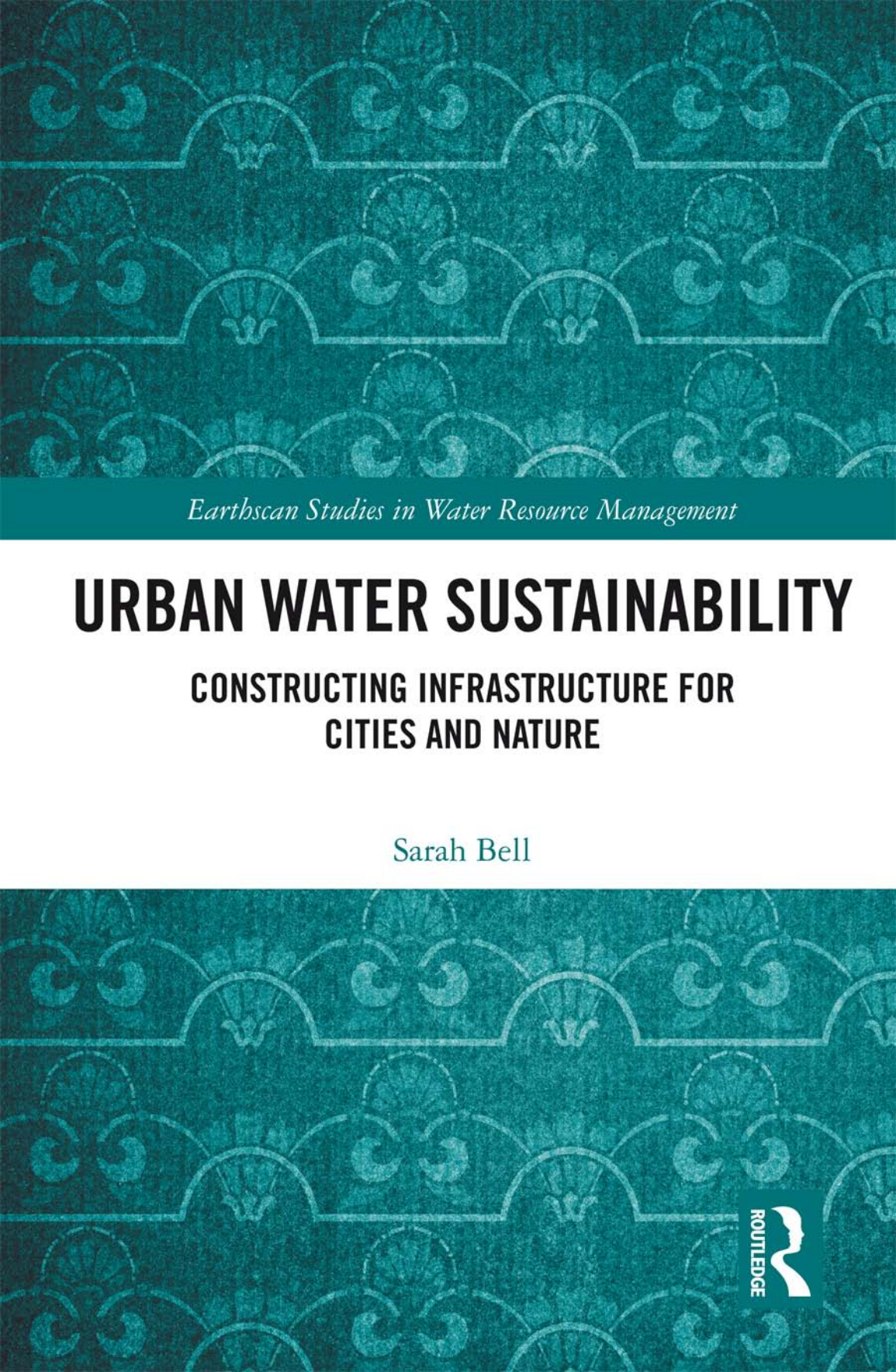
Earthscan Studies in Water Resource Management
URBAN WATER SUSTAINABILITY
CONSTRUCTING INFRASTRUCTURE FOR CITIES AND NATURE
Sarah Bell
ROUTLEDGE

Urban Water Sustainability

The provision of a safe and reliable water supply is a major challenge for the world's growing urban populations. This book investigates the implications of different developments in water technology and infrastructure for urban sustainability and the relationship between cities and nature.

The book begins by outlining five frameworks for analysing water technologies and systems – sustainable development, ecological modernisation, socio-technical systems, political ecology and radical ecology. It then analyses in detail what the sustainability implications are of different technical developments in water systems, specifically demand management, sanitation, urban drainage, water reuse and desalination. The main purpose of the book is to draw out the social, political and ethical implications of technical changes that are occurring in urban water systems around the world, with positive and negative impacts on sustainability.

Distinguished from existing social science analysis due to its attention to the engineering details of the technology, this book will be of use to a wide audience, including students on water management courses, engineering students and researchers, urban geographers, and planners interested in sustainability, infrastructure and critical ecology.

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Preface

As I write this book in the summer of 2017, more than half a million people have contracted cholera in Yemen, and nearly 2,000 have died. Drinking fountains in Rome are being turned off and nearby towns face water rationing as drought continues and more than a third of water supplied is lost from old, leaky pipes. Here in London, the last cholera epidemic was in 1866, just prior to the completion of the intercepting sewer network, one of the biggest infrastructure projects this city has ever seen. Since 2012, London has had a desalination plant sitting idle at great expense, just in case of severe drought, while leakage remains around 25%.

Water infrastructure matters. It protects cities from disease and provides a buffer against seasonal variability in rainfall and the extremes of drought. Water infrastructure is never finished. While Londoners now live without fear of cholera, supplying water to a growing population with finite water resources, fixing leaks, preventing overflows of sewage from nineteenth-century sewers into the Thames, and paying for a desalination plant that has never been used are just some of the complex challenges facing water managers and citizens. Water infrastructure is even more of a challenge in cities of the Global South, which are still struggling to deliver universal access, good public health and basic environmental protection.

Water infrastructure and sustainability defy categorisation into the boxes of technology and society that have come to define our universities, professions and institutions. Technology, society, politics and ecology get all mixed up in trying to talk about sustainable urban water systems. Interdisciplinary approaches are needed, but interdisciplinarity is hard. I've been trying for decades.

I started my career as an environmental engineer in the 1990s. At the University of Western Australia, I studied flow in pipes and channels, rainfall-runoff hydrographs, water and wastewater treatment, the hydrodynamics of lakes and rivers, and the impact of pollutants on human health and ecosystems. In an 'engineering communications' course we debated whether sustainable development was an oxymoron, and I took the side of the optimists – surely development was possible without destroying the planet.

I learned that technology could solve problems, but as a graduate engineer in the aluminium sector I also learned that technology choices are constrained by economics, regulation and the sheer momentum of industrial growth. I wrote an essay for a part-time master's course at the University of New England about the ethics of climate change, and I decided to go back to university to figure out why our technologies were still so bad for the environment. If engineers could solve most technical problems they were set, it had to have something to do with society, politics and economics.

I started a PhD at the Institute for Sustainability and Technology Policy, then at Murdoch University in Perth. There I met scholars who questioned the fundamental basis of human relations with the natural world. I read deep ecology and ecofeminism, and I talked to farmers about the Oil Mallee Project, an initiative to reintroduce indigenous trees back into agricultural landscapes buffeted by global trade and local hydrology. Theories about the dangers of the domination of nature by Western industrial culture rang true as I drove around wheat fields threatened by land salinisation and visited rural towns that were rapidly depopulating, but they weren't much help in figuring out what to do about it. I discovered actor-network theory and ideas that interpreted the modern world as a series of interconnected socio-technical systems. I used them to structure my PhD dissertation and to think about sustainability as an interdisciplinary endeavour.

Sometime later I landed in London, and I returned to water and engineering. At UCL I worked with urban geographers and planners who pointed out that water and power often flow in the same direction. They showed me that the fact that the poorest, most marginalised people in cities are also the most vulnerable to water infrastructure failure is not a coincidence, but the outcome of a form of politics dominated by neoliberalism and global capitalism. I also worked with engineers who remained convinced that technological and economic efficiency were the key to sustainability, and ecologists who turned their scientific understanding of the natural world into 'ecosystems services', so that economists could value it and policy-makers take notice.

Eventually, I came around to writing this book. I wanted to analyse the technologies of urban water infrastructure in a way that represented the complex relationships between cities, nature and water. But who was right? The teenager in the 1990s excited by the possibilities of sustainable development? The young engineer working to design technologies to protect the environment and make money? The wide-eyed PhD student captivated by philosophies of living in harmony with nature? The researcher putting methodologies from science and technology studies to work in understanding sustainability? Or the global citizen worried about the unequal distribution of wealth and environmental costs and benefits?

My own journey as a researcher and engineer reflects wider debates about sustainability, technology, society and nature. The stages of my interdisciplinary development and the colleagues I met along the way map onto wider

theoretical and political frameworks – sustainable development, ecological modernisation, radical ecology, socio-technical systems and political ecology. Each of these positions gave me useful insights, but none of them had all the answers. And so each has its place in my book about water in cities, the subject I have spent the last 12 years researching.

After many years of trying to choose a theoretical framework, or join an academic tribe, I have come to value pluralism. Each of the perspectives I've explored across my career and in the research for this book reflects different politics and values, ways of understanding the world as it is and deciding how it should be. I can analyse the merits and consequences of different positions, but ultimately it is not for me as a researcher to decide which is 'right'.

As global and national politics seem to be moving out of a period where one particular form of politics, neoliberalism, has dominated public policy and discourse, pluralism offers hope. It is possible that the world will emerge into another dominant form of politics that will structure relationships with each other and the natural world for decades to come, but it is not possible at this point to say what that will be, and it certainly will not be decided by academics working in universities.

And so it is with urban water sustainability. There are many different ways of understanding water in cities and working towards a sustainable future. My intention here is to make them apparent to others working and studying in this field, to provide some structure to the rowdiness of debate about how to build cities where people can live healthy, fulfilling lives without undermining the hydrological and ecological systems that we are part of.

This book is not about me. It's about water in cities. I have written it in the absent third person, the standard voice of authority, but my own values and experiences shape the text as much as the data and research it refers to. This story of my own meandering career and academic exploration might help you to read the book as an intellectual and personal journey as well as an analysis of urban water sustainability and contribution to deliberation about the kinds of cities we want to live in.

Sarah Bell, August 2017

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This book is the outcome of more than a decade of research and more than a year dedicated to writing. Many people and institutions contributed to the development of the ideas and provided the space and time to get them onto paper.

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Colleagues in the Department of Civil, Environmental and Geomatic Engineering at UCL worked around my research and writing commitments, allowing me to disappear for long periods. They also provided an environment where thinking strange interdisciplinary thoughts and taking on ambitious intellectual projects was considered quite normal, for which I am grateful. The Institute for Environmental Design and Engineering provided a quiet desk for finishing the project, and a new home for future research. The UCL Grand Challenge for Sustainable Cities, Environment Domain and the Urban Laboratory helped me to learn about cities, development and interdisciplinarity from very clever and generous colleagues from all over the university.

These ideas have been developed in collaboration with many outstanding students who have worked with me over the years. Joseph Hillier, Kate Crawford, Andrew Chilvers, Tse-Hui Teh, Tori Aitken, Ashley Woods, Luke Mitchell, Crystal Fenwick, Vera Bukachi, Atiyeh Ardakanian, Pascale Hofmann, Fernanda Garcia Alba Garcidiego, Usman Akeel and Zeyu Yao all challenged and inspired my thinking about water, cities, technology and sustainability as I supervised their research degrees. Many master's and undergraduate projects are the source of much of what I have learned and written down on these pages. The international ambitions of this book reflect the diversity of students I've taught at UCL. Thanks to all who told stories and showed me around the cafes and drains of their hometowns.

As a researcher, I am lucky to have been able to work with people who are actually doing urban water sustainability. Amongst them are Martin Shouler, Alexa Bruce and Siraj Tahir from Arup; Abby Crisostomo from KLH Sustainability; Aaron Burton, Jacob Tompkins, Ike Omambala and colleagues from Waterwise; Sian Hills, Matthew Greetham, Paul Rutter, Marie Raffin, Andrew Tucker and others from Thames Water; Paul Schaffer at CIRIA; and Samantha Heath from the London Sustainability Exchange.

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Working with David Goldberg of ThreeJoy Associates helped clarify my career priorities and take the plunge in kicking this whole thing off.

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1 Introduction

Urban water sustainability

Water has always been an active constituent of cities. It is a basic requirement for human health and wellbeing, a source of risk through flooding and contamination, a remnant of natural hydrology and ecology in streams and wetlands, a transport route along rivers and canals, and an element of urban design in fountains, ponds and water features. Water infrastructure allows cities to function safely within upper and lower hydrological limits – providing a constant supply of water during dry seasons and droughts, and preventing flooding during high rainfall events. It allows urban citizens to go about their daily lives without being preoccupied with where their water is coming from or going to. Sustainable urban water systems aim to achieve this within environmental limits to water, energy and pollution, in ways that are affordable and equitable and contribute to ecological restoration.

Urban water sustainability aims to manage water in cities to provide for human health and wellbeing within hydrological and ecological limits. Urban water systems include drinking water supply, wastewater disposal, surface water drains and the rivers, streams, wetlands and aquifers of urban water catchments. Urban water sustainability is presented under different labels, for example, sustainable urban water management (SUWM), integrated urban water management (IUWM), and water sensitive cities. As a progressive movement, it anticipates positive change in cities. Sustainable urban water systems are commonly represented as future urban water systems, developed in response to resource constraints, growing populations and climate change.

The sustainability of urban water infrastructure must account for the relationship between the city and its hydrological catchments. Urban water use and pollution have impacts in catchments beyond the city limits. As infrastructures expand to meet growing demand, catchments for urban water supply and waste discharge do not necessarily conform to the geographical boundaries of river basins. Cities draw on regional water resources and some use water transferred over long distances. Urban wastewater and runoff pollutes rivers, estuaries and coastal environments. The energy used for

pumping and treatment of water and wastewater also creates wider impacts and demands on the environment. How water is managed in cities affects health, wellbeing and the environment locally, regionally and globally.

Urban water crises?

Consistent with global environmental discourse, professional and academic movements in support of urban water sustainability are typically founded on the premise that current water systems are unsustainable. The case for the unsustainability of existing infrastructure is made in terms of limits to freshwater resources, environmental impacts of water abstraction and pollution, growing demand for water due to population growth, rising costs of infrastructure provision, replacement and expansion, vulnerability to droughts and floods, and climate change (Marlow et al., 2013; Mitchell, 2006; Niemczynowicz, 1999; Novotny et al., 2010). Sustainability is presented as the means to avoid crises of water shortages and floods in cities, and the related concept of resilience enables sustainable cities to respond more effectively to extreme events, such as drought and flood, which are more likely in an uncertain future (International Water Association, 2015).

Water scarcity provides some of the most alarming projections and warnings about climate change, population growth and development in popular and policy discourse. However, increasing water scarcity in most regions will be driven by increasing demand for water, rather than decreasing supply due to climate change, and the experience of insecure water supply for the world's poorest people is most often the result of political and economic failure, rather than hydrological constraints (Arnell, 2004; Zeitoun et al., 2016).

Water is important for sustainable cities, but cities have a relatively small direct impact on the sustainability of global water resources. Globally, around 70% of water is used for agriculture, 10% for municipal supply and the rest for industry (Oki and Kanae, 2006; Shiklomanov, 2000). Global and regional forecasts of water scarcity mostly result from unsustainable abstraction for agriculture. Given that more than 50% of the global population live in cities, urban food consumption rather than urban water use is the most significant factor in achieving sustainable water resources management at the global scale (Allan, 2011).

Urban water sustainability is a global goal for development and environmental protection, but it is experienced in localised contexts under conditions of inherent uncertainty. Global and regional assessments of water resource availability can hide specific local conditions. Whilst municipal water supply may not constitute the largest proportion of global water resource use, an individual city can have significant impact on the hydrology of its local catchment (United Nations Human Settlements Programme, 2006). Local hydrology, ecology, urban form, governance, climate, economics,

society and other factors shape the form of urban water infrastructure and responses to problems of water scarcity, pollution, flooding and access to water and sanitation services. Cities in the Global South may be focussing on provision of water and sanitation services to a rapidly growing population, while cities with established infrastructure focus on reducing demand and pollution, and restoring degraded freshwater ecosystems (Russo et al., 2014; UN-HABITAT, 2003; Wong and Brown, 2009).

It is common in urban water sustainability to speak of the need for a paradigm shift. Authors including Brown et al. (2009), Novotny et al. (2010) and Allan (2006, 2005) position an emerging paradigm of sustainability and integrated water management in the context of a longer history of water infrastructure. Brown et al. (2009) analyse the history of urban water management in Australian cities and identify six regimes, beginning with early European settlement and projecting into the future. The regimes are the water supply city; the sewered city; the drained city; the waterways city; the water cycle city; and the water sensitive city. Novotny et al. (2010) identify four historical paradigms from ancient times to the modern era: basic water supply; engineered water supply and runoff conveyance; fast conveyance with no treatment; and fast conveyance with end of pipe treatment. They make the case that a fifth emerging paradigm of sustainability will lead to the creation of water-centric ecocities. Tony Allan (2006, 2005) analyses the history of hydro-politics to identify five paradigms of water management – pre-modern; industrial modernity and the 'hydraulic mission' of large-scale infrastructure; environmental awareness; the economic value of water; and integrated water resources management (IWRM), which is still emergent. Allan's analysis recognises paradigms as policy discourses, which may co-exist and contradict each other, in contrast to more linear, progressive notions of paradigms inevitably leading towards sustainability.

The global discourse of environmental crisis that underpins much of the justification for sustainable development and the need for new paradigms of urban water management sits somewhat uncomfortably with the experience of water infrastructure in most cities. Cities can have significant impacts on local water resources and ecosystems, but lack of access to water in cities is rarely the result of water scarcity. Inadequate water and sanitation is usually due to lack of infrastructure, not lack of water (Bakker, 2010; Cook and Bakker, 2012; Zeitoun et al., 2016). With notable exceptions in recent years, few cities in the world face absolute water scarcity sufficient to risk public health. Infrastructure management is typically a bigger factor in water shortages than lack of resources.

Providing water and sanitation to a growing population is undoubtedly challenging, and will impact local resources and ecosystems, but water resource constraints are not the only, or even the most important, factor driving the move towards more sustainable water systems. Beyond alarmist calls to avert catastrophic collapse, urban water sustainability provides an opportunity to reconsider how cities relate to water resources and the

natural environment. Water systems reflect wider sustainability challenges of reducing consumption and pollution, improving equality of access and providing a safe environment in which people and nature can thrive.

Constructing infrastructure

Urban water infrastructures, whether sustainable or not, are human inventions. The particular form of an urban water system is an outcome of design and decision-making. Infrastructure is more than pipes, pumps and treatment works. Infrastructure systems cannot operate without ongoing administrative and institutional structures. They include systems of management, regulation, governance, finance and expertise. Water infrastructures do not exist in technical isolation, but are always deployed within political and social contexts, and are shaped by different knowledge and values. Just as the form of pipes and treatment vary in different cities around the world and at times in history, so the forms of governance and administration of infrastructure also change. Infrastructure is therefore constructed – physically and socially.

The form of water infrastructure shapes and responds to daily life in cities. Water infrastructure that was intended to improve public health has evolved to meet demand for water for automatic washing machines, dishwashers, showers, swimming pools, car washing, lush lawns and candlelit, scented bathtubs (Shove, 2004). The provision of constant water supply and wastewater disposal, as well as reliable drainage networks, have opened up new ways of living in cities. Infrastructure and society are constantly coevolving in cities, with important implications for resource demands and ecological integrity.

In order to understand the role of technology and infrastructure in sustainable cities it is therefore important to be able to discern how their meanings are constructed within different cultural narratives and political discourses, as well as to understand their technical and physical performance. This is particularly important given the long-term nature of sustainability. Political and cultural discourse can change rapidly, while infrastructure may last for centuries and hydrological systems adapt and evolve over millennia. Understanding the relationship between technology and politics allows for longer-term strategies as well as short-term tactics in building cities that support good public health, and human and ecological flourishing.

How cities relate to nature is a political, ethical and technical choice. Infrastructures reflect shared values and priorities in achieving sustainable development. Is water a natural resource to be refined and distributed to meet endlessly expanding demand? Is it a scarce resource best allocated using the market? Is it a threat to human settlements and development, a risk to be managed? Is it a habitat shared by other species and the basis of healthy ecosystems? Is it the source of spiritual healing and reflection? Is it a human right, essential for good public health? How technologies are

developed and deployed now and in the future depends upon the questions asked and the stories told about water in cities, as much as on the technical calculations and physical properties of science and engineering. Understanding and achieving urban water sustainability requires the capacity to discuss technologies, values and nature together.

Frameworks

Different infrastructure and technology choices have different costs and benefits to different people and the environment. Different theoretical and political frameworks understand those relationships in different ways. To make better decisions, design better infrastructure and create useful knowledge about urban water systems, it is helpful to be able to recognise these different positions and their implications. Theories about technology and society can provide structure to analyse different developments towards and away from sustainability in urban water systems.

Understanding how theory and politics frame debates and decisions about urban water sustainability highlights diversity and fragmentation within a relatively recently established field of research and practice. Identifying alternate framings of sustainability and technology may help to explain breakdowns in interdisciplinary and cross-sectoral research and practice. Disciplinary and sectoral silos have long been identified as obstacles to integrated approaches. This is commonly talked about as a language barrier, with each discipline having its own exclusive, specialist terminology. Jargon undoubtedly makes communication difficult, but interdisciplinary ventures still falter even when care is taken to speak in plain language. Professional and academic disciplines not only have their own languages; they also have their own frameworks – shared meanings and stories about how their knowledge contributes to improving the world. Misunderstanding and conflict can arise when frameworks are misaligned. Identifying the most common discursive and conceptual frameworks that underpin alternative narratives may help to explain, if not resolve, some of the challenges of interdisciplinary work in urban sustainability.

Urban water sustainability is simultaneously a unifying proposition for a progressive, positive future and a set of divergent strategies for social, political and technical transformation. As such, it reflects wider debates within environmental politics. Five distinct but overlapping frameworks can be identified in urban water sustainability – sustainable development, ecological modernisation, socio-technical systems, urban political ecology and radical ecology. Sustainable development is the familiar framing of the need to deliver the benefits of development to the global population within ecological and resource limits (WCED, 1987). Ecological modernisation promises that environmental problems can be solved by reforming the institutions of modern society, with a central role for technological innovation (Mol, 2000). Socio-technical systems emphasise the co-evolution of