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ADVANCED REVIEW

# Frameworks for urban water sustainability

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**Abstract**

Integrated water management, sustainable water management, water sensitive cities, and other formulations are often presented as the latest in a series of paradigms of water management. This implies a unified approach, while urban water debates reflect a wide diversity of political, social, and technical viewpoints. Five distinct but overlapping frameworks for urban water sustainability are evident in research, policy and practice, reflecting wider environmental theory, politics, and discourse. Sustainable development is based on meeting the needs for water and sanitation of the urban poor. Ecological modernization focuses on policies to improve water efficiency and treatment through technological innovation and individual behavior change. Socio-technical framings aim to understand how change in water systems occurs across physical and institutional scales and addresses the co-evolution of infrastructures, cultures, and everyday practices. Urban political ecology analyses water infrastructure in terms of relationships of power, pointing to the unequal distribution of costs and benefits of urban water management for the environment and citizens. Radical ecology addresses the relationship between human culture and non-human nature, proposing fundamental reorganization of society to solve ecological and hydrological crises. Characterizing alternate frameworks of urban water sustainability provides clarity on the underlying assumptions, methods, and politics across a diversity of approaches. Frameworks may be deployed strategically to deliver policy impact, or may reflect deeply held political or epistemological standpoints. Understanding different conceptions of urban water sustainability provides the basis for more constructive dialogue and debate about water and its role in sustainable cites.

This article is categorized under:
Engineering Water > Planning Water
Human Water > Water Governance
Water and Life > Conservation, Management, and Awareness

**KEYWORDS**
cities, interdisciplinary, policy, research

## 1 | INTRODUCTION

Water infrastructure is essential for modern cities. Since the 1960s urban water systems have been the subject of concerns about sustainability, consistent with the wider environmental movement and sustainable development (Brown, Keath, & Wong, 2009; Grigg, 1986; Novotny, Ahern, & Brown, 2010; Okun, 1973; Okun, Baxter, Graeser, & Halff, 1969). Urban water sustainability is presented under different labels, for example, Sustainable Urban Water Management (SUWM) (Marlow, Moglia, Cook, & Beale, 2013), Integrated Urban Water Management (IUWM) (Gabe, Trowsdale, & Vale, 2009), and Water Sensitive Cities (Wong & Brown, 2009). Within a diversity of approaches, common characteristics include decentralization, integration, resource efficiency, affordability, participation, and restoring natural systems.

Sustainable urban water systems largely remain future urban water systems, propositions developed in response to resource constraints, growing populations, and climate change. Research and practice in fields related to urban water sustainability are motivated by a perceived need for positive, deliberate, change. Case studies, demonstration projects, and scenario modeling feature strongly in research and policy debates because these practices are yet to be widely implemented in mainstream urban development (Bos & Brown, 2012; Karvonen, 2010; Sitzenfrei, Möderl, & Rauch, 2013; Willuweit & O'Sullivan, 2013).

The nature of research and action is shaped by theoretical and political frameworks for understanding change in cities, the environment, policy, and infrastructure. These frameworks may be implicit or explicit in urban water sustainability debates, and they are broadly consistent with wider debates in environmental politics and policy (Dryzek, 2013). Identifying different frameworks of urban water sustainability highlights political and academic diversity and fragmentation within an interdisciplinary field of research and practice. Urban water sustainability is simultaneously a unifying proposition for a positive future and a set of divergent strategies for social, political, and technological transformation.

This review begins by outlining the core principles of urban water sustainability as a set of policy and technical propositions. Urban water sustainability is positioned as the latest of a series of paradigms of water management. Within the emerging paradigm of urban water sustainability there are different ways of understanding the nature of the problems to be addressed, potential solutions, and how to achieve them. Five distinct but overlapping frameworks for urban water sustainability are then described—sustainable development, ecological modernization, socio-technical systems, political ecology, and radical ecology. Each framework is defined in terms of wider environmental theory and politics before outlining how it addresses urban water management. In conclusion, the review reflects on the value of recognizing a diversity of approaches to urban water sustainability within this emerging paradigm for managing water in cities.

## 2 | PRINCIPLES OF URBAN WATER SUSTAINABILITY

The role of water and cities within international agreements and programs for sustainable development has evolved over the last 40 years. Following the landmark 1972 UN Conference on the Human Environment in Stockholm, the 1977 UN Conference on Water in Mar del Plata, Argentina, showed the emerging importance of water to the environmental movement and human development, but with little reference to cities (Falkenmark, 1977). At the UN Conference on Environment and Development in Rio De Janeiro, chapter 18 of Agenda 21 set the basis for integration of water management and included a program for "Water and sustainable urban development" (United Nations Sustainable Development, 1992). It outlined an approach that integrates supply, demand, sanitation, drainage and flood protection, and is based on full public participation in water management policy and decision-making. Access to water and sanitation was included in the Millenium Development Goals in 2000 (United Nations General Assembly, 2000), and the Sustainable Development Goals in 2015 expanded this to include targets for access, integrated management, pollution, efficiency, ecosystem restoration, participation, and governance (United Nations, 2015). In recent years, water security has come to prominence within international policy, drawing attention to political, economic, and social determinants of access to safe and sufficient water, as well as hydrological and climatic factors (Zeitoun et al., 2016).

Evolving as part of the international discourse of sustainable development, the concept of urban water sustainability is founded on the following principles:

- Access to water and sanitation is a human right and is essential for good public health (United Nations General Assembly, 2010);

- Freshwater is a limited resource (United Nations Economic and Social Council, 1997);
- Freshwater ecosystems need to be protected from pollution (United Nations Economic and Social Council, 1997);
- The public should participate in planning and decisions about water (International Conference on Water and the Environment, 1992); and
- Water resources management should integrate different sectors and systems, including surface water, wastewater, and drainage (Marseille Statement, 2001).

Urban water sustainability is a global goal for development and environmental protection, but it is experienced in localized contexts under conditions of inherent uncertainty (ASCE & UNESCO, 1998). 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 developing world may be focusing 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, Alfredo, & Fisher, 2014; UN-HABITAT, 2003; Wong & Brown, 2009). The translation of principles of sustainable development and integrated urban water management into specific forms of infrastructure and governance has been the focus of research and innovation across professional and academic disciplines (Bos & Brown, 2012).

Consistent with global environmental discourse, professional and academic movements in support of urban water sustainability are founded on the premise that current water systems are unsustainable. The unsustainability of conventional urban water management is attributed to: centralized design and management of infrastructure (Marlow et al., 2013); separation of water systems in to drinking water, sewerage, surface water drainage, and flood protection (Maheepala et al., 2010); single use of potable water for all urban needs; supply-side solutions to water scarcity; fast conveyance of storm water and hard defenses against flood water (SWITCH, 2011); energy intensive treatment and distribution processes; discharge of wastewater and polluted storm water to the environment (Novotny et al., 2010); loss of habitat for biodiversity (Hedgcock & Mouritz, 1993); capital intensity and high costs (Marlow et al., 2013); technocratic decision-making and low levels of public participation (Ashley et al., 2003).

Sustainability is presented as the route 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, which are more likely in an uncertain future (International Water Association, 2015). In contrast to conventional systems, sustainable water systems: incorporate decentralized technologies, ownership, and management; integrate management of water infrastructures (Maheepala et al., 2010); provide fit-for-purpose water for different uses, including reuse and recycling for nonpotable demand (Memon & Ward, 2015; Okun et al., 1969); manage demand through water efficiency and behavior change (Brooks, Brandes, & Gurman, 2009; Butler & Memon, 2006); mimic natural hydrological processes in managing surface water; provide space for flood water and are resilient to flooding (SWITCH, 2011); reduce demand for energy; improve water quality (Mitchell & Diaper, 2006); are affordable (Allen, Davila, & Hofmann, 2006); enhance public participation in decision-making, especially by women (International Conference on Water and the Environment, 1992); and deliver multiple benefits, including contributing to biodiversity, improving air quality and reducing the urban heat island effect (Coutts, Tapper, Beringer, Loughnan, & Demuzere, 2013; Hedgcock & Mouritz, 1993), as well as the benefits of water and sanitation provision (Novotny et al., 2010).

The role of water in sustainable cities provides wider connections to urban life, design, and politics, beyond the efficiency and integration of water and sanitation infrastructure. Water has been included as an element in sustainable city designs and debates, though usually with a lower profile than energy, transport, pollution, and waste. The concept of the "water sensitive city" bridges developments in water and urban sustainability. According to Wong and Brown (2009), the three pillars of the water sensitive city are: cities as water supply catchments providing ecosystem services; and comprising water sensitive communities. Water and wastewater are also considered elements of the circular economy and circular city, focused on resource recovery and reuse (Makropoulos et al., 2018; Sgroi, Vagliasindi, & Roccaro, 2018).

Urban water sustainability research and practice ranges from technological propositions for decentralized technology, assessment of the overall environmental and sustainability impacts of different systems, improved efficiency, and integration of water in cities, to the role of water in broader transitions to sustainable cities. The different scales of focus, disciplinary expertise, and geographic range of activities point to the diverse and divergent developments in the field. Understanding how these different contributions to research and practice in urban water sustainability relate to each other and to wider debate about sustainable cities and sustainable development helps to differentiate strategies for change.

## 3 | PARADIGMS OF WATER MANAGEMENT

Sustainable, or integrated, water management is commonly presented as the latest in a series of paradigms. The “hydraulic paradigm” or “hydraulic society” is widely used to refer to the historic period associated with large-scale, state-led engineering approaches to creating infrastructure to store and distribute water for agricultural, industrial, and urban development. Referring to water management in general, rather than specifically in cities, Allan (2005) identifies five paradigms—premodern, industrial modernity, green economic, and political and institutional. The final paradigm emphasizes integration. The second paradigm dominated the twentieth century, and is characterized by the “hydraulic mission” of state-led construction of large dams and water infrastructure. Saurí and del Moral (2001) describe the development of Spain's dams and water transfer schemes in terms of a “hydraulic paradigm,” “with the ultimate objective of ensuring cheap water availability for economic growth” (p. 351). Worster (1985) and Hundley (2001) both describe the development of water resources and infrastructure in the west of the United States in terms of the “hydraulic society.” The hydraulic paradigm is typically presented as a historic era, which ended around the 1980s, as concerns for the environment challenged dam construction and centralized water management, and neo-liberal policy reforms reduced the role of the state in major infrastructure investment and resource management. However, evidence of the persistence of the hydraulic paradigm exists in ongoing dam building in the Global South. The capital-intensive, centralized features of the hydraulic paradigm also remain consistent with recent investments in desalination, which, as an energy intensive, expensive source of water supply potentially contradict movements toward sustainability (Green & Bell, 2019).

Linton (2014) expands the view of water in society and culture, beyond infrastructure and management to describe “modern water” as a set of political, historical, hydrological, and social constructions. “Modern water” is associated with scientific abstraction of water as $H_2O$, technologies, and infrastructures associated with managing water as a resource within the hydraulic paradigm, and the enabling social and power structures. Linton characterizes “modern water” as being in crisis, arising from the complex interplay between natural, technological, cultural, social, and political elements, despite efforts at rational, technological management of water as a resource. The modern hydrological cycle diagram, depicting the flows of water through a landscape devoid of social life and human structures, is in contrast with the hydrosocial cycle, which recognizes the technological, political, and social constructions of water, and provides the means to achieve fairer policies and restores local meaning in how water is understood and used in society.

Paradigm framings have been used to explain the historic and future development of urban water systems. Novotny et al. (2010) identify four historic paradigms—basic water supply; engineered water supply and runoff conveyance, fast conveyance with no treatment, and fast conveyance with end of pipe treatment—and a fifth emerging paradigm of water-centric sustainable communities. Referring to Australian cities, Brown et al. (2009) identified six regimes of urban water management—the water supply city, the sewered city, the drained city, the waterways city, the water cycle city, and the water sensitive city—with current research and practice moving between the waterways and water cycle city.

The paradigm model of change in water management typically implies unified, sequential transition. Varady, Meehan, and McGovern (2009) provide more nuance in identifying paradigms that operate in parallel, as well as series. Their model shows different trends operating across overlapping timescales, contributing to the transition from state-led, centralized development, to sustainability and decentralization via the influence of rational-actor models, the retreat of the state, structural adjustment, and neoliberalism. While representation of an overall transition in water management and politics remains, this is seen in terms of a confluence of various political and social trends, rather than a wholesale, transformation from one unitary paradigm to the next.

The emerging paradigm of urban water sustainability is far from unified. Global governance and initiatives in water, including urban water, have proliferated since the 1980s, representing diverse interests and approaches (Varady et al., 2009). Mukhtarov and Gerlak identify three epistemic forms of integrated water resources management and water security in policy—prescriptive, discursive, and practical (Gerlak & Mukhtarov, 2015; Mukhtarov & Gerlak, 2014). An overemphasis on prescriptive epistemology, dominated by rationalist engineering-based definition of integrated water resources management, has led to a focus on implementation failures, yet greater attention to the discursive nature of integrated water management would reveal its importance in clarifying water values and ethics, and a practical epistemology would allow for greater learning and improved know-how through experimentation. Epistemic plurality, recognizing different ways of knowing integrated water resources management, is proposed as the means of strengthening the concept and extending its policy relevance.

The diversity of discourses and epistemologies within urban water sustainability can build resilience and responsiveness to new challenges, but it also creates overlap, confusion, and occasionally discord. Analyzing developments in urban water sustainability in terms of wider frameworks for environmental politics and sustainability, provides a means to identify particular sets of assumptions, values, and theories of the nature of the problems facing urban water systems and pathways to delivering solutions. Within urban water sustainability, different frameworks can be seen to be operating in parallel, reflecting wider environmental debate. Five framings of sustainability in urban and global discourse are—sustainable development, ecological modernization, socio-technical systems, political ecology, and radical ecology. These are described in general terms, before outlining how each frame is deployed in urban water sustainability. The frameworks are distinct but overlapping. Sustainable development and ecological modernization are relatively reformist in claiming to be able to deliver win-win outcomes within existing economic and social systems, political ecology and radical ecology provide stronger critiques of existing structures and propose fundamental change, while social-technical system framing provides a more pragmatic analysis of the underlying problems and opportunities for sustainable futures.

## 4 | SUSTAINABLE DEVELOPMENT

Provision of basic water and sanitation to all citizens remains to be achieved in many cities. Achieving basic access to water and sanitation has been a key element of international development discourse since the 1970s (Falkenmark, 1977). Attention mostly focused on rural settlements and households, but water and sanitation infrastructure in cities, particularly in informal settlements where the poorest people live, has become an issue of greater importance in sustainable development discourse in recent decades (ASCE & UNESCO, 1998; Satterthwaite, McGranahan, & Mitlin, 2005).

Sustainable development is itself highly diverse, with different political and practical viewpoints constructing different analyses of the problems and solutions (Dryzek, 2013). Sustainable development as a global discourse is aligned with the international conventions and conferences that have been held since the 1970s (United Nations General Assembly, 2000; United Nations Sustainable Development, 1992). Sustainable development discourse in global dialogue and agreements is necessarily pragmatic, supporting economic growth as the means to achieve poverty alleviation, within resource and environmental constraints. The Sustainable Development Goals of 2015 confirm the importance of sustainable development, including economic growth, human wellbeing, and environmental limits (Waage et al., 2015). The goal relating to water aims to achieve universal provision of drinking water and sanitation and integrated management of water resources (United Nations, 2015).

Sustainable development within urban water sustainability emphasizes the need to achieve basic provision, within environmental limits (McDonald et al., 2014; UN-HABITAT, 2003). The needs and rights of the urban poor to water and sanitation services are the key focus (Satterthwaite et al., 2005). Sustainable development of urban water systems is to be achieved through local and community level development, strong national policy, and global agreements, including international aid and investment (Satterthwaite et al., 2005).

Within sustainable development, the unifying framework is concerned with provision of basic services for public health, livelihoods, and social justice (Montgomery & Elimelech, 2007). While lack of capital investment may be a constraint on achieving infrastructure provision in developing cities, the absence of centralized infrastructure systems provides opportunities for decentralized technologies and alternate business models (Allen et al., 2006; Montgomery & Elimelech, 2007; Satterthwaite et al., 2005).

## 5 | ECOLOGICAL MODERNIZATION

Ecological modernization aims to move "beyond apocalyptic orientations to see environmental problems as challenges for social, technical and economic reform, rather than as immutable consequences of industrialisation" (Mol & Sonnenfeld, 2000, p. 5). As a theory in environmental sociology and policy, ecological modernization first emerged in the 1980s in Germany, the Netherlands, and the UK (Hajer, 1995; Huber, 2005). It developed in contrast to environmental theories of the 1970s, which proposed that modernization was the root cause of environmental harm, and deindustrialization and radical social change were the only solution for the ecological crisis (Mol, 1996). By the turn of the twenty-first century, ecological modernization had matured as a theory and had come to characterize dominant policy approaches to the environment in northern Europe and elsewhere. Mol and Sonnenfeld (2000) outlined the core themes of the theory:

- Changing role of science and technology
- Increasing importance of market dynamics and economic agents
- Transformations in the role of the nation state
- Modifications in the position, role, and ideology of social movements
- Changing discursive practices and emerging new ideologies

Ecological modernization is similar to sustainable development as it aims to work within existing economic structures, but it places much stronger emphasis on innovation, technology, and individual behavior. Ecological modernization policies are evident across the scale of water systems management, from market-based trading of water rights in catchments, to household water metering (Debaere et al., 2014; Giurco, White, & Stewart, 2010; Honey-Rosés, 2009; Richter, 2014). In order to make urban water systems sustainable, engineers need to develop technologies and systems that are economically and resource efficient. People in cities are conceived as individual consumers of water and sanitation services who respond to information about their consumption, particularly if that information is associated with a price signal (Herrington, 2007; Koutiva & Makropoulos, 2016). Techniques for changing individual behavior without directly referring to economic costs draw on theories from social psychology, behavioral psychology and economics, and social marketing (Hurlimann, Dolnicar, & Meyer, 2009; Walton & Hume, 2011).

Ecological modernization conceives of water demand as the aggregate of individual water using behaviors that can be understood through economic and psychological models (Gilg & Barr, 2006; Hills & Briks, 2004; Hurlimann et al., 2009). Reducing water demand can be achieved by changing the behavior of individual consumers, providing information, motivation, social cues, and technologies (Hurlimann et al., 2009). Urban water systems can be modeled and optimized as an integrated technological network using modeling techniques that are transferrable from other domains help to provide data to support decisions (Makropoulos, Natsis, Liu, Mittas, & Butler, 2008; Urich & Rauch, 2014).

Within an ecological modernist framework, new technologies, such as desalination and potable reuse, are able to meet shortages in supply, provided they are economically feasible (Asafu-Adjaye et al., 2015). Water scarcity increases the value of water to the economy and consumers, justifying the use of more expensive and capital-intensive new sources of water. Quantitative indicators are important to measure progress toward urban water sustainability, to inform rational decision-making processes (Aydin, Mays, & Schmitt, 2014; Behzadian & Kapelan, 2015). Existing institutions require reform to ensure efficiency, and sustainability will be achieved through technological innovation, consumer behavior change, and market-based economic management of water infrastructure and resources (Richter, 2015).

## 6 | SOCIO-TECHNICAL TRANSITIONS

Socio-technical discourse is less well characterized in environmental discourse and policy than ecological modernization and sustainable development. While there are important theoretical distinctions within these fields, the main characteristic of this framework is the discussion of social and technical factors on the same terms (Bijker, 1997). Rather than conceiving of technology and society as fundamentally distinct, socio-technical theories show how they influence and create each other (Bijker, Hughes, & Pinch, 1987; Hughes, 2009; Latour, 1993; Star, 1999).

The socio-technical framing of urban water sustainability discusses water in terms of relationships between technology, culture, institutions, people, and infrastructure (Sofoulis, 2006). Water infrastructure, water use, water governance, water in everyday life and urban culture, interact with and depend upon one another. Patterns of consumption are "baked-in" to infrastructural systems, providing material constraints on the rate and magnitude of change that is possible for everyday practices that consume water and produce wastewater (Shove, 2004; Sofoulis, 2005, 2013). The transition to sustainability is constrained by technical "lock-in" as existing infrastructures stabilize conventional patterns of water management, consumption, and governance. As urban water systems evolve to include more decentralized technologies, the institutions that own, operate, and regulate urban water systems will also adapt (Allon & Sofoulis, 2006; Rogers, Brown, de Haan, & Deletic, 2015; Wen, van der Zouwen, Horlings, van der Meulen, & van Vierssen, 2015). Technical solutions are unlikely to be implemented successfully without appropriate institutional support and adaptation.

Socio-technical approaches to the development of new technologies and infrastructures for urban water sustainability promote deliberative processes that allow for public concerns and ideas to be accounted for in engineering design and decision-making (Colebatch, 2006). Public controversies about water reuse show that communities are less willing than they were in the past to accept water infrastructure decisions made by experts (Bell & Aitken, 2008; Chilvers, Bell, & Hillier, 2011; Hurlimann & Dolnicar, 2010, 2016; Russell & Lux, 2009). Moving beyond the sustainable development calls for participation, socio-technical approaches emphasize public deliberation, co-design, and co-production, where the public are directly involved in design and decisions rather than the recipients of technology and infrastructure and customers of water utilities.

Transition theory has been an increasingly influential element of the socio-technical discourse in urban water sustainability research, particularly in addressing the institutional barriers to innovation and implementation (Brown & Farrelly, 2009; Marlow et al., 2013; Rogers et al., 2015; van de Meene, Brown, & Farrelly, 2011). Transition theory draws on theories of complexity, innovation, and socio-technical systems (Geels, 2005; Geels & Schot, 2007). This perspective promotes "experimentation" as a way of initiating urban and socio-technical change within existing systems, including experimentation with different forms of governance, leadership, and expertise in urban water systems (Bos & Brown, 2012; Brown, Farrelly, & Loorbach, 2013; Domènech & Saurí, 2010).

## 7 | POLITICAL ECOLOGY

Political ecology frames urban water disputes as a problem of uneven distribution of power and capital in cities (Swyngedouw, 2009; Swyngedouw & Heynen, 2003). Political ecology researchers may draw on socio-technical theories and use similar methods, but place much stronger emphasis on power and the role of capital (Kaika, 2006; Rodríguez-Labajos & Martínez-Alier, 2015; Swyngedouw, 2006). While concerned with some of the core challenges of urban water sustainability, political ecological authors and activists are cautious of the language of "sustainability" and "scarcity" as underpinning a tendency to deemphasize the role of politics in urban water management and governance (Kaika, 2006; Swyngedouw, 2009). From a political ecology viewpoint, neoliberal policy and private capital in urban development and infrastructure provision are associated with the exploitation of nature, water, and people (Bakker, 2003; Loftus, 2009; Rodríguez-Labajos & Martínez-Alier, 2015). Privatization of urban infrastructure and urban services and the increasing prevalence of market-based solutions undermine the social and environmental justice of urban water systems (Rodríguez-Labajos & Martínez-Alier, 2015). Urban political ecologists use socio-technical theories and methods of analysis in highlighting the relationship of power and exploitation, and the exclusion of social and ecological interests in urban water decision-making (Gandy, 2004; Swyngedouw, 2006). The role of municipalities and states in urban water infrastructure provision in the nineteenth and twentieth centuries reflects the historical power of governments, both democratic and totalitarian (Gandy, 2006; Swyngedouw, 2015). The recent rise of private ownership of infrastructure reflects a shift toward greater power of private corporations and capital, to the detriment of public interests (Rodríguez-Labajos & Martínez-Alier, 2015).

Urban political ecology is particularly critical of neoliberal policy discourse associated with privatization, market-based allocation of resource, deregulation, and a focus on the individual as a consumer and autonomous decision maker (Rodríguez-Labajos & Martínez-Alier, 2015). Neoliberal policies are seen to respond to the needs of capital to the detriment of citizens and the environment (Bakker, 2005). The commodification of water undermines its status as a public good and its roles in ecological processes.

Within political ecology frameworks, democratic and political change is required to achieve socially and environmentally just urban water systems. Aligned with urban activist movements and consistent with sustainable development framings, urban political ecology promotes the "right to the city" and "right to water", as basic human rights rather than services to be bought or sold (Rodríguez-Labajos & Martínez-Alier, 2015; Sultana & Loftus, 2012). Alternative structures of governance and ownership, including communal provision of water infrastructure and remunicipalization of privatized assets might be supported through urban political ecology. However, appropriate governance is required to achieve equitable provision and ecological protection, as no specific model of ownership is inherently immune from the undue influence powerful interests leading to unequal distribution of water and exploitation of the environment (Bakker, 2008; Hall, Lobina, & Terhorst, 2013).

## 8 | RADICAL ECOLOGY

Since the 1960s, environmental activists and scholars have analyzed western society and culture to identify the root cause of environmental problems in the basic structures of western society and culture (Zimmerman, 1987). Deep ecology, social ecology, and ecological feminism have been three key strands in radical ecological philosophy. Similar to political ecology in drawing attention to the relationships between social and environmental injustice, radical ecology places greater emphasis on cultural, philosophical, and ethical issues and places primacy on the value and rights of nonhuman nature. Deep ecology is the deep questioning of human relationships to the natural world, and leads to proposals for bioregional communities as the basis for human development, with deep connections to local landscapes, ecological processes, and nonhuman nature (Foreman, 1995; Naess, 1995; Sessions, 1984). Echoing the concerns of political ecology, social ecologists and ecological feminists more explicitly address connections between domination of nature and structures of power within human society and culture. Social ecologist Murray Bookchin proposes that the ecological crisis is the outcome of the hierarchical structure of modern capitalism, requiring reorganization of society into more decentralized, self-organizing communities (Bookchin, 1982). Ecological feminists, including Karen Warren, Val Plumwood, and Carolyn Merchant, have analyzed the specific association of women and nature in the exploitative structures of western culture (Merchant, 1989; Plumwood, 1993; Warren, 1990). In moving away from hierarchical power structures based on domination and submission, ecological feminist responses to the ecological crisis emphasize negotiation of relationships with the "other", accommodating difference and emphasizing reciprocity and care (Plumwood, 1993, 2002).

A radical ecological framing emphasizes the intrinsic value of water for nature in cities and their catchments and landscapes. Water as a natural material, a force in shaping landscapes and fundamental for all ecological processes is an important element in understanding human relationships to the natural world. Modern construction of dams, treatment works, pipe networks, surface water drains, and flood defenses represent efforts to control and dominate water, and transform natural landscapes for the benefit of humans.

Sustainable approaches mimic natural hydrology and recognize the value of water value to human wellbeing as part of natural systems that can be integrated into urban landscapes. The ethics of "working with water" and "making space for water" in cities is evident in natural flood risk management, water sensitive urban design, and sustainable drainage, particularly green infrastructure approaches that emphasize co-benefits for biodiversity and human wellbeing (Hedgcock & Mouritz, 1993; Marlow et al., 2013; Wong & Brown, 2009). Water demand management campaigns, which aim to reduce outdoor water consumption by "xeri-scaping" to incorporate native plant species in gardens are aligned with radical ecological aims of reconnecting people and cities with local landscapes and bioregions (Askew & McGuirk, 2004; Barthel & Isendahl, 2013).

## 9 | CONCLUSION

Urban water management is in the early stages of transition from the modern, hydraulic paradigm toward more sustainable, integrated approaches (Allen et al., 2006; Brown et al., 2009; Linton, 2014). Within an emerging paradigm of urban water sustainability, distinct frameworks exist, reflecting wider environmental politics and theories. These frameworks provide different definitions of the problems facing urban water systems and possible solutions, based on different conceptions of the core components and their relationships to one another. Table 1 summarizes the key elements of each framework.

These frameworks may be complementary or conflicting, and their relative prominence may shift in time and in different places. For instance, political ecology is critical of policy approaches that emphasize commodification and market-based mechanisms for water management that are consistent with an ecological modernization framework. Ecological modernization might promote water metering and charging as the rational basis for water demand management, while political ecologists highlight the potential for unjust social outcomes if metering and pricing policies do not take account of the needs of vulnerable water users, particularly those on low incomes. Water sensitive urban design and sustainable drainage are consistent with radical ecological approaches of mimicking natural systems and learning to live within landscapes and bioregions, but implementation of such measures requires cultural, social, and institutional change as revealed by socio-technical systems analysis, and development of funding mechanisms and technical innovation as part of an ecological modernization framework.

Acknowledging different frameworks explains interdisciplinary obstacles and conflict within urban water sustainability. In addition to common interdisciplinary challenges of language and methods, different disciplines may be positioned within particular frameworks, often without explicit awareness or acknowledgement. Mainstream engineers and economists typically work within ecological modernist framings, international development workers within a sustainable development framework, environmental activists from a radical ecology viewpoint, and social scientists may be

**TABLE 1** Frameworks for urban water sustainability

| | Water | Technology | Politics | Society | Economy | Ecology |
|---|---|---|---|---|---|---|
| Sustainable development | Basic need | Appropriate | Inter-nationalist | Poverty alleviation | Growth | For current and future generations |
| Ecological modernization | Natural resource | Efficient | Neo-liberal | Individuals | Market innovation | Ecosystem service |
| Socio-technical systems | Material | Co-evolves with society | Deliberative | Networks | Flows of materials and value | Shapes society and technology |
| Political ecology | Socio-ecological metabolic agent | Embodies socio-ecological relationships | Leftist | Co-constructed with ecology | Critical of global capitalism | Co-constructed with society |
| Radical ecology | Element of nature | Exploits nature | Ecocentric | Place-based community | Constrained by ecology | Valued intrinsically |

Source: Bell, 2018

positioned within different framings depending on their theoretical perspectives. Recognizing differences in framing problems and solutions to urban water sustainability is useful in understanding deeper political and theoretical challenges to interdisciplinary research and practice.

The challenges of providing safe water and sanitation to growing urban populations, while adapting to climate change and restoring natural ecosystems are vast. Urban water sustainability captures a range of technologies, policies, and design principles to reduce resource consumption and pollution, and improve urban environments. How these are deployed and how they interact with urban systems, societies, and politics to achieve positive change remains open for debate and deliberation. Identifying distinct frameworks for urban water sustainability provides a means for understanding the terms of such debates. Framings change over time and in different places. As a new paradigm of urban water sustainability stabilizes and matures, being able to negotiate these differences is likely to become more significant than making the case for the unsustainability of the hydraulic paradigm it aims to replace.

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## CONFLICT OF INTEREST

The author has declared no conflicts of interest for this article.

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