Industry: Antecedents and Consequences

The *saqiya/noria* was perhaps the world's most revolutionary technological invention, because it had an enormous impact on all subsequent history. This remarkable leap in technology laid the basis for the use of gears to transfer energy from one plane to another, and introduced the exploitation of animals as a source of energy. The dazzling invention of gears, which often passes unnoticed today, is an integral and indispensable element of modern life, used in everything from analogue clocks to automobiles. But one of the main outcomes of the water wheel's invention, which was also in its turn to have long-reaching consequences for humankind, was its modification for use as a mill. In short, this was the beginning of an age of water-based industry. The invention of the water mill goes back to the fourth or third century BCE, but its great impact on humanity was felt when it became an integral part of the economy of Islamic countries, including Spain, between the tenth and the thirteenth centuries. It spread and began to influence the wider European economy during the twelfth century. A modification from a horizontal to a vertical wheel became dominant in England during the fifteenth century; thereafter it was rapidly to revolutionize industry and transform the hydrographic networks of Europe.

The age of water industry is pivotal for understanding how our modern water management systems and paradigms are linked to earlier developments in water management technologies and practices. We begin by clarifying the transformations in water management systems during this period by focusing on the last of the early tributary empires, the Roman Empire, which ended the succession of earlier empires that had begun in south-west Asia in Mesopotamia, represented by the Akkadian, Babylonian, Assyrian and Hittite empires (from 2350 to the sixth century BCE), and later the Achaemenid Empire in Persia (559–330 BCE).

The rise of the Persian Empire coincided with the emergence of Greece as a rival power, and led to clashes between the two, which were ended by the short-lived Greek subjugation of Persia before the emergence of the indigenous Parthian Empire

(238 BCE–226 CE). Parthia resisted Roman expansion before it was engulfed by the tide of the mighty Persian Empire. However, by 116, after its greatest territorial expansion, the Persian Empire began to shrink, signalling the end of the initial cycle of military tributary empires. Empires backed with military force were to appear again, but they operated under different economic strategies.

The rise of Byzantium, with Christianity as its creed (313 CE), and later of Islam (in the seventh century CE), as world religions, was not without its military and bloody history, but both called for equality in the eye of God, proclaimed the worthiness of human beings, and praised charity as a means of sustaining social cohesion and harmony. Both religions expressed a hope for achieving human unity under the rule of a single God, thus providing the possibility of eliminating the plethora of divisive religious creeds. Such hopes were compromised, however, by an inability to eliminate slavery and by the emergence of competing political movements, each claiming to monopolize truth and to follow the true path, as well as the emergence of priestly elites and rulers who benefited from the theocratic establishment. These religions, as well as Buddhism in east and south Asia (from 300–400 CE), have since been fundamental to the way billions of ordinary people everywhere perceive the world and their destiny, and have nurtured and instilled in the human mind the notions of justice, equality and fraternity. Paradoxically such notions, which were embedded in the ethical revolution of the period from the first to the seventh century CE, were to mark a break away from the hegemony of theocracy, thereby ushering in the modern secular state.

The period from 300 to 700 CE thus marked a structural transformation in the history of humanity, and a change in ethos, where the conception of people as an entity and in particular the notion of equality was buttressed by popular religious ideology. Christianity and Islam today inform the thinking and practices of more than 3 billion people. They not only link humanity with this powerful socio-religious transformation and as such could constitute a source of empowerment against injustice and inequality, they also provide a basis for a spiritual approach to water as a pure, healing and sacred substance. This approach has become instrumental since the 1970s in the ecological movement, in the fight against water pollution and its impact on the integrity and sustainability of the 'natural' support system. The religious paradigm is also often invoked in support of water ethics and the human right to water, and against putting a price on water and treating it as an economic commodity.

There are two other relevant historical trends that mark the beginning of the end of the royal and imperial tributary systems following the demise of the Roman Empire. The first was the weakening of the grip of absolute monarchy on trade, and the emergence of merchants as a powerful segment of society. This was particularly true following the advent of Islam, which emerged within a trading community. Islam dispensed in principle with the idea of an absolute monarch because it viewed society and social ethics as being guarded and legitimized by a supreme God. It also dispensed in principle with the idea of a religious clergy, which had in the past legitimized the role of divine rulers. Water was singled out as a gift from God to all, and it was to be shared. It was a sign of God's mercy and benevolence, and hence *sabils*, street water-drinking fountains, were donated by rich merchants and rulers for the benefit of all passers-by. They are still found in Islamic cities on a modest scale.

Islam also celebrated secular learning, and encouraged Muslims to garner knowledge from all possible sources regardless of their cultural and religious context. This led to the rise in the ninth century CE of a cosmopolitan centre of knowledge under the Abbasids (caliphate established in 750 CE) in the area now occupied by Iraq and Iran. This centre of knowledge was in a sense a reincarnation of Hellenistic, cosmopolitan Alexandria, renewing the opportunity to bring the accumulated knowledge of humankind from the Classical and Hellenistic world, Persia, India and China into a single body of knowledge. Water technologies were also an integral element of the economic pursuits in many countries where Islam was introduced after the seventh century CE. Islam contributed to the mobility and encouragement of thriving trade and learning, which stretched across a vast area of the Old World from Spain to Persia (Adas, 1993).

This led to huge advances in science and technology, which included significant developments in water mechanics, building on previous Hellenistic and Byzantine achievements (Ortloff, 2009). Water mills were widely used, *qanats* were introduced into Spain, and aqueducts were built in Cairo and elsewhere. Under the Muslims, as previously under the Romans and in south and east Asia, water was not only for irrigation and industry; it was a means of displaying wealth and power, and a medium for reflection, relaxation and enjoyment. Many of the water-lifting and other elaborate hydraulic machines were for gardens and orchards, for supplying baths with water, and for fountains and water features.

In addition to Baghdad in Iraq, Al-Andalus (Spain under the Muslims) was another centre of innovation and a key link between the Muslim world and Europe. Under the Muslims in Spain (711–1492), a water wheel with a flywheel to smooth the delivery of water was introduced (by Ibn Bassal, 1038–1075). This was followed by the reciprocating suction pump with valves (by Al-Jaziri, in 1206), and geared and hydro-powered water-supply machines that provided mosques and a hospital in Damascus with water, also developed by Al-Jazri in Baghdad (El Faïz, 2005). The use of water mills in the Islamic world was widespread from Spain to central Asia, and the advances made in the design of these machines and their widespread use in industry made them of great value. Innovations also included mounting the mills on piers or bridges, or even on floating platforms made of boats moored in midstream. In Persia, horizontal water mills were placed in front of dams so that water conducted through large pipes drove the water wheel. Although such mills were used for a variety of industrial processes, one of the most remarkable was the application to prepare pulp for making paper in the eleventh century.

Chemists also pursued investigations of water quality and developed water distillation. They may have benefited from the knowledge that boiling had been used to purify water in India as long as 4,000 years ago, and more recently by Hippocrates, who was known to use both water filters and boiling to improve water quality. The adoption of water management technologies was supported by governments, merchants and developers, in connection with an agricultural revolution which included the introduction of new crops, new methods of crop rotation and land reclamation. It was this integration of water with the economy that facilitated the spread of innovative water technologies into Spain, Sicily and other European countries, south and east Asia, and Africa. The Spanish system of *acequia* (from the Arabic *ya-Saqi*, to irrigate) is still in use in the American Southwest (Hutchins, 1928; Rivera, 1998).

Another significant development was the attention given to domestic water supply, waste disposal and public baths (*hamams*). Purification with water and ablution five times a day were key elements of the Islamic religion, and in a different form, an element of Judaism. The Turkish (Islamic) *hamam*, unlike the Roman baths, was used for ritual cleansing, and had a religious undertone, as was the case in Judaism. The bath house was not so much an element of civic life to promote health and vigour, as an integral element of the system for purifying mind and body (Sibley, 2008).

## The Age of Water Industry and the Making of Europe

The period from 900 BCE to 600 CE was also a time of the expansion of steppe nomads in Asia and Europe. This contributed to the demise of the Roman Empire, and they also became a major force in China. The breakdown and fragmentation of the Roman Empire led to a political vacuum which was filled by regional kingdoms, empires and feudal states with vibrant social dynamics, where artisans, traders and financiers became influential next to kings, emperors and the top priests. The military confrontations between Christian Europe and powerful Islamic states during the Crusades (1095–1302 CE), like the previous confrontations between the Greeks and the Persians, were instrumental in the development of water sciences and technologies. The widespread use of water mills in medieval Europe and the modification of earlier designs were the key to the economic developments that eventually led to the steam engine and the age of industry. The impact of wars, plagues and food shortages, especially during the tenth to thirteenth centuries CE – apparently linked to the climatic upheaval of the Medieval Climatic anomaly – coupled with the activities of monasteries, free traders and artisans (guilds of artisans and craftspeople began to develop in towns around 1100 ce), must have contributed to the popularity of water mills for a variety of industrial functions. Water-powered sawmills, for example, came into use in about 1253.

The adoption of water mills for industrial purposes and the promotion of trade in conjunction with banking and credit facilities in a politically volatile environment, made it possible for merchants to take the lead in societal affairs and to contribute substantially to the emergence of world trade in the fifteenth century CE. Subsequently Spain colonized the New World and secured silver from Peru and Mexico in the sixteenth century, thus increasing the availability of credit and fuelling the expansion of world trade. With the participation and cut-throat competition for colonies, labour, raw materials and markets among several regional polities in Europe, including the Netherlands, France and England, Europe became a dynamic entrepreneurial society characterized by virulent merchant capitalism (Fernandez-Armesto, 1995).

Trade stimulated industry and the manufacture of goods, and the struggle to advance over others in a competitive market encouraged the search for ways to enhance industrial production and transport. Transportation canals, better water vessels, a variety of water mills, riverside factory towns and ports began to alter the cultural landscape of Europe. Agriculture was also beginning to change to meet the new demands of a growing population. New crops, improved crop rotation, better methods of animal husbandry, elaborate farming tools and equipment, and drainage of marginal lands led to a green agriculture which was one of the key ingredients in providing Europe with wealth and prosperity.

Merchant capitalism fostered advanced water technologies and sciences as well as improvements in means of transportation and industry. The fundamental technological breakthrough in water history was the use of water as steam to power sophisticated engines for industry, draining swamps, lifting water and transportation (Pirenne, 1969).

## The Age of Water Science and Modernity

The hydraulic engineering developments in the merchant capitalistic phase proved to be crucial for the next transition in Europe from mercantilism to industrialism, nationalism and European colonialism. This phase was marked by a greater social role for the middle class and sizeable support for the sciences.

The pace of industrialization picked up, and humanity was propelled to a new stage when the steam engine was invented in 1775 (Thurston, 1939). Thus began the age of steam. The tempo of change was accelerating, and in slightly over a century hydroelectric power came to the fore in 1881. Within decades (in 1911), big dams were being constructed in the United States, a development that soon spread to the rest of the world. In spite of resistance to such dams in some quarters today because of their impact on ecology, plans are currently underway for very large dams in China, Turkey and elsewhere.

The construction of big dams has had enormous consequences both for managing technical applications, and because they give rise to social concerns, legal issues, and financial benefits and costs for a broad spectrum of users. This has led since the 1960s to a new managerial paradigm, referred to as integrated water management. Big dams also have an effect on all regions and countries within a river basin. The last two decades have witnessed an increasing concern for alleviating potential conflicts through shared management of transboundary resources. We may thus speak of a water management age since the 1960s, where the most pressing water issues concern how best to coordinate the technical, legal, social and financial aspects of water management at local, regional, national and international levels (Smith, 1972).

Applications of water technologies for industry, irrigation, sanitation and sewerage were the basis for a modern outlook, greater production, and an age of prosperity for Europeans, in sharp contrast with the peoples who suffered the burden of colonialism. This schism remains an obstacle today. The industrialized countries of Europe, joined by the United States and Japan, have moved rapidly into an age of computerized information technologies and a global dominance of finance and economy. However, the impact of industry over the last two centuries has led to unprecedented levels of atmospheric and freshwater pollution, a potentially catastrophic development now being countered with demands for ecological sustainability. This requires a change in the policies of European and other affluent countries toward disadvantaged and poor peoples. Change is hampered by the high economic cost necessary to save the planet, the reluctance of nations to forgo traditional notions of the 'nation-state', and the high levels of consumption that became synonymous with modernity, as well as the short-term strategies of national and international financial institutions, and their commitment to profit-making rather than to the long-term sustainability of the planet.

## Managing Water in a Time of Crisis

It is remarkable that the current *water management age* has come about through the convergence of three fairly new forces in world history: transnational corporations, international organizations and what has become known as civil society. The objectives of these groups and those of the nation-state – which still provides the legal basis for international organizations – are widely and sometimes wildly different. Bureaucrats and 'experts' are contributing to the brewing cocktail of conflicting views and aspirations. The age of water management is in a sense about the management of differences in scale (community, region, nation, transboundary, global), differences among users (agriculture, industry, ecosystems), and differences that have risen because of a lack of harmonization among experts drawn from different disciplines to resolve water issues (Teclaff, 1967; Blatter and Ingram, 2001; Ministry of Foreign Affairs of Sweden, 2001; Ohlig, 2005; Kahan, 2006).

Each transformation is bound to leave traces that continue to operate through successive ages depending on their axial or fundamental role in society. In addition, at a time of accelerating change, societies at different 'water ages' coexist and may be brought into collision, as happened in particular over the last 100 years where structural transformations took place over very short periods of time. The structural transformation in Europe concerning the water sector was embedded in a financial-industrial set-up and a global system of inequities and disparities which has hampered the spread of beneficial developments to all socio-economic segments of societies, or to other parts of the world.

The transformations in water technologies have led to changing paradigms of water. Some of the earliest paradigms are still operative and are clashing with emerging paradigms. Thus, the aim here is not to end with this identification of the historical transformations of society in response to the adoption of particular water technologies, but to extend the historical analysis to an identification of paradigms that have emerged under different historical situations, and have since become powerful elements that inform the decisions of policy-makers, experts and ordinary people.

# SECTION III

## CHANGING PARADIGMS IN WATER MANAGEMENT

At present and in the past, water management systems have been embedded in attitudes and practices that constituted paradigms, which canonized and operationalized mental structures through methodologies of communication, conduct and interpretation. We may contrast for example, the paradigms that view water as a commercial commodity or a chemical compound, with those that regard water as a spiritual, holy substance, a gift from God and a common good. Each of these viewpoints implies and constitutes a paradigm that has its own methodology, technology and world of reasoning. Instead of regarding these paradigms in terms of dichotomous opposition, it is more beneficial to search for a deeper understanding of their historical genesis and the social circumstances that have perpetuated certain historical ways of thinking into the present. Without a clarification of the social matrix and dynamics of these structures of thought, which are closely tied to values, ethics and norms, we cannot hope to find a meeting ground, if there is one, to reconcile such opposing views, or to assess their relative merits and values in the current debate. Water management presumes a set of goals and objectives that are not separable from how water is perceived.

At present there appear to be a number of different paradigmatic currents that undergird contemporary debates on water issues. These currents are of different historical depth and intensity. They are also articulated by different individuals and groups representing overlapping geographic areas. There is, for example, the *spiritual–religious paradigm*, which is deeply rooted in indigenous and religious beliefs.

Then there is the *hydraulic engineering paradigm*, which originated in the first millennium BCE, gaining ground with the spread of Islamic water technologies and becoming a predominant paradigm with the coming of the industrial age. This paradigm was intertwined with a *scientific paradigm.* In this paradigm, water was regarded mostly as a chemical and physical substance whose properties could be investigated by scientific methods like any other substances on the Earth. This paradigm was bolstered by the relationship between water pollution and disease.

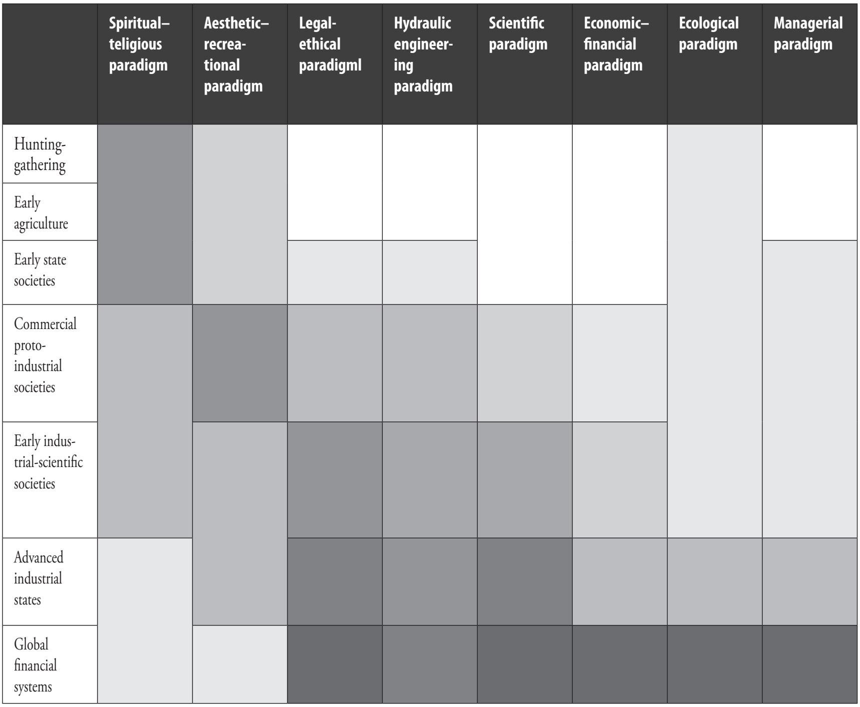
The emergence of the *industrial hydraulic engineering paradigm* was also closely linked to the *economic–financial paradigm*, which became one of the prevalent paradigms by the end of the twentieth century. That paradigm is in sharp contrast with the counter-paradigm that emphasizes ecological sustainability and may be referred to as the *ecological paradigm*, legitimizing its claims by reference to ecological science, environmental ethics, health and spirituality. Thus it can be seen as allied with the spiritual–religious paradigm. We may also recognize an *aesthetic-recreational paradigm*, which flourished when state rulers and the aristocracy deployed water fountains, water gardens, baths and spas for enjoyment and status.

A *scientific–health paradigm,* which regards water as a chemical substance from a scientific point of view and as a potential carrier of diseases, has existed since the eighteenth century. A *legal and ethical paradigm* has been manifest since the rise of the state but has become dominant in recent decades as conflicts among users within and between nations began to escalate. Potential conflicts as well as perceived benefits from coordination of the different domain of water production, supply, sanitation, ecology and economics have also led recently to a valorization of a managerial paradigm which emphasizes the importance of governance and integrated water resource management.

## The Spiritual–Religious Paradigm

David Groenfeldt[1] asserts that the spiritual connection to water and water bodies that indigenous societies maintain as an integral element of their culture is a source for water conflicts with external, predominantly Western agents of development. He suggests that a more explicit understanding of indigenous value systems by the Western world would not only help relieve the pressure on indigenous societies, but would also serve the cause of sustainable development for humanity as a whole.

***Fig. 1.* A diagrammatic illustration of the historical development of water management paradigms.** Shading intensity indicates the degree of dominance of a paradigm relative to others.



In Mesoamerica (Marcus, 2006), water spirits are associated with fertility and fear of droughts. Water symbolism among the Arapesh of New Guinea reveals complex semantic operations that combine water with gender, life, death and rebirth (Tuzin, 1977). In Europe and until the end of the nineteenth century in the east Slavic world, certain water ritual practices as a means to punish those responsible for droughts included ordeal by water (the so-called 'swimming of witches'). Suspect women were tied up, attached to the shore by ropes and thrown into the cold water of the river. If they floated they were condemned because the pure water of the river did not accept them. If they sank they were pulled out. This was common in England in 1590, and was already common among the eastern Slavs during the twelfth century CE (Zguta, 1977).

Water has been used for healing among traditional Yoruba healers in south-western Nigeria. Originating from the ancient tradition of the Yoruba, the various roles that water plays in traditional healing reveal that illnesses and diseases were regarded as misfortunes that can be overcome using water when preparing remedies and in the therapeutic process. This is highlighted by the baths that are commonly prescribed as treatments, especially for women suffering from infertility (Rinne, 2001).

In southern Africa, the Lozi regarded kingship as divinely inspired and associated with the natural rhythm of the river and floodplain (Pikirayi, in press), as in ancient Egypt (Zeisler-Vralsted, in press; Hassan, in press). In Islam and Christianity, water was regarded as a gift from God to sustain life, and as a sign of God's mercy and benevolence. Water was considered as sacred and pure (Hassan, in press).

Among the ancient Maya of the central Yucatan lowlands, many depressions at the summit of hills were artificially modified by an elite to collect water, thus creating 'water mountains' which were used to supply people with water for agriculture. The elite used high-performance water rituals as indicated by Mayan iconography to control the population (Scarborough, 1998).

## The Aesthetic–Recreational Paradigm

The recreational and aesthetic aspects of water must have been experienced from prehistoric times. Fountains, private baths, spas and water sports in reservoirs associated with big dams, lakeview and riverfront residential areas are vivid reminders of how water is prized not only for its utilitarian functions but also for relaxation, reflection, pleasure and revitalization. With the advent of cities, elaborate water features were restricted to the affluent elite. The public baths in Rome and water gardens installed under the Arabs in Spain, as well as the spectacular water gardens and fountains of the Renaissance and the age of the Enlightenment in Europe, were an exuberant celebration of the joys and pleasures of water (see below). Such luxuries are now enjoyed by larger numbers of affluent clients, while more than a billion human beings still have no access to clean water (Hassan, 2000).

Nasar and Li (2004) have examined the human preference for water and water reflectivity, as in many shallow ponds in Islamic gardens. They compared responses to reflection in water versus reflection in glass, and responses to reflection versus transparency. Sixty respondents rated the attractiveness of four scale models which varied on those dimensions. High inter-item reliability across the rating scales called for their combination into a composite measure of attractiveness. The analysis revealed that individuals preferred water to glass, and the reflective to the transparent surface. The most favourable ratings were allotted to the scene with reflective water, thus suggesting the potential desirability of reflective ponds as a design element.

The recreational/aesthetic aspects of water have recently become very important in movements that aim to mitigate the effect of industry and pollution on aquatic landscapes. The realization that waterscapes have aesthetic, relaxing, calming and uplifting qualities has made waterfront areas attractive for parks, water sports and picnics. As a service to communities and with an eye on their good image, the authorities responsible for the reservoirs of big dams have been keen to provide the public with parks and beaches. Tremblay (2008) offers a case study of the social movement behind environmental protection in Quebec, which placed a great deal of emphasis on 'natural capital', virgin characteristics and wilderness. He underscores the difficulty of defining 'natural', and proposes an interpretation for this movement based on the social role of landscape and aesthetic values of rivers, more specifically their cohesive function for fragmented local communities.The recreational dimension of water is now fully evident in the houses of the rich and the trend toward luxurious spas. Recreation here is more synonymous with 'revitalization' and the restoration of health. Although hot water springs and other water sources for bathing were probably enjoyed by our prehistoric ancestors, their use became the hallmark of the affluent in Rome and later in medieval times, and particularly during the Renaissance. At that time saunas and stream baths were introduced. A new historical turn in the history of bathing emerged when the Czech Kalovy Vary published the first scientific study of the healing powers of bathing in and drinking spring waters (Tubergen and Linden, 2002).

With increasing attention to health, fitness and vitality, spas were on the rise during the twentieth century. The spa has also become a place for relaxation and release from stress, as well as self-indulgence in pampering and pleasure through a range of services and techniques including balneotherapy, crenotherapy, thalassotherapy, water flotation, sauna, Swiss showers and Jacuzzis.

## The Scientific Paradigm

In Europe, the enjoyment of the pleasures of water has been complemented since the nineteenth century by the advent of water purification and sanitary water disposal. This development, which has led to an eradication of water-borne diseases and epidemics, was linked to the rise of a scientific approach to water – its composition, its chemical purity and its content of bacterial pollutants. This hastened the emergence of a scientific paradigm.

Polluted water is still responsible in many parts of the world for water-based diseases and cholera pandemics. During the nineteenth century, scientific advances revealed that water-borne diseases and cholera were communicated by biologically contaminated water (Hardy, 1993; Luckin, 1986). The reaction to a series of cholera pandemics in Victorian England led to measures culminating in the implementation of the first-ever comprehensive urban sanitary system between the 1870s and the 1920s. This signalled the end of pre-industrial practices. The measures included separation of drinking water from sewage, elimination of the use of water from shallow wells, use of filtration, a piped water supply, water closets and chlorination. This system, in part or as a whole, has been adopted by many countries since. However, many rural and poor urban areas – amounting to approximately 25 per cent of the world's population – still lack sanitary facilities.

The scientific paradigm is indispensable for achieving a good level of public health on a large scale. Sadly, however, many cities and villages are still deprived of clean water, mostly because of the lack of public water works coupled with a lack of sanitary facilities in homes. This situation is aggravated in developing countries by a rapid increase in the number of inhabitants of cities who live in shanty towns, where water services and waste disposal facilities are absent. The situation is worsened by excessive use of fertilizers, pesticides, and the disposal of untreated industrial pollutants and sewage in rivers and lakes.

One outcome of the scientific paradigm was the fashion for drinking mineral water. The appeal of mineral water was sanctified at that time by the new 'religion' of science. Priestly, Cavendish, Lavoisier and Henry, four of the greatest pioneers of modern chemistry in the first half of the eighteenth and early part of the nineteenth century, studied the content of mineral water and its gases. Their results contributed to the commercial production of gaseous beverages and carbonated water that imitated the popular, effervescent water of famous natural springs with their purported healing properties. By the middle of the nineteenth century, bottling of mineral waters was a well-established American industry. Mineral water was also combined with beverages such as cider or juleps to enhance its remedial value and taste (Back et al., 2005). Today the companies that produce Pepsi-Cola, Coca-Cola and other carbonated beverages are transnational commercial enterprises. In addition, the market for mineral water has become global, spreading from Europe and the United States to developing countries, even when good-quality tap water is available. The reasons include greater awareness of health and fitness combined with fear of drinking contaminated water where water treatment and sewerage are poor or lacking. The spread of mineral water and carbonated beverages among the poor may also be attributed to a desire to imitate the well-to-do as a means of improving their social image. Among the middle classes, the increasing consumption of mineral or bottled water, sometimes of lower quality than that of the local tap water, is partly due to the 'snob' factor. Companies are resorting to marketing strategies that enhance the aesthetic appearance of their bottles and the association of drinking bottled water with health, sport and youthfulness.

## The Ecological Paradigm

Increasing awareness of the negative impact of industrial pollution on water quality and the harmful effects of contaminated water not only on human health, but also on the integrity and viability of life-supporting ecosystems, have led since the 1970s to an increasing appreciation of water as a vital element of ecosystems. In 1962, Rachel Carson in her book *Silent Spring* was the first to suggest that needless and dangerous chemical pollution of our environment is irreversibly harmful, and that technology, when it diverges from science, can be a threat to human beings, wildlife and ecosystems alike.

Although admonitions against polluting water are known from as early as ancient Egypt, it is only during the last few decades that an ecological paradigm has become a significant feature in the ongoing discourse about water issues.

In environmental sociology, pioneer scholars (Dunlap and Catton, 1979; Catton and Dunlap, 1978) focused mainly on the social factors that lead to environmental degradation and the influence of the environment on social conditions. They applied the attitude–behaviour model, which is popularly known as the new environmental paradigm (NEP) scale, to understand environmental concerns (Swarnaker and Sharma, 2006).

Water, along with other environmental issues, is frequently cited as an example of the new dynamics of change in global modernity, addressing the weakening power of nation-states over culture, capital and technology (as in reflexive modernization theory, risk society theory and social constructivism). However, this model calls for a new role for nation-states, which have to give way to actors and arrangements operating at the global as well as local levels. In this context, the 'sociology of flows' (Urry, 2000) opens up various perspectives in environmental sociology, by focusing especially on the material and spatial dimensions of social life (Mol and Spaargaren, 2005). Corral-Verdugo et al. (2003) concluded from a study of two northern Mexican cities that utilitarian water beliefs tended to promote water consumption, while a more ecological approach to water tended to inhibit such behaviour.

The notion of extending ecological concerns into the past is clearly manifest in studies of the relationship between water management and the parameters of rainfall, surface topography and bedrock geology, and their influence on the amount and distribution of surface as well as groundwater resources (see for example Wright, in press; Doolittle, in press; Moseley, in press; and Kusimba and Kusimba, in press). The construction of water works in turn influences local ecological conditions, as is shown by G. M. Bandaranayake (in press), who examines the tanks in Sri Lanka from an environmental perspective. The climate of Sri Lanka is mainly determined by the weather patterns of the south Asian region, particularly by north-eastern and south-western monsoons. The south-western monsoon rainfall brings a higher amount of water for the western part of the island but less rainfall to the northern part, which is called the Dry Zone. The north-eastern monsoon frequently brings little or no rainfall. As these monsoons are confined to very limited seasons (two or three months), there is a lack of water during most of the year. When either one or both monsoons fail, droughts seriously affect the environment as well as the societies whose socio-economic activities are entirely based on water, especially in the northern Dry Zone of Sri Lanka where a large number of rural communities depend on irrigated agriculture.

In the past, storage tanks were built by damming rivers and streams in many places in order to collect, reserve, regulate and use water in a sustainable manner. Tanks were part of a cascading chain of reservoirs located along the streams or tributaries of a river within a macro-catchment area. Every tank was connected to another by the same stream. Excess water from one tank, located along the upper part of the stream, flowed to another located in the lower part of the stream through a network of irrigation channels in the paddy fields. Ultimately the water was collected in a larger reservoir located in the lowermost valley. Under this traditional system the rice paddy field is located just below the tank lying parallel to the stream. The upper part of the tank's water spread area is normally covered with forest, mostly with jungles or dry scrubs. People use this land for a form of shifting cultivation, locally called *chena* cultivation. This land is also used for timber and firewood.

Tanks directly affect the soil, vegetation, surface and ground water, air moisture and biodiversity of the environment. Tanks play a vital role in reducing the dryness of the air, adding a higher amount of moisture to the atmosphere through evaporation from the water body. The atmospheric humidity in tank villages is considerably higher than that of the surrounding area, creating micro-climatic conditions that are favourable for biodiversity.

In addition to illustrating the sustainable and beneficial aspects of traditional historical technologies, Castonguay (2007) reveals that a historical ecological approach is useful in reconceptualizing extreme flood events, which are often perceived and reported as natural catastrophes that threaten the well-being of the population. By examining the extreme events and the construction of vulnerability in the drainage basin of the St. Francis River (Quebec) in the mid-nineteenth to mid-twentieth century, he concludes that a sense of urgency accompanied the flooding events of 1913 and those of 1942 and 1943 because droughts incited the authorities to regulate the river flow and produce energy for industrial purposes. Because they disrupted economic activities as a result of power shortages, both episodes contributed to the perception of floods as natural catastrophes.

An ecological paradigm also makes it possible to discuss problems arising from current water shortages and the unpredictability of climate change. Early civilizations were not only prey to droughts as a result of short-term variability in rainfall within decades, but were also threatened by climatic events at a scale that could not be accommodated by the human scale of perception and reckoning (Hassan, 2009). Such events, often extreme and abrupt, have led to the demise of many cultural configurations (civilizations), but they were also instrumental in stimulating social and technological innovations, as happened after the global cooling event of 4,200 years ago (Hassan, 1997; Weiss and Bradley, 2001). It may in fact be concluded that the early steps in improving water management were a response to the unpredictability of rainfall, which placed early farming communities at risk.

## The Hydraulic-Engineering Paradigm

It is also perhaps telling that industrial society, with its emphasis on technology, has taken water technology to an unprecedented level of sophistication, and that water technology was until recently regarded as holding the ultimate key to water management issues. Although water works in the forms of wells, canals, drains, dams, dykes and embankments are known from the earliest complex societies (beginning about 8,600 years ago), elaborate water works such as aqueducts, *qanats* and mechanical water-lifting devices became widespread beginning 4,000 years ago (see Fig. 2. Chronological Chart). Water engineering took a major turn with the use of water mills (from the fourth to the third century BCE), contributing by medieval times to a significant surge in industrial development (Munro, 2002; Brykala and Podgorski, in press). The next definite turn in human affairs resulted from the invention of turbines[2] in the 1700s and hydropower plants in 1881 (Cech, 2009).

The list of hydraulic technological interventions and their triumphant transformation of Europe since the medieval period is too vast to be enumerated. One notable example is the evolution of the landscape of the western Netherlands examined by van der Leeuw (in press), which does indeed reveal the power of the hydraulic paradigm. Nevertheless, these hydraulic works were embedded in the fertile soil of a rising mercantile economy (900 to 1400 CE), which generated the capital required for financing the initial reclamation projects. Hydraulic projects in the Netherlands initiated by individuals soon led to the rise of collective institutions for water governance – the *Hoogeemraadschap.* Van der Leeuw reveals how large-scale water projects were not a local matter. The reclamation of Haarlemermeer was funded in part by the incoming stream of riches gained from Dutch colonies in the East Indies, where intensive agriculture destined for the European market was established after 1815.

## The Financial–Economic Paradigm

The technological paradigm reached its culmination during the period of big dam construction in the twentieth century. This paradigm was accompanied by financial commitments which eventually led to the aggrandizement of a financial–economic paradigm. Bakker (2005; in press) differentiates between a state hydraulic economic system which aims at cost minimization and the provision of water at a subsidized price or for free, a market (environmentalist) system with profit as a primary goal and a commitment to provide water at market value, and a community movement which aims to provide sustained access to water, relying on diverse approaches to financing water supply, including labour as an in-kind equivalent.

The 1992 Dublin Conference on Water and Environment encouraged privatization of the water sector in developing countries. It declared that water has an economic value and must be treated as an economic good. It also stated that access to water and sanitation at affordable prices is a fundamental human right. The fourth principle of the Dublin Declaration states:

> *Water has an economic value in all its competing uses and should be recognized as an economic asset. Following this principle, it is especially crucial to recognize the basic right of all human beings to have access to drinking water and sanitation at affordable price. Past failure to recognize the economic value of water led to wastage and to uses that were harmful to the environment. To manage water as an economic asset is an important path to the achievement of efficient and equitable use, and to the encouragement of the conservation and protection of water resources.* (Petrella, 2001, pp. 65–66)

## *Fig. 2.* Chronological chart of the world history of water management

| (decimals: thousands of years Before Present) | West Africa | Eastern Africa | South Africa | Nile Valley Egypt | Levant | Mesopotamia & Iran |
|---|---|---|---|---|---|---|
| 13–11.5 BP Younger Dryas Cold Event | | | | | | |
| 11.5–11 BP | | | | | | |
| 11-10 BP | | | | | | |
| 10–9 BP | | | | | | |
| 9–8 BP | | | | | | Irrigation 8600 Samarran |
| 8.2–7 BP | | | | | | |
| 7–6 BP | | | | Agriculture established | | Tepe Yehia (irrigation canals 7 kyr); Ur: transverse canals/<br>Late Uruk 6.5 kyr |
| 6–5 BP | | | | 5200 Egyptian nation state<br>Canal irrigation | | Wright: 5.4 kyr ED 20 km canals |
| 5–4.2 BP | 4400 BP<br>Cattle | 4500–3500 BP<br>Cool season crops like barley, emmer wheat, lentils are introduced into Ethiopia.<br>C. 4400 Cattle | | 4600 Sadd el Kafara dam | | Ur-Nammu irrigation projects 4200–4100<br>Shaduf<br>4400–4200 |
| 4200 BP Global Climatic Event | | | | | | |
| 4.2–2.7 BP | 3800 BP Rice domesticated in seasonally flooded areas of the Niger | Domestication of native Ethiopian crops (e.g., Teff) | | Collapse of centralized government<br><br>4000–3800 state hydraulic projects<br><br>?3800 BP<br>Shaduf introduced | | 3570 Cassite transverse canals and salt-destroying canals |

| Mediterranean & Europe | India, Sri Lanka, Angkor | China | Andes | Highland Mesoamerica | Lowland Mesoamerica | North America |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Wells: Cyprus | | | | | | |
| | | | 8700 BP<br>Early Sierra canals | | | |
| | | Paddy rice canals ditches wells and ponds | | | | |
| | | | 6500 Supe coastal valley spring irrigation | | | |
| | 5800<br>Early Harrapan | | | | | |
| | 4500<br>Mature Harrapan<br>4600 possible domestication of animals in Southern Neolithic | | 4150 BP major ENSO event | | 4000 Preclassic | |
| | | | | | | |
| Pulley<br>9th century BC | 4200 Archaeobotanical evidence for cultivation in southern Neolithic<br>3100–3000 Iron Age (Megalithic) Warfare<br><br>3900 BP<br>Collapse (Post-Urban Harrapan).<br><br>3500 forest to savanna in S. India. | 4000 BP Great Yu irrigation inventions<br><br>Yellow River Shang Canals<br>4000 oracle bones irrigation canals | Moseley:<br>3800–3200<br>Moche enormous irrigation systems | SC Mexican Highlands: 3000-3200 BP wells, short canals, drains, cisterns, terraces, and small dams | 3200–2800<br>Early Olmec Aqueducts<br>3200 Middle Preclassic Maya movement inland | |

## *Fig. 2. continued:* Chronological chart of the world history of water management

| (decimals: thousands of years Before Present) | West Africa | Eastern Africa | South Africa | Nile Valley Egypt | Levant | Mesopotamia & Iran |
|---|---|---|---|---|---|---|
| C. 2700 BP Global climatic event | | | | | | |
| 2700–2000 BP (700 BC–1 AD) | 500 BC Nok<br><br>400 BC Iron smelting | 600 BC Iron smelting<br><br>300 BC Deforestation caused by iron smelting | | 2600 BP Qanats in oases<br><br>2300–2200 BP Ptolemaic hydraulic and reclamation projects including Archimedes screw | | 547 BC Rice and sugar cane probably arrived from South Asia during the late second or first millennium. buffalo. Water wheel mills 4th–3rd century BC<br><br>Qanats |
| 1–200 AD | Middle Niger urbanism | | | | | |
| 200–300 AD | | | | | | |
| 300–400 AD | | | | | | |
| 400–500 AD | | | | | | |
| 500–600 AD | | | | | | |

| Mediterranean & Europe | India, Sri Lanka, Angkor | China | Andes | Highland Mesoamerica | Lowland Mesoamerica | North America |
|---|---|---|---|---|---|---|
| | | | | | | |
| 2800 deep wells dug after drought<br><br>Water wheel mills 4th–3rd century BC | Large reservoirs by late Iron Age<br>Noria 530 BC?<br><br>S. India 2300 BP end of Megalithic Iron age and beginning of Ancient History:<br>Canals and tanks in riverine areas, pastoralism in semiarid; swidden agriculture & hunting in hilly areas<br>Vedic religion | Warring States 770–256 BC; military use of water 2250 BP<br>Qin: Diversion canals<br>2600 earliest large-scale irrigation<br>255 BC Qin and Han great irrigation projects<br>246 BC Zheng Guo engineer | | 2500 BP–1900 BP planned landscapes inclusive of raised field systems | Royal Maya power 100 BC-900s AD<br><br>Initially Maya people depended on permanent sources of water lakes, rivers, bajos<br><br>Cenotes central or artificial wells; Aguadas rain fed natural depressions | |
| | | 1st century AD waterwheel | Kolata<br>100–750 Moche | | | 50 AD small canal at Salt River |
| | S. India:<br>Migrations<br>Kingship<br>Expansion in new lands<br>Irrigation canals and tanks<br>Stratification<br>Jainism & Buddhism<br>Trade | | | All basic techniques appear | Classic Maya 250/200–950 AD<br>Reservoirs, raised fields,<br>Water symbolism<br>Monuments<br>Wetland reclamation, silting up | |
| | | | AD 300–1000<br>Tiwanaku apogee | | | |
| | | | | | | |
| | S.India Medieval I:<br>Expansion<br>Royal sponsorship of tanks<br>War<br>Serfdom<br>Agriculture and pastoralism<br>Trade | | Kolata: 500–1500 large-scale irrigation urban polities<br>500 AD ENSO 524–540, 563–594, 636–645 droughts | | Late Classic 550–800/850<br>Increase in size and scope of water systems | Hohokam Massive irrigation;<br>Central Plazas |

**_Fig. 2. continued:_ Chronological chart of the world history of water management**

| (decimals: thousands of years Before Present) | West Africa | Eastern Africa | South Africa | Nile Valley Egypt | Levant | Mesopotamia & Iran |
|---|---|---|---|---|---|---|
| 600–700 AD | | 600 AD<br>Move to lake-shore<br>Deforestation and soil depletion | | | | |
| 700–800 AD | | | | | | |
| 800-900 AD | Ghana Empire | | | | | |
| 900–1000 AD | | | | | | |
| 1000–1100 AD | 1040 Almoravids | | | | | |
| 1100–1200 AD | | | | | | |
| 1200–1300 AD | 12th Sasso Empire<br><br>1230–1600 Mali (Manden) Empire | | | | | |

| Mediterranean & Europe | India, Sri Lanka, Angkor | China | Andes | Highland Mesoamerica | Lowland Mesoamerica | North America |
|---|---|---|---|---|---|---|
| | | 618 AD Tang rapid irrigation progress | | | | |
| | | | 800–1500 Post-Moche Chimu | | | 700–1150 Hohokam ball courts |
| Angkor Roluos Network | | | | 800–1100 AD Cenotes | Postclassic<br>800–850 AD<br>850–950 AD<br>Reservoirs dry up<br>People abandon rulers | |
| | S. India Medieval II<br>Big states<br>Quasi-Imperial expansion<br>Tribal alliances with states<br>Warfare<br>four-tiered bureaucracy.<br>Remarkable expansion due to irrigation.<br>Large temples patronized by royalty encouraged reclamation.<br>Breakdown of landrights by 11th century. Crafts, urbanization, trade<br>Siva and Vishnu<br>Architecture, painting, dance, music | | | | | |
| West Baray Addition<br>Jayataka additions | | | | | | |
| | | | Moseley<br>1150 Droughts<br>1150–1200 AD<br>Tiwanaka cities abandoned | | | 1150 Hohokam build platform mounds |
| | | | Kolata<br>1245–1310 AD droughts<br>1230 ENSO | 1200<br>Mayan migrate<br>1200-<br>Wetland reclamation<br>1450 AD<br>Mayapan defensive walls | | |

## *Fig. 2. continued:* Chronological chart of the world history of water management

| (decimals: thousands of years Before Present) | West Africa | Eastern Africa | South Africa | Nile Valley Egypt | Levant | Mesopotamia & Iran |
|---|---|---|---|---|---|---|
| 1300–1400 AD | | Nyanga canals, terraces, ridges and furrows | AD 1300 collapse of Mapungubwe because of droughts | | | |
| 1400–1500 AD | | | 1450 AD Great Zimbabwe collapses/ Drought | | | |
| 1500–1600 AD | Songhai empire (Gao) on bend of Niger River (Niger and Burkina Faso) | | 1450–1700 Mutapa State: wells | | | |
| 1600–1700 AD | | | | | | |
| 1700–1800 AD | | | 1714 AD droughts epidemic civil war famine Human dispersal and end of Mutapa state | | | |
| 1800–1900 AD | | | Luzi divine kings annual flood transhumance | | | |
| 1900–2000 AD | | | | | | |
| | | | | | | |

| Mediterranean & Europe | India, Sri Lanka, Angkor | China | Andes | Highland Mesoamerica | Lowland Mesoamerica | North America |
|---|---|---|---|---|---|---|
| Siem r Reap addition | S. India Medieval III<br>Single mega-state<br>Military society<br>Money<br>Royal industry<br>Forts, arts<br>Multiethnic communities<br>migrations | 1264 AD irrigation in remote areas<br>Ming Dynasty –AD 1300<br>Grand Canal<br>1046 large water works all over the country | | | | |
| | | | | | | 1400–1550 Hohokam disappear |
| | | | 15th century AD Inca Empire | | Colonial 1521 AD | |
| | | | | | | |
| Mid-1700s<br>Water turbine<br>1775<br>Steam engine | | | 1770 ENSO | | | |
| 1881<br>Hydroelectric power | | | | | Modern 1821 | |
| 1911<br>Huge dams (in the USA) | | | | | | |
| | | | | | | |

The transition to modernity was thus a product of the economic and social trends that began to take shape between the sixteenth and eighteenth centuries in Europe. Water sciences and technologies became increasingly important. Water companies took over many important water projects, and the role of financiers and government was crucial. Modernity was accordingly accompanied by new sources of conflict between local communities, municipalities, private companies and the state. Nair (in press) concludes that one of the principal problems was that investment in water supply projects was at variance with economic enterprises characteristic of twentieth-century models. The projects generated little revenue by comparison with their capital cost, and states were confronted with significant failures, especially in the domain of water supply to urban populations. By the 1990s, states that were burdened with other economic priorities provided opportunities for privatization of their water supply. This led the private sector to take advantage of lending opportunities, donor institutions and profit-making strategies to enhance its revenues, which peaked in 1997. In any case, citizen movements and regulations regarding water conservation, and anti-pollution measures linked to market environmentalism, were also leading to a decline in private investment.

In general, market water economics catered mostly to the rich while often disadvantaging the poor, which led to calls for ethical freshwater uses, emphasizing human rights to water and social equity. Reference to the role of ethics as offering guidance and solution to ecological problems had already been emphasized by Rachel Carson in 1962.

According to Ramachandraiah (2004), the advent of multinational capital together with privatization and post-liberalization in India since 1991 has strengthened the hold of powerful rich and middle-class groups over the state machinery on natural resources. The enthusiasm of the 'state' in undertaking large water projects through these groups, according to Ramachandraiah (2004), is not matched by its concern in practice to extend a clean water supply to the poor on a sustainable basis. The condition of the poor and their bargaining power seem to have been further weakened in the wake of the alliance of these powerful groups with the corporate capital in the water sector. Ramachandraiah (2004) furthermore contends that the state in India has become more emboldened today than ever before to divert municipal and river waters, and allow excessive extraction of groundwater, in favour of the corporate sector. However, in public all parties managing the state openly adhere to the constitution (and the fundamental right to life). The courts, which generally rule in favour of citizens on fundamental rights, are not in a position, or are rather reluctant at times, to step in to enforce people's right to adequate clean water. As the state turns away from its obligations, the 'right to water' becomes no more than a slogan. However, Ramachandraiah (2004) asserts that there is nevertheless greater awareness today of the social and economic rights of citizens.

## The Managerial–Governance Paradigm

Big dams and increasing demands for water by multiple users led to a trend toward establishing national and international institutions for water management, marking the rise of a managerial–governance paradigm (Smith, 1972; Billington and Jackson, 2006). Management of river basins for hydropower, irrigation, flood control, urban water supply, river channel dynamics, transboundary navigation and environmental protection provided the impetus for technical water commissions, inter-state water management institutions, integrated water basin management plans and international water laws (McIntyre, in press; Downs et al., 1991).

River basin management plans are currently a requirement of the European Water Framework Directive (WFD),[4] and a means of achieving the protection, improvement and sustainable use of the water environment across Europe. This includes surface freshwaters (such as lakes, streams and rivers), groundwater, and ecosystems such as wetlands that depend on groundwater, estuaries and coastal waters extending out 1 nautical mile. The WFD requires Member States to aim to achieve at least 'good' status in each water body within their river basin districts. Each Member State must produce a plan for each of the river basin districts within its territory. Plans must include objectives for each water body, reasons for not achieving objectives where relevant, and the programme of actions required to meet the objectives.

McIntyre (in press) reveals how 'common' management works through the management of water problems, and cites the Danube Commission and the River Niger Commission among several others, including technical commissions. Such commissions have become entangled with the conservation of water ecosystems, and operate according to international conventions, treaties and laws when common interests are compromised by individual preferences. Water law and governance have also become elements of a new legal–ethical paradigm.

## The Legal–Ethical Paradigm

The issues of water rights and governance may be traced back among Europeans to Roman and European customary law (Barraqué, 2004). However, they are not separate from the overall scheme of appropriate and acceptable or commendable norms, laws, duties and regulations, which lies in the domain of ethics. This perspective should inform the debate concerning *naturalis ratio* and civic law, in as much as laws are predicated on a world view and an ethical paradigm that specifies the right handling of the relationships among members of a society, and between their own and their neighbours' societies, and the relationship between members of a society and their natural setting. Many countries including the United Kingdom, Canada, Australia and the United States have a heritage of common law.

The legal and ethical dimensions of water law and water rights were addressed in early civilizations. For Egyptians, for example, it was ethically unacceptable to pollute water. In Mesopotamia, the Code of Hammurabi provided four water laws concerning liability and restoring injured parties to their former position (Kornfeld, 2009). In ancient China, every dynasty issued some regulations on water management. During the Han Dynasty (206 BCE–25 CE) and the Tang Dynasty (618 CE–907 CE), the government issued some famous water decrees to regulate water use (Xiangyang, 2004). The history of water law shows that two traditions have been most influential, the Roman and the Islamic. The spread of Islam, like that of the Roman Empire before it, influenced local laws in the Eastern world. Islam provided a religious basis for laws that emphasize the human right to water, equitable access to water, the rights of animals to water, and even regulating distance between wells (Al-Ansari, 1996).

Living examples are the Arab-inspired customary water users associations of the Vega de Valencia in Spain and the *Subak* system of water management in Hindu Bali, both of which have inspired the new water legislations of Christian Spain (Glick, 1970) and Muslim Indonesia (Wohlwend, n.d.). In general, except when it is covered by laws inspired by religious doctrines, the legal status of water is often customary. Customs deal with the legal status of water, rights of water distribution and management, procedures and penalties for the settlement of disputes, and the rightful way to administer water. Under the Romans, water laws derived from long-established customs, legislation by the senate and *comitia*, regulations by magistrates, interpretations by people qualified in law, pontiffs and jurists, and Huperial constitutions.

The laws dealt with both the private and the communal allocation of water, and were influenced by the agrarian economics of the empire (Kehoe, 2008; Peyras, 2008) and the maintenance of aqueducts (Rodgers, 2008). Roman water laws evolved to be able to accommodate the legal regimes of the empire's territories and the sensitive issue of neighbouring properties (Salerno, 2008).

Barraqué (in press) traces European water law back to the Romans, and to the Germanic customary community law. The transitions in the history of water law vary greatly in their source, context and theme.[5]

Getzler (2004) also provides a comprehensive account of the history of water rights in the common law of the United Kingdom. From 1750 the British courts developed a large but unstable body of legal doctrine, specifying strong property rights in flowing water attached to riparian possession, and also limited rights to surface and underground waters. The new water doctrines were built from older concepts of common goods and the natural rights of ownership, deriving from Roman and civil law, together with the English sources of Bracton and Blackstone. Water law is one of the most Romanesque parts of British law, demonstrating the extent to which common and civil law have commingled. Developments in other countries, as well as evolving supranational and regional water laws and politics, and current trends in international water law, are included in an edited volume by Dellapenna and Gupta (2009). Hildering (2004) explored the relationship between international law and sustainable development in water management. Recent historical developments include the International Water Law Project,[6] which is intended to serve as the premier resource on the Internet for international water law and policy issues, to educate and provide relevant resources to the public and to facilitate cooperation over the world's fresh water resources, and the UNESCO Centre for Water Law, Policy and Science.[7]

Both religious and customary (positivist) paradigms have emerged in early civilizations within particular sociopolitical and economic systems that were based on protecting and maximizing the benefits to first ruling elites and later property owners. Measures to protect other social groups or ecosystems were developed only to the extent that they served those who managed the system, monopolized power and amassed wealth. Attentive to the role of ethics in society and the implication of ethics in managing water ecologically, Harremoës (2002) argues that ethics is a viable substitute for overregulation (see below).

The rise of Christianity and Islam represented a breakthrough in conceptions of the way society ought to be organized and managed. The emphasis on equality, brotherly love (*agape*) and charity in early Christianity was an antidote to previous hierarchical social systems and inequities. Islam also emphasized charity (*rahma*) and promoted notions of equality among Muslims regardless of ethnic origin. However, this Christian–Islamic initiative was compromised by the persistence of pre-existing systems of inequalities, paradoxically perpetuated in many cases by religious leaders.

An ethical perspective on water management has been one of the priorities of UNESCO. I have been privileged to be a member of the Working Group on the Ethics of Freshwater Resources, which held four meetings from October 1998 to December 1999,[8] and of the UNESCO/World Water Assessment Programme (WWAP) and International Hydrological Programme (IHP) project From Potential Conflict to Cooperation Potential. In the context of this project, I offer a cultural strategy for introducing social change toward an equitable and just management of water as a means of mobilizing water for peace (Hassan, 2004b). Hefny (2006) gives an example of how ethical principles can be operationalized. In a conference on water ethics held in 2007, the contributors emphasized human water rights and dealt with issues such as traditional approaches to water ethics. Some discussed the ethical aspects of new water management, privatization, water ownership, and the more recently raised issue of intergenerational equity (Llamas, 2009).

# SECTION IV

## HYDROPOLITICS AND WATER HISTORY

The sociologist/historian Karl Wittfogel (1896–1988) has advocated that the relationship between political organization and water management systems was the principal factor in explaining the rise of centralized states in Egypt, Mesopotamia, India, China and Pre-Columbian societies. He argued that centralized state organization first emerged in arid regions to control large-scale hydraulic irrigation, drainage and flood-control works. According to his theory, only a complex state organization can manage the problems and activities associated with large-scale irrigated agriculture, such as the construction and maintenance of canals, embankments, dams and reservoirs; the allocation of water between upstream and downstream cultivators; and the arbitration of conflicts (for example, when downstream cultivators feel that upstream cultivators are using too much water or are polluting it).

According to Wittfogel's analysis (1957), control over the vital resource of water gave rise to social classes, and widespread specializations typical of centralized urban life, while it also gave the government power of life and death over its population. Thus a particularly extreme form of despotism is typical of hydraulic empires. Water control spawned authoritarian centralized empires and sprawling bureaucracies, which were deeply hostile to change. By contrast, he portrays Western Europe as having been free of such limitations, and therefore able to develop along a different non-despotic trajectory.

Wittfogel asserted that such 'hydraulic civilizations' – although they were neither all located in the Orient nor characteristic of all 'Oriental' societies – were essentially different from those of the West.

Wittfogel's hypothesis has been harshly criticized by archaeologists and anthropologists who are familiar with the empirical data from all the civilizations cited by him in *Oriental Despotism* (1957). For example, his ideas were refuted by Needham (1959), who argued essentially that Wittfogel's thesis was faulty on many accounts and that it was in essence a political polemic. First, Wittfogel accepts from the classical economists and from Marx their original conception of a special 'hydraulic Asiatic' mode of production, often called 'Asiatic bureaucratism'. Second, again according to Needham, Wittfogel proceeds to derive from this type of society, and indeed to read back into it, all the faults of modern totalitarian state power. Third, attacking these in the unmeasured language of the political pamphleteer, he finds himself forced to denigrate the medieval hydraulic bureaucratic society of certain cultures, especially the Chinese, as the source of all the evils of modern authoritarian states. Needham, who is very familiar with Chinese history, also points out that Wittfogel misread the role of bureaucracy in Chinese society, and that he misconstrued the role of religion.

In general, those archaeologists and ethnologists who have tested or examined Wittfogel's assertions over the last fifty years, on the basis of their intimate knowledge of most of the societies used by him to argue his case, have found Wittfogel's theory lacking (Earle, 1997; Johnson and Earle, 1987; Hassan, 1981; Hunt and Hunt, 1976; Hunt, 1988; Lansing and Kremer, 1993; Leach, 1959; Lees, 1994; Mitchell, 1976; Scarborough, 2003; Zimmer, 1995).

Bell (1994), in his examination of method and theory in archaeology, noted that Wittfogel's theory has rightly been criticized because it involved empirical tautologies, vague theoretical components, qualifications, and an unwarranted proclivity to draw from specific case studies a 'universal' theory. In addition, Wittfogel's thesis has been criticized because it assumes a unicausal relationship between complex water works and irrigation, and the emergence of centralized power, notably that of despotic rulers (Bray, 1986).

Wittfogel's treatise highlights the relationship between complex hydraulic works and political organization, but it does not follow that controlling hydraulic works was the prime cause for the rise of centralized government in great river valleys. The evidence indicates, contrary to Wittfogel's claim, that centralized state societies emerged before any major hydraulic works were attempted. Many case studies refute Wittfogel's grand theory.

In Egypt, for example, the earliest state-sponsored water works emerged a millennium after a centralized unified state was consolidated. These works were short-lived and were not attempted again until the Ptolemies ruled Egypt, about 1,700 years later. It does not follow either that bureaucrats or priests were restricted to hydraulic societies. Bureaucrats have many other functions related to collecting taxes and revenues, overseeing monumental edifices and temples, participating in artistic and intellectual life, and administering justice (Hassan, in press).

In a study of Mexican irrigation societies, Palerm-Viqueira (2006) concludes that there are two distinct types of self-management, based on who carries out the administration and operation of the irrigation system: specialized bureaucrats or the irrigators themselves (a non-bureaucratic system). She argues that a specialized staff for irrigation administration and operation characterizes all large systems, but that both small and medium-sized systems may be administered and operated by the irrigators themselves. Smallholdings and non-bureaucratic self-management of irrigation are linked.

However, Lees (1994) remarks that irrigation technology has as much to do with bureaucratic power as with water. Bureaucratic management *and mismanagement* of irrigation technology mediate the outcome of such development projects on the affected populations.

It is important here to consider not only the scale of irrigation projects but also the technologies involved in irrigation. Accordingly, there is a huge difference between modern or paramodern irrigation societies and those of earlier civilizations when irrigation techniques and hydraulic works were not very sophisticated. Let us consider the case of the development of a modern hydraulic society in the Mekong Delta.

According to Evers and Benedikter (2009), people in the lower Mekong Delta have traditionally lived in a way that is attuned to their natural surroundings, without much human impact on the complex natural water system of the delta. However, this has changed dramatically in recent decades, when hydraulic management became a key component in the development of the lower Mekong Delta. After the Second Indochinese War a new socialist government's policy of rapid agricultural extension through hydraulic management created a landscape of canals, dykes and sluices. This led to a social transformation, in particular the appearance of new strategic social groups struggling for access to resources and power, and marked the appearance of a state bureaucracy of hydraulic management and hydraulic construction companies as its clients. Strategic alliances between both groups have increased the chances of jointly appropriating the government funds spent on hydraulic works.

Almost paradoxically, Wittfogel's theory seems to apply more to Western, or westernized, scientific hydrotechnologies. According to Molle et al. (2009), who coined the phrase 'occidental despotism,' nineteenth-century colonial powers were in a position to mobilize massive corvée labour and the technical and scientific knowledge of enthusiastic engineers. This led to the transformation of local labour, land, and agricultural products grown in plantations or collected from local farmers. Notable figures associated with the diversion of great rivers to irrigate large and fertile alluvial plains and deltas include Sir William Willcocks and Sir Arthur Cotton in India and Egypt, H. de Bruyn in Indonesia, Homan van der Heide in Siam (now Thailand), D. Godard in Viet Nam, and E. L. Bélime in French Sudan (Mali).

A good example is the development of modern irrigation in Java, in the context of the establishment and transformation of the colonial state in the Dutch East Indies/

Indonesia. In order to make this relationship comprehensible the concept of a 'large technical system' has been adopted. The colonial irrigation system was built between 1830 and 1942, mainly by engineers, civil servants and agricultural experts who formed specific coalitions practising specific irrigation approaches. After Indonesia gained its independence in 1945, the colonial irrigation system remained in existence, and as a result irrigation engineering remained top-down, large-scale and focused on agricultural-technical management.

During the second half of the nineteenth century most irrigation development was based on private enterprise, with the exception of India and Egypt, where the British state invested heavily in irrigation and created irrigation departments. It was only at the beginning of the twentieth century that public investments in irrigation became common, leading to the creation of state water bureaucracies. The justifications brought up at that time embody many of the ingredients that would later shape, and still shape today to a large extent, the worldview and ideology of water specialists; encompassing enthusiasm for 'scientific irrigation', perpetuation of notions of domination and control of nature.

# SECTION V

## WATER GOVERNANCE AND SOCIETY: INTO THE FUTURE

By the 1990s, major changes in water governance were underway. The changes mostly involve a shift toward a greater role in water management for transboundary technical and administrative institutions, the increasing role of the private sector, including multinational companies which often operate from a base in developed countries, and the appearance of numerous global water initiatives. As a prelude to highlighting such recent historical developments, it is important to take into consideration traditional methods of water management, because such systems are still operative in many parts of the world and because in most cases, recent developments are in conflict with indigenous, municipal and state policies and strategies.

One of the major developments in the twentieth century was the emergence of national water laws, codes and acts with the aim of integrating water resources, providing administrative and financial institutions for water management, conserving ecosystems, and facilitating the public participation of water users. Such developments in Europe are exemplified by the case studies of Germany, France and Spain (Narasimhan, 2007).

In Germany, a Federal Water Code was promulgated in 1957 to unify water management practices throughout the country. This led to consolidation of the nineteen different pre-existing water regimes. The federal government became responsible for the policy framework of water management, while the German states have executive responsibility for management. When a watershed extends beyond one state, integrated management is facilitated through coordinating committees. The law was guided by the ideals of public good and social responsibility, which stipulate that ownership of land does not entitle a landowner to the use of surface water or groundwater without public consent. Except for small quantities of water, all users are required to obtain permits issued within the framework of scientific water management. In 1985, the Water Act was amended so that managing water could be an integral part of integrated ecosystem management.

In France, an inter-ministerial water commission set up in 1959 recommended unified water legislation. This led to the Water Law of 1964 and its amendment in 1992. Under this Water Law, water is regarded as a public good and all users must obtain permits for any type of water use. The Law provides for the active participation of citizens and users at all levels of decision-making. The Law also includes provisions to ensure the conservation of biodiversity and aquatic habitats. Surface water and groundwater are combined as complimentary sources of water. The country is subdivided into six river basins as units for management, an arrangement based on an infrastructure of technical institutions which gather, disseminate and monitor hydrological data. The managerial process is entrusted to a hierarchical structure of national, regional basin and local financial and administrative bodies. There is also an institutional set-up to deal with international water management issues (Narasimhan, 2007).

In Spain, water acts passed in 1866 and 1879 placed most water in the public domain, but left groundwater in the private domain. In the 1920s, river boards were established to harness rivers through the construction of hydraulic structures. In 1985, the Water Act 29/1985, amended in later years, focused on the management of river basins, with executive power vested in autonomous communities, but the state was made responsible for coordinating water management when a basin is shared by two or more communities. By the 1990s a National Hydrological Plan had been conceived to link river basins in order to allow for the transfer of water to arid regions, but the plan was shelved in 2004.

The 1990s witnessed the European Union's engagement in developing a global approach to water policy in Europe based on a wise, unified management of the water resources of all Member States. After open consultation with all interested parties, the European Union issued its WFD in 2000, calling upon Member States to enact suitable laws to comply with it. Declaring water to be a common heritage, the goals of the Directive were to ensure that Europe's water became cleaner through water management over river basins, to achieve a good status for all waters by a set deadline, to get citizens directly involved and to streamline legislation.

The history of European legislation on water goes back to the 1970s (Page, 2005; Kaika, 2003). From 1975 to 1988 it was primarily concerned with public health, and set standards for the quality of water used for drinking and the different aquatic environments that could affect public health, such as fisheries and bathing areas. From 1988 to 1996 the priorities shifted away from the protection of public health towards pollution control and environmental management. More attention was paid to preventing pollution emanating from urban wastewater and agricultural runoff. In parallel with this new emphasis on preventing pollution, the legal standards for drinking water sources were updated in the 1998 Drinking Water Directive, which introduced improved public access to information and clarified earlier legislation. This stimulated dramatic investments in water treatment infrastructure during this period. By the late 1990s it became necessary to strengthen the legislation to further protect water resources. This was partly a case of integrating separate but related directives, partly one of updating directives to meet new scientific knowledge, and partly about fortifying existing legal obligations to ensure better compliance. After twenty-five years of European water legislation both the scientific community and environmental groups were demanding more dramatic improvements.

The new EU WFD, affecting twenty-seven countries, signals an important trend towards ecosystem-based approaches for water policy and water resource management. The directive institutionalizes ecosystem-based objectives and planning processes at the level of the hydrographic basin as the basis for water resource management. However, Kallis and Butler (2001) are of the opinion that the fulfilment of the ultimate objective of a good overall quality of all waters is questionable because it entails high costs, and on account of the lack of adequate legal enforceability. Nevertheless, the directive will transform water institutions and planning processes, generate information and ensure no further deterioration of waters. According to Moss (2004), the WFD is creating new opportunities for overcoming problems of the institutional interplay between water management and land-use policy and planning. However, this will depend to a large extent on the willingness of water authorities in each Member State to take a partnership approach to implementation. This will prove difficult in those Member States that have traditionally relied on hierarchical, sectorial structures and regulator instruments to achieve environmental objectives. Bakker (2005; in press) examines recent developments from an economic and political perspective, arguing that a 'state hydraulic paradigm' was dominant until the 1980s. This paradigm was predicated upon a commitment to a universalized, integrated utility network as a key element of modernity (see above). However, since the 1990s, in parallel with the developments toward the EU framework, an economic market paradigm has been on the ascent. This paradigm is characterized by a neoliberal ideology based on the superiority of markets in allocating water, and the claim that our interactions with nature are best served by a market economy and a liberal international order. Bakker attributes the rise of the marketing paradigm to the perception that the failure in the water supply sector was governments' fault. By the time privatization of water supply was at its peak, the private sector was focusing its attention on large urban areas, and had failed to provide water to rural communities. In addition, changing economic conditions led to a marked decline in financing private sector water supplies.

In a study of colonial and postcolonial water management in Lagos and Mumbai, Gandy (2006) concludes that there has been an attempt since the 1990s to export the water privatization model to many cities in poor countries, but this has had a deleterious impact on water access and sanitation. The current policy debate is shifting towards a recognition that large-scale divestment programmes selected by transnational water companies will not benefit the poor, and that a combination of local solutions such as municipal bonds combined with guidelines for best practices may provide a better way. The state, whether as coordinator or direct provider, will continue to play a central role, not least through its control of politics and the economy. In Lagos and Mumbai the majority of the population in both cities lack direct access to municipal water supplies. As a result, the urban poor largely depend on exorbitantly priced private sources of water, such as tankers and street vendors. The municipal sector faces formidable fiscal, organizational and political challenges. In both cities there is intense debate over how to improve services and widespread scepticism about externally imposed privatization programmes. There is a high level of commitment in both cities to improving the efficiency, transparency and equity of service provision, but this rests on securing sufficient capital for investment, employing high-calibre dedicated staff and rebuilding public confidence in municipal government.

On a national level, Narain (2000) identifies some critical shortcomings in the governance structure of India's water resources. He makes a case for reforming the bureaucracy, for greater accountability and linking performance with reward. He argues that to achieve institutional reform in India's water sector means securing greater coordination and integration within the organizational structure for water management. It is also necessary to restructure water bureaucracies to become interdisciplinary and financially autonomous organizations. In addition, efforts have to be made to empower user groups with well-defined water rights and to foster a reciprocal accountability between them and the state bureaucracy.

In Kenya, Biongo and Le (2005) conclude that the population in urban slums continues to increase because of the availability of relatively affordable housing. However, most slums lack basic services. The majority of the inhabitants are low wage earners, but they have to pay more for water than their neighbours in well-to-do neighbourhoods. In Kibera, arguably the biggest slum in Africa, the water governance problems are multifaceted, and corruption is one of the main factors aggravating them. The authors recommend multilateral and bilateral dialogues involving stakeholders, and the establishment of an association of water consumers to represent and protect all household users. Privatization of water has already infiltrated China, and as a consequence the traditional structure of full government provision of water supply and wastewater treatment has changed dramatically in recent years. Zhong et al. (2008) provide evidence of the contribution of these new modes to increased capital investment, and especially to more efficient operations and improved service. In order for this scheme to succeed in the future, they recommend a balance between the water tariff level, investor profits and governmental subsidies. Lobina and Hall (2005) have already discovered that most instances of water privatization fail because of public resistance following sharp price increases and job losses. They also recommend a speedy implementation of a systematic and comprehensive governmental regulatory framework because current ad hoc, fragmented and diverse regulatory systems endanger both efficiency in water service development and the stability of foreign investment.

Récalt (2005), dealing with water management policies and governance in Ecuador, points out the disparity between traditionally based territory-bound systems, and current regulation on a global scale. Indigenous communities that remain attached to a water governance system based on links between territory and society are now obliged to follow a system independent of territorial considerations and social peculiarities. In addition, Ecuador's national economy is confronted with the globalization of markets, which creates transterritorial and transnational information systems and productive and financial organizations, while the socio-political regulations and institutional structures remain conceived and implemented within a national framework.

Many proposals for improving water management are largely based on models of developed countries that are often not compatible with the political and socio-economic realities of developing countries.

Examination of the governance of the Mekong as a transboundary basin reveals that the effectiveness of water governance cannot be assessed in terms of simple environmental, economic or social outcomes. Governance agendas, and even definitions, are too diverse, and the interests of stakeholders are too complex, to come up with a straightforward, universal master plan of catchment-oriented water governance. In practice, catchment governance in the Mekong is an arena for negotiating more sustainable transboundary water management.

Narasimhan (2007), who examines the performance of pubic water companies, contends that most public water companies in Europe are strongly committed to universal service and offer a high degree of capacity. This concerns in particular the quality of drinking water and sewage services. There is also, he infers, an increasing awareness of the necessity of achieving sustainable water management practices. Water companies have shown that they are willing to undertake ambitious programmes to protect natural water cycles, and to show ecological responsibility. However, he concludes that the social side of water supply is often not reflected. Almost everywhere, the costs of water provision and treatment are completely covered by water tariffs that relate to consumption but not to the individual financial situation of consumers. This mechanism of full cost recovery is often codified in law – among others in the EU WFD – and thus it is difficult for water companies to do anything different in this matter. The only place that addresses this issue is Dikili, Turkey, where debts from unpaid water bills have been cancelled and a minimum quantity of water is provided to people for free. Because of that, Dikili's mayor was brought to court in 2008, which shows that it is difficult to implement a social water finance system in the context of neoliberal political policy.

There is a campaign in Italy to provide 50 litres per day per person free of charge and to adjust water tariffs according to personal income and the size of household, which may be a step toward a more socially committed water policy. Other developments include the water law in the Netherlands, as well as the water regulations in the constitution of Vienna (Austria) and the charter of its water company. In addition, the people in the Swiss canton of Geneva included a water paragraph in their 2006 constitution stating that water supply and distribution must be public monopolies.

Furthermore, in 2007, six other Swiss municipalities supported moves to put water in public hands and to submit all important decisions to a participatory process. In most cases, the absence of adequate participatory processes makes it difficult to evaluate how effectively systems meet people's needs.

Narasimhan warns, however, that improvements in the social dimension of water supply are threatened by privatization and commodification pressures. One company, Stockholm Vatten AB, Sweden's biggest public water company, was for many years exemplary for its holistic approach in managing water resources and its earnest engagement with improving access to high-quality water for people beyond the Stockholm city borders. With two non-profit public–public partnerships, the company helped the cities of Riga (Latvia) and Kaunas (Lithuania) to build new modern water treatment plants and improve the quality of existing structures. But in December 2006, Stockholm's city council decided to commercialize the company, accompanied by outsourcing, reduction of investment and job losses.

Varaday and Meehan (2006) provide an insightful review of another phenomenon in water management, the emergence of 'global water initiatives', which consist of international societies, organizations and forums bringing together experts and academics from different disciplines to engage in discussions, dialogues and exchange of information and expertise, with a spectrum of objectives that range from policy and planning to technology applications in water management. Scientific organizations and societies have been involved for some time, beginning with the major global mega-conferences on water that have been held since the 1977 United Nations Conference on Water in Mar del Plata. Viewed from any direction, this conference was an important benchmark. There have been many other international efforts since that time, including the UN International Conference on Water and the Environment in Dublin in 1992, and the UN Conference on the Environment and Development in Rio de Janeiro the same year. The results of these two meetings have had only marginal impacts on water management processes and practices. The impacts of the World Commission on Water for the 21st Century, the Bonn Consultation, the Johannesburg Summit and the five World Water Forums are likewise debatable. However, a systematic study of the global water initiatives (GMI) reached differentiated results (Varady et al., 2008).

The increase in the private sector's involvement in water supply management on a global scale in recent decades has been met with anti-privatization campaigns and advocacy for water as a human right. Activists have promoted alternative water governance models through alliances among organized labour, environmentalists, women's groups and indigenous peoples. Bakker (2005) suggests that the adoption of a human rights discourse by private companies indicates its limitations as an anti-privatization strategy. She suggests instead that alter-globalization strategies – centred on concepts of the commons – are more conceptually coherent, and also more successful as activist strategies. Her paper concludes with a reiteration of the need for greater conceptual precision in analyses of neoliberalization by both academics and activists.

# SECTION VI

## WATER WISDOM IN A TIME OF CRISIS: THE ETHICS OF COOPERATION

Poor countries in many parts of the world are now facing the dilemma of having to undergo rapid industrialization in order to meet the challenge of growing population numbers, migration to cities, and greater demands for the amenities of urban living and a middle-class lifestyle. In the process they are causing stress to existing water resources, hastily and rather inefficiently developing new water resources, overlooking the degradation and breakdown of urban water and sewage infrastructure, and failing to minimize or prevent water pollution from modern farming and industrial installations.

Big dams and more dams are being developed at the expense of local ecosystems and indigenous populations as demands for both water and energy soar.

Industrial nations too face an increasing demand for energy, industry, services and urban growth. They are interlinked with non-Western countries through a web of economic transactions, and must accordingly cope, for the sake of economic sustainability and world peace, with the relative scarcity of water, water pollution from unclean modern farming, dirty industry, ecologically damaging dams, irresponsible withdrawal of groundwater, and unsanitary water management in urban slums in their own countries and elsewhere in the world.

We may cast our gaze back in time to the Roman Empire, with its population of 54 million people (about a quarter of the total world population) spread over Europe, Asia and Africa. The Roman Empire was the culmination of the growing interdependency of the world nations of early civilizations, the closest in antiquity to a global civilization. The fall of that mighty empire, in my opinion, was the result not only of a threat from its northern neighbours, but also of the heavy cost of an overextended military establishment and an unprecedented stress on water resources, which extended to very marginal and fragile domains such as the desolate Egyptian oases, with diminishing returns.

Investments in water works and water technology were too costly to sustain. In addition, graft, corruption, ostentatious consumption and greed prepared the way for the demise of the first quasi-global society. The Roman Empire was exploitative and oppressive, with a deplorable dependence on slavery. Revolts and discontent rendered occupation costly and its subjects ripe for social movements and resistance. The rise of Christianity and its appeal in the colonies are perhaps best understood in terms of this situation.

By the third century CE, the Roman Empire had also to face the threat of climate change and outbreaks of epidemics. According to Reale et al. (1995), most of the events of decline, famine and pestilence in Roman history can be explained by droughts. In their view, the entire process of the 'decline and fall of the Roman Empire' which took place between the third and fifth centuries CE can be correlated with a long and continuous drift towards drier conditions.

Today we suffer from the same ills: military over-expenditure to maintain the privileges of a segment of the world population, civil unrest as a result of inequities and flagrant differences in income, rampant urbanization, runaway technological advancements at great economic and ecological cost for short-term financial benefits, a precarious economy, the threat of global climatic change and epidemics.

Did the Roman Empire collapse because it had failed to produce a philosophy of equality and social justice to match its advanced water-engineering feats and military prowess? Did Rome, with its great 'democratic' institutions for those who were recognized as 'citizens', conquer the world, but fail to conquer its vanity, greed and blinding, misguided notion of who was a Roman, and who was not?

History reveals that our problems today are not without precedent, except that: (1) our water demands are rising sharply; (2) our ability to pollute is global; (3) our pollutants are more deadly; (4) our interference with ecosystems is both far-reaching and nefarious; and (5) all societies are closely interlinked so that any regional catastrophe can have global repercussions.

With the change in the scale of our relationship with nature and other societies, we are still constrained by the sentiments, ideologies and worldviews shaped in our remote and recent past by nation-states, religious divides, racial discrimination, elitism, consumerism, so-called 'rational' economic thinking, faith in technological fixes and anthropocentrism (the view that we are the masters of nature and that the world was created for our pleasure).

Although I firmly believe that we are at a stage where we cannot forgo advanced technology, and must rely on new technological measures to alleviate our current water shortages, I am equally convinced from historical hindsight that what we need first is a new vision and a new ethos. The current scarcity is a function of uneven distribution of financial and technical resources, as well as an explosive demand for worldly goods.

Let us recall that the great civilization of Ancient Egypt collapsed 4,200 years ago, when a series of severe, unforeseen lower Nile floods led to a devastating famine. The starving peasants were reduced to eating filth and then their children. Communications were disrupted, the peasants rioted and began to plunder places and tombs. The government collapsed and the social order was overturned. The country lapsed into an age of misery and turmoil, and struggled for 200 years to re-establish national unity and centralized authority (Hassan, 1997).

It is important to reflect upon the strategic measures employed to recover from that catastrophic breakdown. Shattered and depopulated, the country was put back together and mended by rulers who realized that a civilization could not be sustained without two things: (1) attention to water management; and (2) an ethical code of justice and compassion. The kings who succeeded in reunifying the country undertook major hydrological projects. In addition, they were no longer rulers solely (at least in principle) by divine right. They proclaimed instead that they were sent by the gods to protect the poor, feed the hungry and help their neighbours. For the first time, the names of the kings were conjoined with the name of the goddess of justice, *Ma'at*. In addition to the impact of (external) climatic conditions on global water resource problems and the social conflict they precipitate, there are also conflicts that result from internal social dynamics.

Today, potential and current conflict as a result of perceived water scarcities has led some to suggest that future wars will be about water. This is one of the most disturbing issues in the current discourse on water scarcity and its effects. Historically, conflict is a result of conflicting objectives among contenders, and may be resolved by a variety of strategies. It is also a product of framing problems within a scenario of antagonistic relationships with others. On a national level, such antagonistic relationships intensified with the rise of empires, and have continued ever since as a political strategy among 'nations' or political entities. However, the first steps toward resolving water problems, mostly caused by unpredictable rainfall, came through the emergence of collaborative and cooperative water communities.

As empires rose and fell, population increased, urbanization occurred, and there were increasing water demands by certain socio-economic segments of societies, water scarcities were created as demand exceeded locally available water resources, either for agriculture or for the urban centres. Such water scarcities were overcome by a spectrum of large-scale or sophisticated hydraulic engineering projects, such as grand canals, aqueducts, *qanats* and water-lifting devices.

Increasing demand for water was also linked to increasing agrarian production in order to provide the revenues needed to support a growing sector of non-food-producing rulers and their functionaries and service providers. This implied, in an economy based on agriculture with limited technological water management technologies and low-level sources of energy (human, animal, water and wind), a promotion of population increase. More people provided more revenues, and were also an asset in warfare, which emerged as an inseparable element of imperial expansion to add yet more people and more land, and to secure trade goods for the rulers and their supporters (religious functionaries and military officers). History reveals how religion was also mobilized to wage or justify warfare. The modern world, in spite of the rise of nations that claim a separation between 'church' and 'state', is not without religious ideologies, since individuals in and outside the state machinery are often religious. Today, many serious political confrontations within and between nations are overtly expressed through religious discourse.

Such conflicts are, in my view, symptomatic of a structural failure in the ideology and operational strategies of the nation-state since the eighteenth century. The strategies included colonialism, slavery, and unbridled, massive exploitation of natural resources. The huge technological advances in water management for industrial, agrarian and energy production have aggravated inequalities, and led to poverty and the deterioration of many fragile planetary ecosystems. These developments have also been coupled with an unprecedented increase in world population, mostly in poor countries, and a significant scarcity of freshwater resources. The situation is worsening as the scenario of a changing global climate threatens many countries with severe water shortage in the coming decades.

Conflict, then, cannot be viewed solely as a political issue, and scarcity cannot be combated merely by more technological advances. Conflict is a product of social processes embedded in a deeper cultural matrix. As such, any attempt to transform situations of conflict or potential conflict must entail an understanding of social change.

Societies are neither homogeneous nor static, passive recipients of traditional lore because societies consist of cognisant, purposeful individuals who process information to make decisions. A society is a society of minds, minds that are in a state of dialogue to create viable corporate entities for doing the work and taking the actions that ultimately lead to the survival, welfare or demise of the group.

Modern societies exist in an arena of transactions structured by governmental and state organizations, financial and economic corporations, military establishments, educational institutions, science and technology foundations and organized religious orders. The 'public' consists of individuals who belong to a matrix of regional communities, occupational associations and socio-economic segments.

There has been a tendency in dealing with water conflicts to regard such conflicts as a matter of intergovernmental concern that can be resolved or reversed through treaties. However, the role of individuals (as members of government or the public) is rarely considered as the primary locus of social change (Saunders, 1999). Harold Saunders, who has been involved in conflict resolution for more than two decades, has aptly concluded that:

> *recognizing the human dimension of conflict opened the door to seeing peacemaking as a process not limited to the work of governments. Important as that work was ... it depended in fundamental ways on changes in human relationships – an arena well beyond the reach of governments alone. As that insight became more concrete, it enlarged the concept of the peace process.* (Saunders, 1999, p. xix)

Change in societies, in the long run, is a function of the differential adoption of novel ideas, modes of behaviour, belief systems, technical innovations and social institutions. Such innovations may prove to be ephemeral or permanent. Their permanency depends on their compatibility with pre-existing cultural modalities and their perceived benefits weighed against their perceived ill-effects. The preference for cooperative strategies that characterized early farming communities was an extension of the ethos of sharing that was fundamental to the sustainability of hunting-and-gathering societies. The widespread adoption of *qanats* was advantageous for communities anywhere in the world where springs or groundwater resources could be tapped at a reasonable distance in arid lands. It was beneficial to local communities as well as to the rulers.

Innovations may be adopted by the masses or by non-governmental associations, leading to a tide that may force a gradual or revolutionary change in government. Alternatively, innovations may be dictated by governments. In general, governments may co-opt mass movements (as happened with Christianity in the later phase of the Roman Empire and trade unions in modern nation-states) and the public may come to transform a governmental dictate into a popular belief.

Perhaps one of the most relevant issues in the modern discourse on water managements concerns the notions of water rights and responsibilities. From the beginning of state societies, the banks of rivers were used for fishing, fowling and hunting, as well as irrigation and drainage. Ports, towns and cities were subsequently installed at key locations along the banks of rivers. Ports contributed to the transcultural flow of information as well as the flow of goods. With the rise of industry, river banks were favourable sites for factories. As different users – and more users – competed for the resources of river banks, the optimal and equitable allocation of resources became essential for peaceful coexistence and social concord, and perhaps enhancement of the quality of life for all. This raises many questions related to rights and responsibilities, which were addressed, for example, as early as the second millennium BCE in the Code of Hammurabi.

As already noted, rights and responsibilities, however, are not separate from the overall scheme of appropriate and acceptable or commendable norms, laws, duties and regulations which lie in the domain of ethics.

Conflict over water today cannot be considered solely in terms of existing laws embedded in older models of governance and exploitation. A peaceful resolution to conflicts over water must be managed with reference to the universal ethics of humankind, current postmodern transcultural forces, the potential of the booming information networks, and the persistence of traditional models of culture.

An in-depth exploration of the role of cooperation in the evolution of civilization has been brilliantly attempted by Robert Wright, who in *Non-Zero: History, Evolution and Human Co-operation* (2000) reveals the hidden logic of cultural evolution as an outcome of long-term profitable payoffs if contenders adopt a strategy of cooperation, thus increasing the range and variety of payoffs. For example, competition over Nile water could be replaced by a strategy to cooperate among contenders in economic and cultural fields, thus creating the potential of a much greater gain for each contender than would come from a limited share of water. Such cooperative ventures also eliminate the cost of conflict, especially if such a conflict escalates to a military confrontation involving loss of lives and the diversion of much-needed financial resources to a wasteful effort.

The recognition of the plight of more than 884 million human beings who live in poverty with no access to safe drinking water, and of more than 2.5 billion who have no access to proper sanitation (WWAP 2009), has meanwhile created an outcry echoed by various international bodies. This outcry is being translated into action and recommendations for action, such as those spelled out in the Bonn Ministerial Declaration (December 2001), which includes:

1. Secure equitable access to water for all people.

2. Ensure that water infrastructure and services are delivered to poor people.

3. Promote gender equity.

4. Appropriately allocate water among competing demands.

5. Share benefits.

6. Promote participatory sharing of benefits from large projects.

7. Improve water management.

8. Protect water quality and ecosystems.

9. Manage risks to cope with variability and climate change.

10. Encourage more efficient service provision.

11. Manage water at the lowest appropriate level.

12. Combat corruption effectively.

This declaration, signed by 46 ministers responsible for water affairs from countries all over the world, is a positive step toward improving the current situation. The declaration must be viewed as a step in a long process, and the outcome of previous efforts by UNESCO, the International Hydrological Programme and other international organizations.

# SECTION VII

## VALORIZING WATER HERITAGE

Throughout history water has been our most precious and critical resource. It has been so intimately linked to our very existence and cultural development that it has become the source of rich symbolism, rituals and religious beliefs. Throughout history, our vital relationships to water have led to material testimonials of how water was used, managed and valued. These material historical and archaeological remains range from humble water-lifting devices such as the *shaduf* to elaborate, spellbinding monumental works of art and architecture, such as the stepwells of Rajasthan (Misra, 2009; Livingston, 2003).

Among the earliest legacies of our common human past was the management of water to cultivate rice in China, wheat and barley cereal crops in south-west Asia, and maize in South and Central America. This first attempt at 'domesticating' water created a landscape of irrigation canals, drains, embankments and terraces to sustain and develop agriculture as a dominant way of life which has since expanded to most of the world. The rural landscape and the urban life of the elite, supported by agrarian products, have bequeathed us with a world legacy of ingenious water works.

In one of China's World Heritage sites, an ancient system of dams, dykes and sluices has helped control water and irrigate the Chengdu Basin of central Sichuan since the third century BCE. The system included dividing and channelling the Minjiang River.

In the Mediterranean region, cultural landscapes are infused with the legacy of such water-lifting devices as the *shaduf* and the Alexandrian (Archimedean) water screw, combined with the Nabatean aqueducts, and subterranean water tunnels (*qanats*).

The *shaduf*, a common feature of the rural landscape in Egypt fifty years ago, has now virtually disappeared, except for a few that may still be seen in remote areas. The Nabatean aqueducts in Petra, Jordan, part of a complex water-harvesting system, are now included in a World Heritage site, a favourite tourist attraction. *Qanats* are well represented in Iran, where tens of thousands were constructed. The oldest and largest known *qanat* is in the Iranian city of Gonabad, which after 2,700 years still provides drinking and agricultural water to nearly 40,000 people. Its main well depth is more than 360 m and its length is 45 km. *Qanats* are well represented at Yazd, where an International Centre on Qanats and Historic Hydraulic Structures (ICQHS) has been established under the auspices of UNESCO.

Water-lifting devices and advanced architectural principles provided the basis for hydraulic engineering in Roman times. One spectacular example is the Pont du Gard, which was built shortly before the Christian era to allow the aqueduct of Nîmes (which is almost 50 km long) to cross the Gard River. This 275 m long aqueduct, which stands on three levels, almost 50 m high, is a technical as well as an artistic masterpiece. Numerous other examples of water heritage have been compiled in a pioneering work by Hermon (2008).

Given the transcultural perceptions of the symbolism of water which combine a sense of the divine and a manifestation of power, water gardens were often a feature of palaces and temples. In ancient Egypt (from 3200–300 BCE), for example, a sacred water pool was an essential aspect of temples, which also featured gauges for measuring the height of Nile flood levels (Bellinger, 2008; Wilkinson, 1998).

In Mohenjo-Daro and other cities of the Indus civilization (2500–1700 BCE), ritual bathing areas were prominent. In other cities throughout history water played a role in making palaces, gardens and public spaces places for tranquil reflection, joyous exuberance, spiritual renewal and community celebrations.

Lansing (1991) reveals how water temples were an integral element in Balinese water management. Different types of water temple architecture such as ghats, tanks, wells, pools and baths were common in south Asia (Hegewald, 2002).

Wealth and power provided the means to bring the pleasurable sensations of water pools, streams, waterfalls and springs to luxuriant gardens. Such gardens promoted the invention and development of ingenious hydraulic water features. The Sigirya in Sri Lanka, with water gardens and moats, displays one of the world's most sophisticated hydraulic technologies dating to the fifth century CE.[9]

A remarkable example of the earliest use of water in garden architecture comes from Mesopotamia, and is attributed to Sennacherib (704–681 BCE), who brought clear water from a mountain river down to his gardens and parks at Nineveh along channels and aqueducts from a beautiful place called Bavian, north-east of Nineveh. The remains of this aqueduct can still be seen, built in monumental stone, with arches that have pointed tops. The Hanging Gardens in Bablyonian Mesopotamia were among the wonders of the ancient world (Dalley, 1993).

The legacy of water gardens in association with palaces is also clearly manifest in Suzhou, China, where four gardens were included in 1997 on the list of World Heritage sites.[10] In Japan, ponds are an integral element of palace gardens. In addition, ablution containers by the gate are an essential element of temples. Also, Kiyomizudera ('Clear Water Temple' in Japanese), a World Heritage site and one of the oldest temples in Kyoto, the country's ancient capital, takes its name from the clear, pure waterfall that originates from an unknown source deep within Mount Otowa (Sound of the Feather Mountain). On many occasions, festivals linked to water are celebrated, as in the case of the festival of the plenitude of Nile floods (*Eid Wafa el-Nil*).

The legacy of water gardens and architecture is everywhere rooted in the earlier developments in China and India, as well as in Mesopotamia and Persia, which inspired the Greeks and thereafter the Romans (Farrar, 1998).

One of the major factors in the history of water gardens was the spread of Islam outside Arabia to Persia, where gardens had a long history before Islam. Muslim rulers continued the Persian water garden tradition and incorporated it into their vision of Paradise (*Al-Gana* in Arabic, pronounced *Al-Janna* in Classical Arabic, and *Al-Ferdous*, adapted from the word for Paradise in Persian, a word derived from the word used by Persians for an enclosed [walled] garden).

Islamic gardens were characterized by two contrasting elements, water and shade. Four water canals typically carry water into a central pool or fountain, the four streams symbolizing the four rivers of Paradise. In Andalusia, Spain, where Muslims first established their rule during the eighth century CE, the Alhambra's patios and nearby Generalife Garden were designed with garden paths, water streams, garden pavilions and fountains in a geometric form of landscape that is full of peace and comfort (MacDougall, 1976; Geddes-Brown, 2008). El Generalife was the summer palace of the Nasrid Muslim kings of Granada. It stands on top of the hill of El Sol, twin to that of the Alhambra, towering over the River Darro. In this World Heritage site, the spectacle of El Patio de la Acequia, with a central channel and countless little channels, fountains and water jets, is unforgettable. Here one must also recall the hydraulic achievements involved in such lovely gardens, which included an aqueduct that brought water from the River Darro all the way to the top of the Red Hill in the thirteenth century CE. Indeed, modern water technology is indebted to the legacy of water gardens and bathing, which were once only enjoyed by the wealthy and powerful. Today, modern science and technology have made baths and private home gardens affordable and practical.

In Western Europe, where modern sanitation and water garden technologies originated, the great period of water gardens was the Renaissance. At this time a variety of water features invoked Roman mythological characters, and a dazzling array of grottos, fountains, troughs, waterfalls, ponds and water jets created a fabulous water spectacle. Water features in gardens displayed the technical skills, aesthetics, wealth and power of the garden owners (Lazzaro, 1990). One of the most celebrated Renaissance gardens with marvellous water features is at Villa d'Este, which is on the World Heritage List (Hunt, in press; Durand, 1992).

The Loire Valley, also on the World Heritage List, is a showcase for a cultural landscape suffused with the practical utility and aesthetic enjoyment of riverine water. Its magnificent chateaux, pleasure gardens and river scenes capture the sensibility of *l'aquisité*, the Renaissance term for the enjoyment of water in all its forms. In the meantime, one may grasp the historical imprints of Roman legions, medieval monasticism, feudal castles and the temporary presence of the royal court. In managing World Heritage sites, this intimate link between aesthetics and hydraulics on the one hand, and the transcultural, universal history of water works from irrigation canals to water mills on the other, cannot be ignored or minimized.

The art and technology of water gardens reached new heights in Versailles. The gardens cover some 800 ha of land, much of which is landscaped in the classic French garden style perfected by André le Nôtre in 1688. Dating from the time of Louis XIV, they still use much of the original hydraulic network. The artistic extravaganza at Versailles would not have been possible without the water wheel as a water-lifting device. Water was supplied from a complex of water wheels, known as the machine at Marly. This was the biggest water-wheel installation ever constructed, and was completed in 1682.

The role of water mills in the industrial development of Europe is highlighted by the Derwent Valley Mills in the United Kingdom (which were started in 1771). Indeed, the emergence of Europe as a world power can not be appreciated without recognition of the critical role played by rivers in industry, trade and nation-building.

The world's water heritage is at the moment threatened by development projects, urbanization and 'modernization' (Hassan, 2003). For example, unregulated development of areas of traditional farming, such as the Ifugao rice terraces in the Philippines, another World Heritage site, has led to a progressive disintegration of the mud-walled terraces, regarded as one of a few surviving wonders of the world. The plight of the Ifugao rice terraces highlights the complexity of managerial issues, and specifically the need to take into consideration both the regional context of sites and the socio-cultural matrix of national development, including tourism.

The Ifugao farmers converted their paddies to residential and marketing lots. The young are no longer interested in the arduous, low-income tilling of the mountain-side. Another catastrophic development is the destruction of the fragile mossy forest of stunted oaks and other trees of the mountain tops by farmers seeking to grow vegetables. This practice is causing an increasing number of landslides which destroy terraces that are already suffering from neglect. In the past, the mountain top was managed by an indigenous clan system (*muyong*). In this system, small patches were owned by clans to support the rice fields below. In these patches trees, animals, food and water coexisted.[11] Thus, as in other cases, the social fabric is threaded together with the natural elements to sustain a unique cultural landscape. Management plans in such cases require a broad outlook on a national as well as a local scale, with due consideration to social mobility and economic incentives.

Another example of a unique water heritage is Hue, the nineteenth-century imperial city of Viet Nam, which is crossed by the River of Perfumes, and is situated in a land of water, a country of mist and rice with canals and hanging gardens. Here heritage and development conjoin in a programme of eco-development inspired by traditional models of irrigation and farming.

Yet another World Heritage area provides us with a glimpse of the struggle for survival by our human ancestors before agriculture was introduced. The following examples focus on natural – as opposed to built – sites, which are important in revealing the variety of water sources that support life on this planet, and our own life-support system.

In the Tasmanian Wilderness World Area, listed in 1982, which covers approximately 1.38 million ha and includes four large national parks and reserves, an indigenous (aboriginal) population, which had once survived by subsisting on the coastal resources and the plants supported by a network of rivers and lakes, was doomed to virtual extinction by 1905 after the arrival of European settlers (mainly convicts from the United Kingdom).

In addition to standard management procedures,[12] the management of the Tasmanian Wilderness World Area provides a rare opportunity to inform the public and visitors of the role of water in the life of pre-agricultural peoples. Clearly this is an area where aboriginal involvement can be effective and rewarding. The area also provides a framework for contrasting aboriginal management of water resources with what followed, which included the building of the Gordon River Dam in the 1970s. This dam included the flooding of Lake Pedder to supply cheap electricity to spur industrial growth. The construction of another dam, which would have flooded the Franklin River wilderness, was stopped by the government. However, mining and exploration in national parks has been allowed in Australia since 1989.

Mining is one of the main threats to our world natural heritage. In one of the worst environmental disasters in Europe, a supporting wall of the reservoir containing the toxic wastes of Aznalcollar mine in Spain burst in 1998, releasing 5 million cu. m of toxic mud and acid water into the surrounding landscape. The toxic waste entered the Agrio River, a tributary of the Guadiamar River, which feeds the swamps of the Guadalquivir situated within Doñana National Park, a World Heritage site listed as a wetland of international importance. Long-term problems and threats include possible contamination of groundwater.[13]

On the Newnes Plateau in the upper Blue Mountains in New South Wales, Australia, the Calerence Colliery discharges 14 megalitres a day of polluted water into the Wollangambe River. The upper reaches of the river are coated in black muck, placing at risk the ecological integrity of this pristine river in the Wollemi wilderness within the World Heritage area.[14] Also in Australia, the Jabiluka uranium mine poses a 'serious and specific danger' to the World Heritage listed Kakadu National Park. In Canada, the Prairie Creek mine includes barrels of polychlorinated biphenyls (PCBs) and cyanide which could be flushed downstream by flash floods, contaminating the watershed of the Nahanni National Park, just upstream from the Heritage site.[15] In addition to mining, threats to aquatic World Heritage sites also include, as at Lake Baikal, logging, pulp and paper mills that pump toxic effluent into the lake. Lake Baikal is the largest freshwater lake in the world. The surrounding forests and Kamchatka volcanoes provide one of the most stunning landscapes in Russia.[16] In some cases, as in Baikal, these economic activities are among the most politically sensitive, and progress in resolving conflicts and removing the threats of pollution is slow or non-existent. In Tunisia, for example, Ichkeul Lake, a haven for migrating palaearctic water birds, was under such severe threats from damaging human activities that it was placed on the list of World Heritage in Danger in 1996. Two dams built upstream have reduced the flow of freshwater, leading to a damaging increase in water salinity. Overgrazing and land clearance by eighty families living in the area, as well as fishing, logging and farming, pose additional threats. Proposed management strategies to remedy this situation include establishing a central authority to deal with the threats of human activities, the infilling of a canal that drains the marshland and thus increases salinity, and the construction of a sluice to control water salinity and restrict seawater entry.[17]

Water heritage sites, notably those on UNESCO's World Heritage List, should be used as venues for making both the public and policy-makers aware of our common water legacy, and the ingenious technical and social solutions devised by our predecessors to overcome water scarcity. We can learn from their innovative ways and implement better approaches for shaping our common future (Hassan, 2003). The rich and diverse water heritage will have to include not only monumental sites from the past, but also the range of tangible and intangible legacies of water management. The management of monumental and material heritage sites as well as heritage water landscapes (oases, terraced fields or parks) provides ideal places for water heritage centres, parks or museums to celebrate our common water heritage though water poetry, music, songs, dances, festivals, plays, photography and painting.

In light of the intricate link between water and both natural and cultural heritage, our approaches to water and world heritage require both reflection and strategic planning. One clear objective should be the protection of World Heritage sites from natural and human-induced water hazards. Another objective would be the preservation of sites by ensuring adequate and sustainable water conditions (in terms both of supply and drainage). Another key objective, which has regrettably been ignored so far, is how to deploy World Heritage sites to further our appreciation of water as the most critical resource for future peace and prosperity, and to inform the public of the role of managing water in our human journey from the ancient past to the present.

These examples are clearly a matter of concern. They point to the conclusion that any management plan for World Heritage sites must take into consideration pragmatic (feasible) measures to leverage political will and financial resources to provide alternate means of living for the communities that depend on mining and milling; and for the clean-up of the threatening pollutants, as well as the reorganization of other harmful activities. A review of the impact of mining and similar water-polluting activities on World Heritage sites is needed, and specific guidelines for action in view of the numerous cases where environmental damage has already been done or is imminent should be included. In partnership with other organizations such as the International Union for Conservation of Nature, the UN Foundation, the UNESCO International Hydrological Programme (IHP) and the World Heritage Centre may develop a programme for monitoring and mitigating threats to the water resources of World Heritage sites that are vital to the integrity of the ecosystem, biodiversity and sustainable development. The measures to be contemplated cannot just be technical. Rather, a consideration of social, economic and political variables, and efforts to implement viable measures to protect and conserve World Heritage sites, requires that an integrated management strategy be applied. Such an integrated approach is advocated here to counteract the impact of water runoff charged with sediments and pollutants that threaten the quality and integrity of lakes and shallow marine and coastal ecosystems. The introduction of new technologies to treat wastewater should involve stakeholders in order to achieve an acceptable convergent view, performance targets and evaluative measures.

The variety of World Heritage sites, including waterfalls (such as the Victoria Falls, 'The Smoke that Thunders', Zimbabwe), subterranean caves with underground passageways, tunnels, shafts, dripstones, stalactites and stalagmites (such as Mammoth Cave National Park, Kentucky, USA), delta wetlands (for instance, Sreburna in the delta of the Danube River in northern Bulgaria, fed by river and karstic water), and the areas mentioned above, provides an extraordinary opportunity to inform the public and future generations about the water cycle, thus contributing to a common vision of the current problem of water scarcity and how to deal with it. We refer here to the educational activities offered by the Tongariro World Heritage area in New Zealand.[18] Of particular interest would be the explication of the movement of water below the ground, an enigmatic subject for the general public, yet a matter of great importance in understanding ecosystems and water pollution. Mound Springs of South Australia, along with caves such as Mammoth Cave, is an outstanding site of groundwater discharge at the south-western edge of the Great Artesian Basin, the world's oldest and largest groundwater system. These sites provide educational opportunities for enhancing our awareness of how nature works, which can be a decisive factor in seeking public support for protecting World Heritage sites, and in itself an essential activity in developing an appreciation of our natural world heritage.[19]

The Mound Springs of South Australia, which have yet to receive recognition as a World Heritage area, were vitally important for the non-agricultural Australian aborigines who recognized them as sacred cultural sites. They were also critical in the European expansion of Australia's interior, and later in the opening-up of this land for pastoral use and large-scale mining. Having been affected by mining and dams, and by excessive extraction of groundwater over the last century, the Springs are instructive in revealing the close link between land use and the scarcity of water resources, as well as in showing the unprecedented impact on water resources and the integrity of ecosystems when their water supply was undermined over the last century. Sites with groundwater resources must include management measures to incorporate development of the groundwater reservoirs, the renewal rate of water supply, and the effect of intrusive activities in the catchment area on the sustainability and integrity of the site. The concept of zoning must thus be extended well beyond the declared boundaries of the sites, for sites with both subsurface and surface water resources. For example, in Florida, safeguarding the Everglades World Heritage site and National Park required the acquisition (by purchase) of 40,500 ha of land along the eastern boundary of the park. The problems of World Heritage sites, however, are often regional. The Everglades, for example, encompass the southern end of a 150 km drainage system for central Florida, requiring coordination with other state authorities to control water quality and the timing of water delivery.

Protection, preservation and conservation are important priorities in managing World Heritage sites, but it is also important to reflect on the objectives that impel us to preserve and conserve such sites for future generations, and what kind of information we need to transmit. In designing a strategy for the conservation and revitalization of our world water heritage, we should not overlook the rich diversity of intangible heritage that often survives in the proverbs, songs, festivals, stories, games and celebrations of ordinary peoples all over the world. Water monuments may serve as social spaces for the transmission and perpetuation of water lore and traditional values.

In the process of examining water history for a better future, sites on UNESCO's World Heritage List may be used as venues for making both the public and policy-makers aware of our common water legacy, and the ingenious technical and social solutions devised by our predecessors to overcome water scarcity as a means toward innovative approaches for shaping our common future.

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