



# Hydrosocial geographies: Cycles, spaces and spheres of concern

Progress in Environmental Geography  
2023, Vol. 2(4) 240–265  
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DOI: 10.1177/27539687231201667  
journals.sagepub.com/home/peg



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## Abstract

Over recent decades, hydrosocial scholarship focusing on the plural, often contested relations of waters and societies has advanced significantly. This article reviews hydrosocial scholarship in three steps that are contextualized by geography's long-standing efforts to use water to 'think geography'. The article begins by revisiting critiques of the hydrological cycle as circulating free of anthropogenic forces and wholly on the 'nature' side of the society/nature dualism. We consider how this critique shapes engagement with other fields where human–water relations are crucial, such as socio-hydrology and those focused on climate change. The article then examines the extension of hydrosocial scholarship from critiques of the hydrological cycle to its use in explaining social spaces, such as territory, urban processes and citizenship. Finally, we consider how hydrosocial scholarship from Black, Indigenous and anti-colonial praxis challenges epistemologies and ontologies that, even in their critiques, recentre Eurocentric notions of water.

## Keywords

Hydrosocial, cycle, space, relations, hydrology

## 1 Introduction

In recent decades, hydrosocial scholarship has become a mainstay in critical water studies. Environmental geographers anchor key aspects of hydrosocial research that travels widely – successfully – to make visible the connections amongst humans, non-humans and water once overshadowed by divides of nature and society. A 2019 study in *Nature Geoscience* cited geographers Linton (2008) and Schmidt (2014) to critique the absence of human impacts on the water cycle in textbooks (Abbott et al. 2019). In October 2022, the US Geological Survey (2022) updated its diagram of the global water cycle to include social processes, including agriculture,

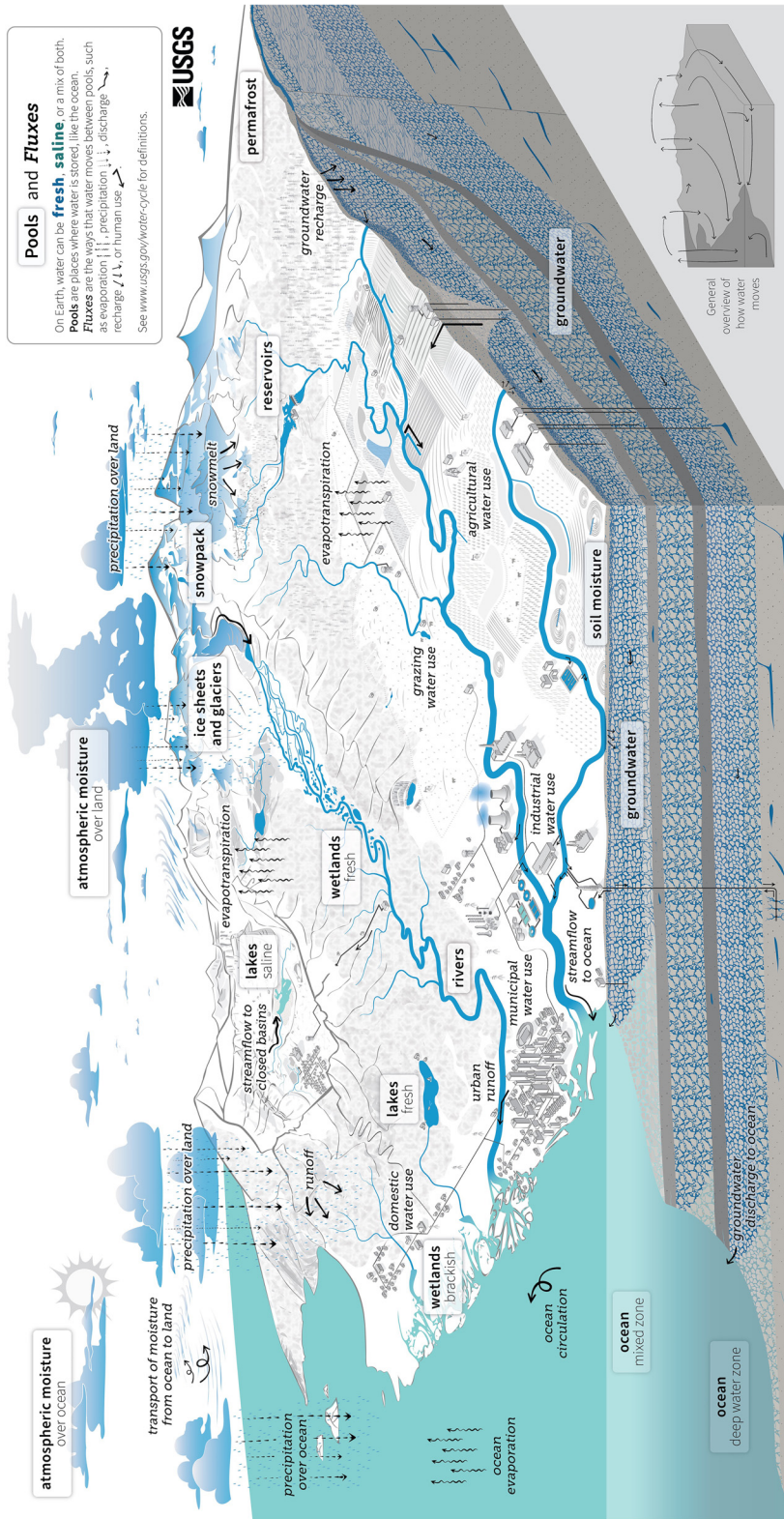
urban runoff and industry uses amongst others (Figure 1). However, hydrosocial accounts aren't only about the hydrological cycle; they affect concerns regarding territory and Indigenous ontologies while working adjacent to critical physical geography on socio-hydrology and climate change. This article has three aims: First, it evaluates critiques of the 'hydrological cycle' to open conversations with socio-hydrology and geohistorical fields concerned

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## The Water Cycle

The water cycle describes where water is on Earth and how it moves. Water is stored in the atmosphere, on the land surface, and below the ground. It can be a liquid, a solid, or a gas. Liquid water can be fresh, saline (salty), or a mix (brackish). Water moves between the places it is stored. Water moves at large scales and at very small scales. Human water use affects where water is stored, how it moves, and how clean it is.

**Pools** store water. 96% of all water is stored in **oceans** and **lakes**. Fresh water is stored in liquid form in **freshwater lakes**, **artificial reservoirs**, **rivers**, and **wetlands**. Water is stored in solid, frozen form in **ice sheets** and **glaciers**, and in **snowpack** at high elevations or near the Earth's poles. Water vapor is a gas and is stored as **atmospheric moisture** over the ocean and land. In the soil, frozen water is stored as **permafrost** and liquid water is stored as **soil moisture**. Deeper below ground, liquid water is stored as **groundwater** in aquifers, within cracks and pores in the rock.

We alter the water cycle. We redirect rivers. We build dams to generate electricity and for water storage and development. We use water from rivers, lakes, reservoirs, and groundwater aquifers. We use that water to supply our **homes** and **communities**. We use it for **agricultural** irrigation and **grazing** livestock. We use it for **industrial** activities like thermoelectric power generation, mining, and aquaculture. The amount of water that is available depends on how much water is in each pool (water quantity). It also depends on when and how fast water moves (water timing), how much water we use (water use), and how clean the water is (water quality).

We affect **water quality**. In agricultural and urban areas, erosion and precipitation wash fertilizers and pesticides into rivers and lakes. Pollution from factories and cities returns heated and contaminated water to rivers. Runoff carries chemicals, sediment, and sewage into rivers and lakes. Downstream from these sources, contaminated water can cause harmful algal blooms, spread diseases, and harm habitats. **Climate change** is affecting the water cycle. It is affecting water quality, quantity, timing, and use. It is causing ocean acidification, sea level rise, and more extreme weather. By understanding these impacts, we can work toward using water sustainably.

**Figure 1.** The 2022 update to the hydrological cycle by the United States Geological Survey. Credit: U.S. Geological Survey, Department of the Interior/USGS.

with how Earth's deep past contextualizes anthropogenic impacts. Second, it assesses hydro-social research as a register for explaining socio-spatial relations to water on matters of territory, urban processes and multiple materialities of deltas and ice (amongst others). Third, it considers how anti-colonial praxis of Black and Indigenous scholars, and those in solidarity with them, generate distinct spheres of concern for understanding water–society relations. This introduction explains these goals through a brief history of how water has been used to 'think geography' – an issue returned to in the conclusion.

Geography has a long tradition of using water to 'think geography'. In 1931, Halford Mackinder argued the elusive 'unity of geography' could be solved by thinking through Earth's watery dynamics. As he put it: '*A planet with a hydrosphere is a unique object of study*' (Mackinder 1931, 324, original emphasis). He argued Earth is important 'not merely subjectively and because we men [sic] who inhabit it are the students; in the university of the impartial angels it would be an object of intense interest and speculation' (Mackinder 1931, 324). Mackinder (1931, 331) then extolled the virtues of granting the hydrosphere analytic priority in thinking through landscape formations, energy distribution, water's role as a limiting variable for biological environments and the 'value of so-called "liquid" capital' in agricultural produce – which predates ideas of 'virtual water' by decades (cf. Allan 2003).

Using water to 'think geography' also animated Derwent Whittlesey's arguments at Harvard before that department shuttered (see Mountz and Williams 2023). Whittlesey (1945) argued water was key to advancing disciplinary thinking beyond two-dimensional time and space to concerns of verticality, volume and velocity that would link colonial expansion to the accelerating, industrial-scale, anthropogenic forces affecting Earth processes. Whittlesey, like Mackinder, anticipated contemporary concerns even if he didn't capture the directions they took. Using water to 'think geography' was also politically

potent. Resource geographer White (1963, 1976) lauded geography's contribution to the 1965–74 International Hydrological Decade. As discussed below, the IHD was significant in establishing hydrology as a science. In 1977, White (1978) positioned geography centrally at the first UN Conference on Water in Mar del Plata by authoring the proceeding's opening essay on 'resources and needs' in the world's water situation.

Amidst focus on water, Tuan (1968) incisively examined the metaphysical roots of the geographic imagination at work in hydrology by tracking the secularisation of western notions of a divinely regulated water economy to a naturally balanced hydrological cycle. Tuan, like Illich (1986), saw in water a modality that not only offered a vector for critique but also a site in which the social conditions of knowledge production connected to place and identity. Lefebvre (1991, 87) thought through water too, even considering hydrodynamics as a root concept for the production of space:

'A much more fruitful analogy, it seems to me, may be found in hydrodynamics, where the principle of the superimposition of small movements teaches us the importance of the roles played by scale, dimension and rhythm'.

Lefebvre (1991, 87) withdrew this proposal, however, complaining hydrodynamics didn't explain what 'produces these various movements, rhythms and frequencies; nor how they are sustained; nor, again, how precarious hierarchical relationships are preserved'. If wholly accepted, Lefebvre (1991) worried too fluid an orientation might obscure the material sites of contest in which social space is produced.

These examples reveal a tradition of using water to broker disciplinary 'unity' and to conceptualize matters of history, politics and theory. In this context, this review focuses on understanding how hydrosocial scholarship contributes to environmental geography. The section titled 'The hydrosocial cycle' examines the critique of dualisms separating societies from a 'natural'

hydrological cycle. We show how prominent hydrosocial contributions draw this distinction in historical terms open to challenge – Mackinder and Whittlesey are absent even in influential accounts (e.g., Linton 2010; Schmidt 2017). Historical inaccuracies raise concerns about engagements with other geohistorical fields, such as those focused on human–water cycles under climate change. These limitations affect work that relies – implicitly or explicitly – on historical critiques of the hydrological cycle to mobilize accounts of contemporary hydrosocial spaces. These accounts are the focus of the section on ‘Hydrosocial spaces,’ which considers how concerns of territory, urbanization and citizenship (amongst others) not only confront society/nature dualisms but also show how water co-constitutes social and spatial relations. These accounts face other challenges too, such as ‘production of nature’ theses that – like Lefebvre – eschew too much fluidity.

The section on ‘Spheres of concern’ considers how Indigenous, Black and other anti-colonial geographies press for reorganisation of water–society relations. We mobilize Stengers’s (2005, 185) insights into an ‘ecology of practice’ that refuses to view progress in terms of how past, often violent practices become ‘a path leading to our present and future’. For Stengers (2010), no ecology of practice is neutral. Instead, each is constitutively attached to the matters of concern it pays attention to – a river, for instance, may matter in constitutively unique ways to fluvial geomorphologists, Indigenous peoples and mining companies. Respective matters of concern are shaped by their milieu; the surroundings – including non-humans – that prompt hesitation and attention. Given this non-neutrality, Stengers’s (2011, 56) stresses that ‘any comparison involving or implying the nature/culture opposition [is] foul play – definable here as a play in relation to which the Euro-American protagonist is both a participant and the arbiter’. We neither compare nor arbitrate Black, Indigenous or other anti-colonial geographies. Instead, we stress their importance as spheres

of concern. We use the definition of a sphere as a distinct area of activity or praxis.<sup>1</sup> As we show, attention to multiple spheres of concern points beyond singular matters of concern to the ways anti-colonial geographies have built solidarities while respecting distinctiveness. The conclusion reflects on using water to ‘think geography’ and opportunities for further hydrosocial contributions to environmental geography.

## II The hydrosocial cycle

The hydrosocial cycle is marked by critiques of society/nature dualisms. Hamlin (2000) argued this dualism drove historical efforts to reduce social relationships to different waters (plural) to a singular ontological kind: H<sub>2</sub>O. A similar concern enlivens geographic scholarship. Bakker (2002, 774, original emphasis) argued that ‘[w] hereas H<sub>2</sub>O circulates through the hydrological cycle, water *as a resource* circulates through the hydrosocial cycle – a complex network of pipes, water law, meters, quality standards, garden hoses, consumers, leaking taps, as well as rainfall, evaporation, and runoff’. Likewise, Swyngedouw (2004, 2005); Swyngedouw et al. (2002) argued that socio-economic pressures on water increasingly interfered with the hydrological cycle at different scales, especially under regimes of privatization. These formulations advanced the idea that the political economies and political ecologies that ‘produced’ society/nature dualisms also revealed hydrosocial productions (Swyngedouw 2009). So understood, a core concern of hydrosocial geographies became how the hydrological cycle and its fundamental unit – asocial H<sub>2</sub>O – were enrolled in productions of nature that perpetuated modernist dualisms at expense to other ways of knowing and relating to water.

### 2.1 Historical construction of ‘modern water’

In a landmark hydrosocial study, Linton (2010, 3) argued ‘water is what we make of it’. Linton’s

(2008, 2010) argument rested on historical claims about global hydrology and the making of water as a resource – Bakker’s twin concerns. However, Linton further argued the history of hydrology was emblematic of the modernist propensity to produce abstract knowledge that claimed universality and objectivity by denying the social conditions of its own production. Linton (2010) followed Latour’s (1993) diagnosis of modernity as an attempt to purify phenomena into either non-human nature or human culture and to then translate phenomena into these terms despite their propensity to be hybrids of the two. From this basis, Linton (2010) argued the hydrological cycle is a social construction.

Linton’s (2008, 2010, 2014) critique focused on the version of the hydrological cycle developed by Robert Horton in 1931 because, although many predecessors exist, it was Horton who sought to establish hydrology as a ‘pure science’. This was

Horton’s (1931, 190) stated aim, although he considered his account a mere ‘birth-certificate’ of hydrology as a science set between geography and meteorology yet with ties to other geosciences as well as engineering, hydraulics, ecology and botany (amongst others). Despite this interdisciplinary focus, Linton makes Horton’s work an exemplar of how hydrology reduced water to  $H_2O$  that flowed ‘naturally’ through a hydrological cycle purified as non-human nature. This reduction, Linton (2010) argues, anchors the social construction of the hydrologic cycle as circulating freely – abstractly – without human influence. A key piece of evidence is Horton’s schematic of the hydrologic cycle, which Linton (2014, 112) argues represents an ‘asocial’ view of water (Figure 2). For Linton (2010), Horton’s hydrologic cycle continues unperturbed into the International Hydrological Decade (1965–74). The chair of the IHD, Raymond Nace (1980), described the

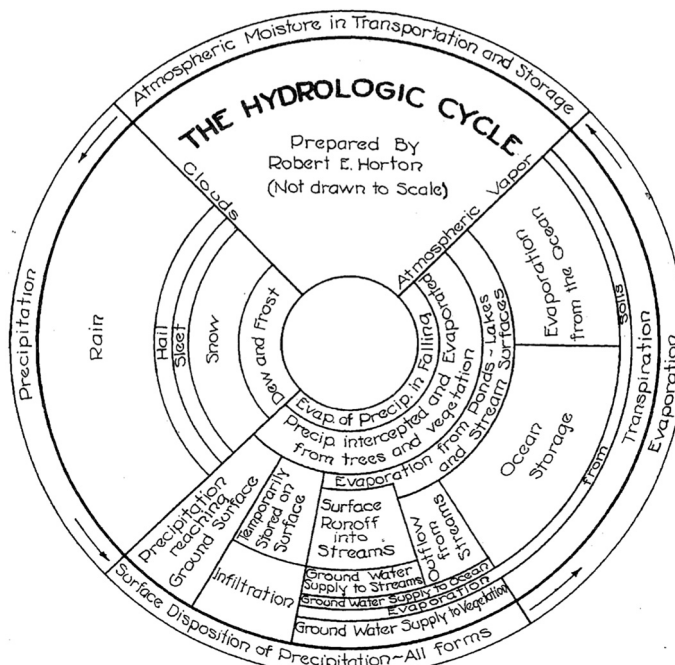


Fig. 1--The hydrologic cycle

**Figure 2.** Horton’s (1931) schematic of the hydrologic cycle at the watershed scale. Reproduced courtesy of the American Geophysical Union.

decade as when hydrology ‘came of age’ as a science. In Linton’s account, the neologism ‘modern water’ becomes shorthand for how hydrology *qua* science developed largely through the quantification of global water flows which, in turn, solidified an asocial notion of water at the ontological heart of a hydrological cycle that is socially constructed as non-human nature.

For Linton (2010), socially constructing a putatively ‘natural’ hydrological cycle was part of converting water into ‘water resources’. The argument bears similarities to Scott’s (1998) work regarding how nature is converted into ‘natural resources’ through state rationality and technology. Linton (2010) argued water resources are an exemplary case of how constructions of water as H<sub>2</sub>O deploy hydrological science to embed the nature/society binary in state ends deemed ‘objectively’ justified. Linton’s account turns on McGee’s (1909) essay declaring ‘water as a resource’ in the United States. Linton interprets McGee’s (1909) essay as exemplary of how states pursue programs of quantification and bureaucratic rationality. As we consider below, however, McGee’s broader corpus complicates this interpretation. Nevertheless, McGee is crucial owing to his role in the national conservation program of US president Theodore Roosevelt. For Linton, McGee’s position afforded a key role to advance ‘modern water’ through state programs that manage water resources (as H<sub>2</sub>O) by ontologically reducing relevant social relations to those that fit with the society/nature dualism. For Linton (2014), the ‘state-hydraulic’ program that synchronizes capital accumulation with water management is emblematic of how the hydrological cycle is socially constructed in ways that purport to be value-free but which advance one way of knowing, relating and producing water.

## 2.2 Limitations of ‘modern water’

Linton’s account is a key reference point of hydrosocial scholarship. Yet aspects of it have been unsettled by further historical work. We

evaluate Linton’s account in two ways: his history of hydrology and his account of water resources derived from McGee. The critique is not for its own sake, but to open conversation with socio-hydrology and fields of geohistorical inquiry in which the reality of a hydrological cycle *without* people is important to understanding anthropogenic forces driving unequal planetary shifts to climate and water.

Horton’s (1931, 190) brief history of hydrology culminates in his statement that: “‘Natural waters’ have come to mean those which are pursuing their natural course of circulation’ and hydrology is ‘not concerned with waters which have been temporarily removed from such circulation’”. Elsewhere, Horton (1931) discusses water conservation and economics in ways that parse naturally flowing waters from those interfered with by humans (e.g., agriculture). His dualistic account, however, comes heavily caveated. This likely owes to how, at the time, hydrodynamics was a science but hydrology was deemed mere practical exercise (Darrigol 2005). In this context, carving out disciplinary space required elbow room. Given this, it is important to recognize two things: First, Horton’s diagram of the hydrological cycle (Figure 2) was not intended as a global representation but as a schematic depicting the area of knowledge that would be a constitutive matter of concern for a new field. Horton (1931, 192) explicitly limits his claim to just the ‘principal steps involved in the hydrological cycle in the most typical case, that of a drainage-basin tributary to the ocean’. Second, Horton’s explicitly stated aim is to correlate that limited case with other geosciences, especially geology and meteorology. Here, Horton recognized that any science of hydrology would require integration with other geosciences, some of which have temporal scales reaching to Earth’s past when there were no humans. So, although Horton’s schematic excludes social processes, it is somewhat difficult to rest critiques of a *global* hydrological cycle on his account.



Second, Linton's argument that the International Hydrological Decade relied on water *qua* H<sub>2</sub>O is an incomplete story. At mid-point in the decade that saw meteorology and hydrology come together (Schmidt 2022), Nace (1969, 14) pointed out 'that "H<sub>2</sub>O" is not the whole chemical story of water'. In fact, it had not been since Urey's work in 1934. By the time of the IHD, 18 chemical subspecies of water were recognized.<sup>2</sup> Even these, Nace (1969, 14) stated, 'gives scarcely a hint of [water's] importance in the history of the earth and its inhabitants'. Indeed, even McGee's (1908) work on hydrology argued the singular module H<sub>2</sub>O could not be the basis of hydrology since water's many characteristics – its rhythmic movements and phase changes – required more than one molecule. This led McGee to argue for 'water modules' as fundamental to hydrology. Here, our claim isn't that Horton or the IHD viewed water as social but that reducing historical explanations to critiques of water *qua* H<sub>2</sub>O presents an incomplete picture.

Aside from his hydrologic history, Linton's account of water as a resource has also been critiqued. Schmidt (2017) demonstrates at length how McGee's idea of water as a resource was not an outcome of a society/nature dualism but an attempt to get beyond that dualism by treating water as a geologic agent. McGee (1899) explicitly rejected the mind/matter dualism; a view developed alongside his more famous counterpart John Wesley Powell (2009), who rejected the mind/matter dualism in favour of a vitalist view in which consciousness inheres in every particle. McGee (1899, 172) explicitly rejected the mind/matter dualism when he critiqued Bacon, Humboldt, Kant, Hegel and Schopenhauer for how they 'limned nature as a mental picture'. As Schmidt (2017) detailed, McGee's rejection of mind/matter dualisms led him to embrace vitalism, in which water and all other matter had agency differing only by degree.

In this context, Schmidt (2017) argues that declaring water a 'resource' takes on a different

tenor because it isn't the nature/society divide that requires critique but how social and geological sciences were used to naturalize water to settler colonial institutions of American liberalism. As is well known, Powell and McGee united American geology and anthropology – McGee co-founded the American Anthropological Association with Franz Boas – through colonial, racialized hierarchies of evolutionary difference (King 2019a; Schmidt 2017). Clarifying these concerns matters for environmental geography. Recently, Linton (2022) footnoted differences with Schmidt as being over a 'different historicity'. There seems more at stake, however. Lehman and Johnson (2022) argue that grappling with colonial inheritances of science and technology is non-negotiable for environmental geography. Likewise, decolonial efforts to support reparations for injustices require facing history as fully as possible. Here, plain language definitions of historicity render it as historical authenticity or actuality, and addressing colonial dispossession is best facilitated by accurate historical accounts.

### 2.3 Socio-hydrology

Historically, geographers like Mackinder and Whittlesey attempted to unify human and physical geography through water. They built on earlier work, like Tyndall's (1872) *The Forms of Water*, now recognized as a forerunner to thinking through water and climate (Edwards 2010; Coen 2018). Tyndall's account is full of metaphors that explain Earth's energy balance through examples of how humans use water, especially coal-fired steam engines. Hydrosocial scholars are interested in these links too. Budds (2009) notes that a critical perspective towards political uses of science is critical to water politics. After discussing how critical physical geographers appraise water sciences via socio-hydrology in ways relevant to hydrosocial work, we consider how climate change presents a critical domain for thinking water across human and physical geographies.

Socio-hydrology begins not with a critique of hydrology but with the incorporation of social concerns into understandings of complex hydrological systems. The approach was developed by Malin Falkenmark in the 1970s, as Sivapalan et al. (2012) explain in their description of socio-hydrology as a threefold approach that: addresses historical dynamics of society–water interactions, compares concerns across scales and utilizes a process-driven engagement across water-related disciplines (cf. Sivakumar 2012). Falkenmark is most widely known for developing an early, influential metric of water scarcity (Falkenmark et al. 1989) and more recently for approaches to ecohydrology that incorporate social–ecological complexity within hydrology (Falkenmark and Rockström 2004). The result has been advances in socio-hydrology that, as Sivapalan et al. (2014) argue, approach future scenarios of climate-driven flood and drought in the context of accelerating human impacts on the water cycle (cf. Devkota et al. 2020).

Critical physical geographers, such as Lane (2014), argued socio-hydrology should be sensitive to constructivist critiques of science – hydrosocial critiques – and especially so on matters of model prediction owing to how models don't merely represent the world but transform relations to it (cf. Lave and Doyle 2021). Ashmore (2015) argued fluvial geomorphology needs to incorporate anthropogenic influences into accounts of sociogeomorphology that reflexively understand human–environment relations not as impacts but as mutually constitutive processes (Tsouvalis 2023). Flooding, for instance, is not 'just floodwater' but a result of sociogeomorphology that shapes river systems and processes, including responses to climate change (Best et al. 2022; cf. Lane et al. 2011). Micheaux and Mukherjee (2021) show how groundwater withdrawals present a complex case for critical physical geography where asymmetries of power and knowledge intersect with complex socio-hydrogeological claims. These power differentials are matters of justice relevant

to hydrosocial scholarship too owing to the distributive impacts and the politics of representation (Haeffner et al. 2020; Thaler 2020).

There have been attempts to connect hydro-social scholarship and socio-hydrology to maximize the insights of each. Wesselink et al. (2017) sought to combine the rich narratives of hydrosocial scholarship with the quantitative modelling of socio-hydrology. Ross and Chang (2020) claim the two fields are 'two sides of the same coin' forged by the common currency of human–water relationships. By contrast, Rusca and Di Baldassarre (2019) argue that even though the respective approaches have different theoretical and methodological orientations – different ecologies of practices, to recall Stengers – a unified 'water resources geography' is possible and desirable. In their own collaborations with hydrologists, they combine socio-hydrology with political ecological analyses of social power to examine the 2015–2017 drought in Cape Town (see Savelli et al. 2021). Climate change was a key factor in the Cape Town drought (Pascale et al. 2020), and we focus next on contributions of hydrosocial scholarship to climate change.

## 2.4 Hydrosocial climates

Water is a key way climate change is experienced (Morgan 2019). Hydrologists like Falkenmark and Wang-Erlandsson (2021) now argue hydro-social dimensions are critical owing to how they can perpetuate climate change inequalities. They also produce new vocabularies for water–society scholarship: Climate change amplifies concerns over atmospheric waters and changes to the 'precipitationshed' that alter evaporation, water availability and rainfall intensity (Keys et al. 2012); Haeffner and Hellman (2020) describe the 'social geometry' of climate-driven flood risks; Klaver (2021) proposed the concept of the 'riversphere' to address blurred boundaries amongst the hydrosphere, atmosphere and geosphere, and; Jackson et al. (2022) cite hydrosocial



scholarship extensively as they attend to the ‘rhythmicity’ of rivers to overcome human–nature divides. Here, we consider the contributions of hydrosocial research to the reality of climate change.

Bulkeley (2019) argues geographers shouldn’t treat climate change as a phenomenon external to social relations but as a condition for social life, much like gender, race or class. Treating ‘climate-as-condition’ has watery implications. Mills-Novoa et al. (2017) show why analysis of ‘climate adaptation’ discourse and hydrosocial concerns are jointly needed to explain disparities between water users in Peruvian and Chilean mountain regions. There, differences are exacerbated by climate change responses that don’t consider different social relations or ontological orientations to water. In Ecuador, Mills-Novoa et al. (2020) identify distinct hydrosocial territories constructed through discourses of climate adaptation that combine with the politics of recognition to produce ‘subjects’ and spaces in need of intervention. Elsewhere, Parsons and Chann (2019) show how responses to climate change are perceived through hydrosocial relations in Cambodia, often in combination with labor and mobility dynamics that complicate notions of ‘climate migration’. Clark et al. (2017) argue water is a ‘time-substance’ – a conditioning dimension of hydrosocialities that combine hydrosocial formations, transformations and information affecting responses to climate change in Nepal.

Hydrosocial responses to climate change operate across water’s multiple materialities. Glacial loss poses new kinds of hydrosocial risks, like flashflooding, for which many communities and governing agencies aren’t well equipped (Carey et al. 2014; Mark et al. 2017). As geographers reflexively engage male-dominated glaciological praxis and colonial histories of icy environments, the potential for hydrosocial scholarship to engage icy and formerly icy environments is significant (Carey et al. 2016; Smith 2021). Dodds (2021) argues

against colonial notions of icy landscapes as ‘empty’ to consider how melting and thawing of sea ice and glaciers are matters of and for geopolitics. Gagne (2019) argues retreating glaciers in the Himalayas alter multiple human–water relations, as well as livelihoods oriented to care for land, animals and glaciers. Brandshaug (2021, 52) considers how the waterworld of the Yanque in the Peruvian Andes involves a form of intimacy in which uncertainty over water loss ‘makes humans and nonhumans suffer together’.

## 2.5 Hydrosocial realities

This section identified tensions in histories of hydrosocial scholarship. Previously, Mollinga (2014) identified how nature–society hybridity mightn’t be hydrosocial scholarship’s primary challenge given complexity across water–society relations of infrastructure, land and technology. To this may be added how, for geohistorical fields of inquiry, the reality of a pre-human hydrological cycle matters to understanding climate change impacts on water. Of course, there are co-productions of climate change too – ways that scientific practices and standards of evidence articulate with social processes (Bremer and Meisch 2017). What is also clear, however, is that hydrosocial work on climate is already showing how not only critiques of asocial water cycles matter but also how social space is produced through broader discourses on human–environment relations.

## III Hydrosocial spaces

Hydrosocial scholarship has expanded from critiques of the hydrologic cycle to highlight different co-constitutions of water and society or hydrosocial space (Linton and Budds 2014). Notably, Budds et al. (2014: 167, original emphasis) introduced a special issue in *Geoforum* by stating hydrosocial work is ‘not concerned with *water* per se, but with *hydrosocial*

*relations*' in which water is always 'produced as a particular "water", materially and discursively... within specific moments, contexts and relations'. Emphasis on hydrosocial relations has two implications beyond the need for reappraisals of how 'modern water' anchors historical claims or provides theoretical warrant for critique. First, hydrosocial relations challenge society/nature dualisms but also require space for positive accounts of different co-constitutions of water and society. The result has been a proliferation of particular yet plural 'waters' (cf. Vogt and Walsh 2021) through spaces of territory, urbanization, citizenship and adjacent concepts like waterscapes. Even religious studies of Buddhist hydrosocial thought are now available (Walters et al. 2020). Second, it indexes hydrosocial scholarship to broader concerns with the 'production of nature' (Harvey 1996; Smith 2008). This section concludes by considering tensions for 'thinking geography' by 'thinking hydrosocial relations' vis-à-vis the production of nature.

### 3.1 Territories, waterscapes and urbanization

In a special issue of *Water International*, Boelens et al. (2016) proposed the notion of hydrosocial territory to capture the spatial co-configurations of people, institutions, water flows and hydraulic technology. Hydrosocial territories are not fixed spatial boundaries but relationally contested, dynamic processes of boundary-making or territorialization (Boelens et al. 2016; Hommes et al. 2019). In this sense, hydrosocial territories implicitly critique traditional transboundary water scholarship, which reifies international borders in territorial water disputes. Instead, hydrosocial scholarship examines the materiality of territory *through* water and, as Rogers and Wang (2020) show, the social and economic processes that back infrastructural projects. Hydrosocial territories shift understandings of how water is configured within and across states (Pandey et al. 2020;

Miller et al. 2021). For instance, Menga and Swyngedouw's (2018) edited collection shows how state-building proceeds through technopolitical relations in which contests over water co-constitute hydrosocial territories. Hommes et al. (2016) argue competing imaginations of hydrosocial territories in conflicts over dam development in Turkey entangle water in broader social, political and ethnic tensions. Mason (2020) examines how a water pipeline from southern Turkey to Cyprus affects patronage relations in new territories and environments.

The concept of 'waterscapes' also animates work on hydrosocial territories, and the ways spatial configurations are transformed by social, political and material processes. Though conceptually adjacent, one distinction between waterscapes and hydrosocial territories turns on how the former focuses on everyday practices of different social groups whereas hydrosocial territories emphasize contested spatial boundaries (Karpouzoglou and Vij 2017; Flaminio et al. 2022). There are overlaps too. Waterscapes are used to explore injustices, such as uneven water access in urban environments (Loftus 2007, 2008; Kooy 2014; Goh 2019), vulnerability and rural livelihoods in wetlands (King et al. 2019; Hurst et al. 2022). Drawing on the case of Seine and the Rhône Rivers in France, Bouleau (2014) treats waterscapes as a snapshot of the hydrosocial cycle, identifying how observers mobilize professional practices to define and manage water quantity and quality at different scales. As Budds and Hinojosa (2012, 125) argue, 'water and waterscapes are co-produced, which avoids the limitation of thinking about water as a purely material resource'.

Approaches to waterscapes and hydrosocial territory both inform understandings of hydrosocial relations involving urbanization, especially the movement of water from rural to urban areas and demand shifts on peri-urban and rural areas. These movements operate through physical and social infrastructures of

dams, pipelines and hydropower plants as well as economic, legal and social institutions (Gandy 2003, 2014; Kaika 2005; Loftus 2012; Swyngedouw 2015; Hommes et al. 2020). Urban processes are thereby a critical site of analysis where flows of water and economies shape urban metabolisms. Cantor (2021) examines rural–urban linkages to show how urban political ecologies are configured differently across hydrosocial territories; these are not simply cases of rural to urban water transfers but particular ways rural practices encounter and inflect urbanization. Cousins (2017) shows how moving water to cities does not reduce its plurality; instead, different visions of water reforms, management, technical considerations and pragmatic constraints compete. Gandy (2003, 2014) analyzed how the urban water supply system in New York City – its investment and decay – was constructed alongside changing state relations and technological development, from upstream dams to household plumbing. Urban water supply crystallizes hydrosocial relations amongst state, market and community and reveals how power relations vary in different spatial-temporal settings. The focus of hydrosocial relations here is ‘both “the urbanization of nature” and “the nature of urbanization” at a variety of spatial scales rather than a reified emphasis on the city as a spatial container’ (Gandy 2022, 39).

### 3.2 Infrastructures of hydrosocial citizenship

Hydrosocial spaces are deeply affected by power. In Mexico, Meehan (2013) argued illegal connections become sites where water authorities can exercise power over ‘hydrosocial orders’ and discipline informal water access (cf. Banister 2014). As Meehan (2014) subsequently argued, hydrosocial analysis should focus on infrastructure not merely as an instrument of state power but as itself bearing a kind of power that constrains and enables different claims. Elsewhere, Colven

(2017) argued that Jakarta’s Great Garuda Sea Wall project betrays an institutional preference for large infrastructure that is underpinned by the Dutch colonial histories and Indo-Dutch post-colonial relations (cf. Batubara et al. 2018; Goh 2019). Octavianti and Charles (2019) argue that Jakarta’s sea wall plan is ‘rendered technical’ such that it dehumanizes certain citizens while promoting the interests of others. In post-colonial India, Björkman (2015) demonstrated how urban administrators envision, invest and construct Mumbai as a global, entrepreneurial city through hydraulic infrastructure; Anand (2017) showed how water access in Mumbai’s informal settlements is affected by differential ways that hydraulic and political pressure are put on urban authorities, particularly by those in informal settlements (cf. Truelove 2021).

Infrastructure, water and citizenship were jointly put to work by Gearey, Church and Ravenscroft (2019) work on new forms of hydrosocial citizenship in the English water sector. These, they argue, are tied to how spaces of community, water stewardship, citizen science and volunteering take shape amidst broader material and political forces of water governance. Similarly, McEwen et al. (2020) focused on how local stories and participatory action can reconnect individuals and communities to waters and revitalize hydrocitizenship. By contrast, Sarmiento, Landström and Whatmore (2019) show how different forms power produce different kinds of ‘hydrocitizens’ in the UK owing to different ways that droughts are managed through both models that operate in modalities of biopower versus efforts to mobilize particular (i.e., disciplined) community and individual responses to water shortage. Elsewhere, McLean et al. (2018) showed how hydrosocial relations in Australia must attend to the ‘shadow waters’ that are pushed out of view by dominant actors who normalize unequal relations. As von Schnitzler (2016) demonstrated in South Africa, prepaid water meters have become sites of democratic struggle as a political technology

that is used to reconfigure the relationship between citizens and the state.

Debates over water infrastructure have taken a new hydrosocial turn through digital technologies. Lally et al. (2022) trace how digitally mining for cryptocurrencies like Bitcoin can place demands on hydropower in ways that affect both existing human and non-human communities. Other technologies, such as the 'water ATMs', increasingly found across the Global South, purify and dispense water in ways that do not fit distinctions of formal or informal infrastructure as they operate locally yet manage water quality and payments through cloud computing (Schmidt 2020). Tristl (2022) shows how similar technologies in Kenya operate through forms of blended finance and data-driven governance that facilitate and complicate multiple water ontologies. As Hoefsloot et al. (2023) show in their analysis of the 'datafication' of water in Lima, hydrosocial geographies are increasingly shaped by the data used to monitor and control water access and relations between utilities and consumers. Hoolohan et al. (2021) argued that new digital water technologies must be situated socially to understand their effects. Amidst these concerns, the environmental geographies produced by computing infrastructure more generally cannot be overlooked given their significant water demands (see Pickren 2018).

### 3.3 *Multiplying materialities*

Hydrosocial scholarship has also expanded beyond freshwater. Water's many materialities now include sediments and sites where distinctions of land and water are difficult to draw. For instance, Micheaux et al. (2018) increase the ambit of hydrosocial scholarship through focus on the interrelation of relations linking water, sediment and society in the lower basin of the Ganges River. Bhattacharyya's (2021) historical work showed how sediments in the Bengal Delta became an object of scientific inquiry

through hydrosocial, political and colonial relations to India's amphibious landscapes. As Lahiri-Dutt and Samanta (2013) have shown in the Sundarbans of South Asia, riverine lives and livelihoods flex with historical and contemporary processes of sedimentation, erosion and institutional arrangements. Sediments also matter to infrastructures, as Carse and Lewis (2020) point out by linking hydrosocial concepts to practices of dredging ports to contemporary ecologies and politics (cf. Carse 2014, 2017).

Fluxes of water and land shape lives and livelihoods in estuaries, deltas, wetlands and permafrost (Krause and Harris 2021). Krause (2022) develops the notion of 'solid fluids' to analyze seasonal changes of water/ice and mud/permafrost in the Mackenzie Delta in Arctic Canada to argue relative temporalities of solidity and fluidity shape Inuit relations and livelihoods (cf. Clark et al. 2021). Elsewhere, efforts to manage delta ontologies by letting water flow, versus separating water from land through canals or dikes, are rarely straightforward (Morita and Jensen 2017). In Germany's Elbe Estuary, Hein and Thommsen (2023) argue that moving water, mud and sand present a slippery ontological conflict involving contested knowledge amongst fishers, port authorities and environmental NGOs. Albrecht and Lukkarinen (2020) argue multiple ontologies matter for policy-making in the emerging blue bioeconomy of Norwegian coastal seaweed farming. Scaramelli's (2021) research in Turkey identifies how competing scientific and governing logics shape hydrosocial accounts of what constitutes a wetland. The stakes of these contests are high. King *et al.* (2019) provide a hydrosocial analysis of the Okavango Delta in Botswana that bears directly on issues of governance, access and equity. Likewise for Venot and Jensen (2022), who consider how *prek(s)* (or canals) are sites of multiple ontologies as irrigation infrastructure for rice intensification in the Cambodian Mekong Delta operates in tension with efforts towards climate change adaptation. By contrast, 'stagnant waters' lingering

in homes, and eddying in streets owing to combinations of infrastructure, urban politics and tidal flooding of coastal rivers in Samarang, Indonesia, demand rethinking the socially situated ways in which multiple waters combine together (Ley 2022).

### 3.4 Producing hydrosocial relations

The turn to hydrosocial relations rather than water per se opened the field to multiple materialities at work in the co-constitution of water and society. There are more domains than we have covered, from sand mining in rivers and estuaries (John 2021) to impacts of hydraulic fracturing (fracking) for natural gas (Finewood and Stroup 2012; Lave and Lutz 2014; Pearson 2017), to the ‘wet ontologies’ Steinberg and Peters (2015) use to transgress geographic moorings to land-based categories. By reframing longstanding considerations of geography, like territory, hydrosocial scholarship presses on assumptions of fixity and permanence and challenges received ideas of the production of space. For instance, ‘hydrosocial territories’ navigate around the ‘territorial trap’ (Agnew 1994) through a focus on the integral relations of water across social, political and ecological space. The initial conceptualisation by Boelens et al. (2016, 2), however, does not explicitly mention land, which figures prominently in geographical genealogies of territory (Elden 2013, 2017).

Relatedly, hydrosocial scholarship has potential to further engage historical-materialist accounts of the ‘production of nature’. Some, like Lefebvre (1991) didn’t want too fluid an account in case watery metaphors obscured site-specific concerns. Harvey (1996, 8) also did not embrace a fully processual ontology and rejected the ‘dissolution of all fixity and permanence’ in favour of ‘the “solid rock” of historical-geographical materialism’. Often, as in the case of desalination, Harvey’s (2001) notion of a spatial fix is applied to a ‘hydrosocial fix’ where relative stability arises through a coalescence of economic, techno-political

and hydrological processes (Swyngedouw 2013; Odell 2021; Williams 2022). For hydrosocial scholarship, using water to ‘think geography’ might press further on commitments to processual and relational ontologies of water. This includes reckoning how different forms of political economy produce different waters – and different or no ‘natures’ – in ways that also elude its preferred target of ‘modern water’. For instance, Valladares and Boelens (2019) show how relational Indigenous ontologies of water figure in claims to be ‘mining for Mother Earth’ in Ecuador. As the next section shows, relational ontologies – where society–nature divides do not have a monopoly on the ‘production of nature’ – point to new concerns regarding water and efforts to ‘think geography’ through alternate ecologies of practice.

## IV Spheres of concern

As explained in the introduction, we suggest spheres of concern as a way to retain Stengers’s appreciation of how fields of inquiry are co-constituted by matters of concern – lakes matter to limnologists – while also appreciating how different ecologies of practice may ally with one another. For Stengers (2005, 2011), the ecology of practice that connects the ethos of particular matters of concern to the knowledge produced carries with it a rejection of comparison. Instead, the aim is to understand what each way of knowing may become. So too, we argue, for hydrosocial scholarship and the praxis of Black, Indigenous and Dalit geographies that structure this section and the article’s concluding engagement with more-than-human hydrosocialities. These warrant attention for how they refuse core points of geographic reference; dualisms parsing society from nature are less helpful in explaining hydrosocial relations amongst people who never subscribed to them. Wilson et al. (2023) argue entire hydrosocial systems – laws, expertise, governance, politics and kinship – must return to considerations of

relational ontology and epistemology to establish trustworthy relations in contexts where particular ways of knowing and relating to water are oppressed (cf. Boelens et al. 2023).

#### 4.1 *Black geographies, Dalit solidarity*

Noxolo (2022) reviewed how Black geographies have established a crucial form of geographic praxis that confronts erasure and centers Black agency. An important strand of that work involves water. Vickers (2023) detailed how swamps in the United States were marked as sites of death and decay – socially and ecologically – in a moral geography that legitimized anti-Black violence. Hosbey and Roane (2021) examined practices of marronage through which Black communities established commons, sovereignty and ecological relations outside of the plantation system in the United States and in wetlands, swamps, bayous and along rivers. Gaber (2021) tracks how the well-known case of water pollution and environmental racism in Flint, Michigan, continues to threaten the city's poorest residents through hydrosocial infrastructures that could further dispossess them to achieve water 'solutions'. Milligan et al. (2022) examine regional challenges near Atlanta, Georgia, and argue that a hydro-racial fix aligns racialized, hydrosocial relations with the infrastructures that support racial capitalism at the expense of Black citizens.

Black geographies also attend to tidewater ecologies, deltas and offshore shoals, which have been critical to rethinking how settler colonial relations were and remain shaped through racial oppression of both Black and Indigenous peoples (King 2019b). For instance, Roane (2022) examines the dynamic relationships of Black communities and subaquatic species such as crab, oysters and clams to critique extractive practices of dispossession that displace Black ecologies and relations to water in the Tidewater region of Virginia and Maryland. Freshour and Williams (2023) argued Black ecologies in the Mississippi Delta provide critical alternate

avenues for achieving both racial justice and improved ecological relations to water-saturated environments. Elsewhere, Debbané (2013) examined how control over water shaped agricultural economies along with racial lines in post-Apartheid South Africa. And Meché (2022) showed how notions of 'Black as drought' were shaped through twentieth-century environmental programs like UNEP that associated Blackness with desertification and social destitution. The drought in Cape Town mentioned earlier was also deeply inflected by racial inequalities both in policy responses and those built into infrastructural inequity (Robins 2019; Millington and Scheba 2021).

There is long-standing solidarity amongst Black and Dalit scholars jointly confronting oppression (Slate 2012). Similar connections are visible in hydrosocial scholarship. Ranganathan and Balazs (2015) drew lines of solidarity from the United States to India to confront issues of hydrosocial water injustice. For Shrestha et al. (2020), water debates in peri-urban Nepal are a clear case of caste exclusion as Dalits are marginalized in ways that require a socio-hydrological response to inequality. In her work on intersectional justice, Sharma (2022) argues that forms of political solidarity have rich potential to extend to Dalit-Black ecologies. Here, what emerges for hydrosocial scholarship is an opportunity to engage more directly with anti-racist and anti-caste concerns that think water through alternate practices of responding to, and thriving amidst, oppression. These concerns, as the next section considers, also extend to forms solidarity with Indigenous peoples.

#### 4.2 *Indigenous hydrosocial kinship*

Hydrosocial scholarship challenges singular ontologies and modernist epistemologies that preclude other ways of knowing water (Bakker 2012; Barnes and Alatout 2012; Linton 2019). As Yates et al. (2017) argue, appreciating multiple water ontologies focuses attention on cultural



categories, ways of being and relationality. Their focus on relational Indigenous ontologies positions water amidst anti-colonial struggles in which water figures centrally in contests over environmental governance and resource extraction (Wilson 2014; Stevenson 2018). In this section, we consider Indigenous geographies that push hydrosocial scholarship to explain cases where modernist ontologies are colonial impositions and where kinship relations demand explanations that do not center Eurocentric categories.

Hydrosocial scholarship often discloses conflicts and contests between state and Indigenous ways of knowing and governing water; Curley (2021) aptly states dams and irrigation infrastructures form a ‘colonial beachhead’ in Indigenous territories. Extractive industries, such as mining and oil and gas operations, often feature in studies attentive to how hydrosocial concerns articulate with Indigenous resistance and efforts towards self-determination (e.g., Boelens 2014; Yazzie 2018; Estes 2019). Contests over hydrosocial territory extend in numerous directions. In California, Underhill et al. (2022) argue groundwater has long been mobilized as a vertical frontier to support agricultural production in colonial settlements that undermine Indigenous sovereignty. Correia’s (2022) study in the Chaco identified racial assumptions operating through physical sciences to produce oppressive hydrosocial relations of flood and drought on Indigenous territories. The issues are not limited to water quantity; Berry and Cavazos Cohn (2023) show how Indigenous hydrosocial imaginaries of the Pyramid Lake Paiute (US) matter in efforts to secure adequate water quality. Based on work in Chile, Acuña and Tironi (2022) argue different aspects and implications of extraction require thinking through the plurality of ways Indigenous inventiveness, reappropriation, ethnic assertions and strategic adaptation operate as a kind of hydrosocial endurance. Seemann (2016) shows how tropes of ‘recognition’ in the determination of Indigenous ‘water territories’ in Bolivia get only limited material purchase

on the actual redistribution of water under extractive influences.

Götz and Middleton (2020) apply hydrosocial critiques in Myanmar to argue ontological differences between the state and Indigenous peoples mean hydrosocial relations are assembled and articulated not merely with respect to competing perceptions of contested water, but over what water itself is. It is important here to note how Indigenous oppression cuts across different relational ontologies and obligations within Indigenous legal orders (Norman 2015; Jackson and Head 2020; Wilson 2014; Perramond 2018; Estes 2019; Wilson et al. 2021). As McGregor (2015) considers in Anishinaabek law, for instance, water is to be treated as sentient and through relational forms of kinship and *zaagido-win* (love) that require responses to trauma for people and water. For Wilson and Inkster (2018), respecting Indigenous obligations and sovereignty requires recognizing Indigenous kin relations to water are non-metaphorical. In the case of New Mexico, Jaramillo’s (2020) proposal to think with ‘fluid kinship’ points to a disposition at once attentive to local experiences in water sharing and the racial configurations of colonial extraction. As Daigle (2018) notes, resurgent forms of Indigenous water relations needn’t recenter colonial categories in the process, such as those parsing land from water.

Explaining Indigenous relations to water in terms of hydrosocial relations requires navigating the limits of critiques that center Eurocentric categories. Leonard et al. (2023, 379) compellingly demonstrate how the rematriation of waters – ‘the process of returning Water, Land, culture and spirituality to Indigenous women to address the ongoing impacts of colonialism, patriarchy, and gender-based violence’ – is central to prioritizing Indigenous authority, sovereignty and relationality. Quintero-Weir et al. (2023) present one way this might be done through a ‘decolonial geonarrative’ that, in their case, centers Wayúu ways of knowing hydrosocial territory in Venezuela. Jackson (2022) argues, similarly, that addressing the colonial destruction of Indigenous water

infrastructures in Australia might draw selectively on hydrosocial scholarship along with narratives of Earth's deep history (the Anthropocene). Behn and Bakker (2020) argued academic and Indigenous critique can jointly challenge Indigenous dispossession. In cases such as these, respective ways of knowing are not necessarily compared for how they tally against some standard presumed independent of either. Instead, each contributes to an emerging sphere of concern that seeks to organize water–society relations – often beyond species – anew.

## V Conclusion

In the tradition of using water to ‘think geography’, hydrosocial scholarship has substantially contributed to understandings of human–environment relations, productions of space and reflexive disciplinary praxis. Yet rather than projecting its insights towards a horizon of disciplinary unity, multiple environmental geographies are possible. With Stengers, it is helpful to resist comparison and to consider anti-colonial geographies on their own terms, as well as to reflexively examine the limits of hydrosocial concepts. Exchanging comparative impulses for plural engagements presents hydrosocial scholarship with opportunities for continued dialogue on: the limits of historical critiques of the hydrologic cycle, their influence on studies of hydrosocial spaces, and engagement with spheres of concern that emerge through solidarity against oppression.

Critical engagement with hydrological cycles remains a key area for further hydrosocial research. Scientific determination of basic hydrological units like the watershed (or catchment) continues to pose problems, like where they bottom out geologically (Condon et al. 2020). Ballesterio (2019) argues for a social approach to aquifers not as static tanks but as sponges, where water constantly transgresses boundaries in hydro-lithic choreographies. Wang (2021) applies subterranean, volumetric politics to groundwater in Yunlin, Taiwan, to argue for

further attention to how state hydrogeological models configure Earth's unruly materialities and emergent relations. Below-surface hydrosocial relations contrast with those above it. Radonic (2019) argues rainfall in desert cities co-produces unique hydrosocial subjectivities. Tozzi et al. (2022) suggest that the colonization of rainfall provides a useful lens to explore how colonial imaginations deemed irrigation ‘stable’ over and against the ‘unstable’ rainfall of the Bombay Deccan in India. Jackson and Head (2022) extend hydrosocial territory to atmospheric concerns of evaporation in the Murray-Darling Basin in their critiques of Australian settler colonialism.

Hydrosocial spaces are critical sites for addressing injustice (Harris et al. 2020). They also address relational considerations that span multiple domains of more-than-human geographies: Acevedo-Guerrero (2022) pushes for more-than-human treatments of ‘*water with mosquitos*’ in order to track how mosquitos and stagnant waters are co-constituted as vectors of Dengue fever and Zika virus in Colombia and Brazil. Liao (2023) develops the notion of hydrosocial life to examine how more-than-human relations in shrimp aquaculture are co-produced by Vietnamese and Taiwanese laboratory scientists for biosecurity on farms. Hurst et al. (2022) highlight how more-than-human life, such as microbes, plants and animals, form a part of water infrastructure as they examine knowledge claims in wetland projects and wastewater treatment in rural India. More-than-human relations also matter for queer ecology, as Hazard (2022) argues for in a conception of the ‘watershed body’ that relationally situates ecological sciences for work with Indigenous peoples, and species such as salmon and beaver, to transfigure riverine relations. Flaminio (2021) argues that anti-dam movements now challenge the narrative of water as a resource by highlighting the alternate, ontological relations of ‘being-with’ environments.

The anti-colonial praxis of Black, Dalit and Indigenous geographies, and those in solidarity

with them, present key areas for hydrosocial research. Dotson and Whyte (2013) show how Black-Indigenous solidarity can confront water injustices not recognized in dominant ways of knowing. In this review, we eschewed ‘progress’ that relies on past harms as the explanatory path to the present or future. Even so, it is important to clarify the historical claims of hydrosocial scholarship in order to not perpetuate forms of erasure. This will involve a broader project than we have covered here owing to the different ways that water matters in anti-colonial agendas and praxis. It may be that ‘hydrosocial ideas’ are primarily instrumental to other ends rather than themselves desiderata for research. Indeed, geographic practices of using water to ‘think geography’ presuppose a kind of water and a kind of geography that anti-colonial work complicates in ways that can push hydrosocial research – and environmental geographies – further towards reparation.

### Acknowledgements

The authors are thankful for engaged, thoughtful comments by the reviewers and the directions suggested by the journal editors.


### Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

### Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: While revising the manuscript, the lead author received support from the Research Institute for the Humanities and Social Sciences, National Science and Technology Council, Taiwan (MOST 110-2420-H-002-003-MY3-D11203).

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### Notes

1. To clarify, we do not use ‘spheres’ metaphorically, or in a way that positions different ways of knowing as equidistant from a presumed center.
2. Nace noted H<sub>2</sub>O, deuterium (D<sub>2</sub>O) and tritium (T<sub>2</sub>O), along with three isotopes of oxygen would make these 18 combinations theoretically possible.

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