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*Research*

# Post-crisis risk management: water, community, and adaptation in a South Australian irrigation district

*William Skinner* [1], *Douglas K. Bardsley* [1] and *Georgina Drew* [1]

ABSTRACT. Farmers in the Langhorne Creek–Angas Bremer basin irrigation district of South Australia have faced a series of hydrosocial crises relating to drought and groundwater depletion and degradation. The crises have been negotiated through concerted community engagement and cooperation. Adaptation responses have included a combination of infrastructural development and changes to the licensing, regulation, and oversight of irrigation governance, easing extraction pressures on the local groundwater catchment. However, new risks have emerged in the wake of, and as a result of, these solutions. One aspect of the solution has been to connect the Angas Bremer basin district more intimately to the much larger continental riverine system, the Murray-Darling basin, which stretches across multiple regional and state jurisdictions. The very success of that scalar response to hydrological risk generates broader systemic risks: to water supply and quality from climate change and upstream extraction; to basin governance; and to community cohesion, engagement, flexibility, and resilience. In a post-crisis period, there is a need to understand the emergent risks from transformational adaptation and guard against complacency to ensure that the hydrosocial qualities of flexibility and resilience that enabled positive responses to the initial crises endure to respond to future crises in water supply and its management.

Key Words: *basin management; climate change adaptation; community; crisis; governance; hydrosocial; irrigation; Murray-Darling Basin; resilience; risk; South Australia*

## INTRODUCTION

Risk management is dynamic, requiring an evolution of social and political responses over time. This dynamism is particularly evident in the case of water risk management, especially as levels of extraction for agricultural irrigation are challenged by urban expansion and climate change. Basins and aquifers are complex hydrosocial systems and represent paradigmatic examples of the thorny problems associated with governing the commons (Ostrom et al. 2003). Decision makers frequently pursue overarching solutions to manage aquifers and surface catchments to help enable equitable resource access for human and environmental needs. Many interventions involve complex technological infrastructure such as networks of pipelines, pumps, dams, and channels, requiring equally sophisticated social and political-economic coordination. The resulting hydrosocial systems draw upon combinations of political power, scientific expertise, capital investment, and networks of local and supra-local social relationships to dominate and guide water outcomes (e.g., Linton and Budds 2014, Boelens et al. 2016). Such systems are experiencing significant strain in many places around the world. In places such as Italy's Po Valley (Bozzola and Swanson 2014), South Africa's Western Cape (Enqvist and Ziervogel 2019), and California's Central Valley (Ray et al. 2020), limits of water infrastructure and governance arrangements are being tested by periods of drought and competing agricultural, urban, and environmental needs. To remain effective, adaptive responses to change are necessary as new complications arise.

Here, we contribute to the field of hydrosocial inquiry by analyzing water security challenges and risk management in Langhorne Creek, an important viticultural region in rural South Australia, centered around a small town of the same name and traversed by the Angas and Bremer Rivers.[1] The Angas Bremer basin constitutes a sub-basin at the end of the Murray-Darling basin (MDB) system, which is an enormous, overburdened water catchment stretching over 1 million km² and supporting much of the nation's agriculture, as well as adjacent towns and cities, including Adelaide (Figs. 1 and 2). Here, we emphasize two moments of hydrosocial crisis experienced since the 1970s in Langhorne Creek: (1) aquifer degradation and salinization through overextraction of groundwater in the localized Angas Bremer basin from the 1960s to 1980s (Waterhouse et al. 1978, Harris 1993; Howles, *unpublished report*: http://www.angasbremerwater.org.au/documents/ABhowlesPpr.pdf), and (2) a crisis of ground- and surface-water access and management as a result of the "Millennium Drought" that affected much of eastern Australia and the broader MDB from approximately 2000 to 2010 (Connor et al. 2009, Kirby et al. 2014). Responses to these crises were transformational, involving first the application of new groundwater prescription, licensing, and regulation systems, and second, the construction of a major public-private pipeline scheme to secure MDB water directly from the Murray River, 40 km away from Langhorne Creek. In effect, the responses have led to a reorganization of technical infrastructure and governance, necessitating a change in sociocultural relationships with water.

Existing scholarship indicates that past crises in Langhorne Creek were averted and solutions achieved through concerted community action and cohesive political engagement (Harris 1993, Cuadrado-Quesada and Gupta 2019, Shalsi et al. 2019, 2022, Skinner et al. 2023). We build upon these insights to argue that these apparent resolutions to crises bring with them new risks, emerging from new interplays of climate, weather, landscape, technological infrastructure, governance regimes, and, crucially, the social relationships that frame the regional social-ecological system. In discussing the dialectical relationships between water and society, we focus not just on crises per se, but also on the post-crisis periods during which novel risks emerge from the new relational configurations.

[1]University of Adelaide

**Fig. 1.** Map of the location of the Murray-Darling basin in Australia.

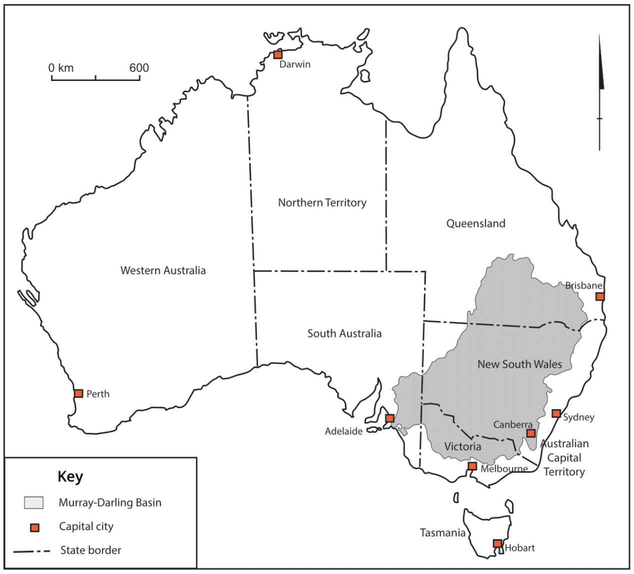
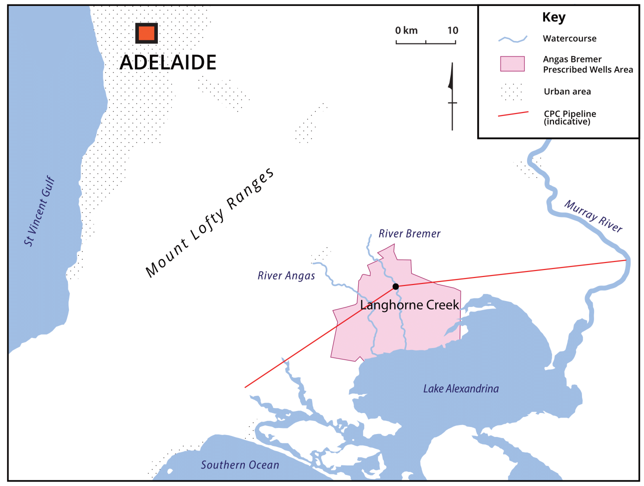



**Fig. 2.** Map of Langhorne Creek and the Angas Bremer basin district.




Changes in one area may generate new, unexpected risks and problems elsewhere, not only in their hydraulic and ecological functions, but also in attendant networks of social connection and reliance. This complexity provides justification for attempts to manage systems holistically, through whole-of-basin plans and strategies that seek to allocate water resources, identify and manage risks, and mitigate potential crises. Through this governance process, localized water management tends to become nested within ever-larger jurisdictional spheres and territorial configurations, from local catchments, through regional, basin-wide, and national institutions, to sometimes supranational governance arrangements (Boelens et al. 2016, Götz and Middleton 2020, Fragaszy et al. 2021). Individual water users such as farmers drawing from a creek or bore for irrigation become responsible not only to their immediate neighbors and local community, but to others, often hundreds of kilometers away. Actions taken by individual water users are thus increasingly subject to oversight and regulation by bureaucracy that, from ground level, feels enormous and impersonal.

Increasingly pervasive and bureaucratic governance processes often appear an inevitable aspect of modernization, products of increased scientific knowledge of the complexities of hydrological systems and their risks and affordances. However, these shifts are not uniform. Transformational change in water management is often catalyzed by moments of crisis because systemic adjustments appear most urgent during these periods (Abel et al. 2016, Taing et al. 2019). Such crises might include, variously, periods of water shortage exacerbated by drought and/or overextraction, environmental or crop damage through pollution, or serious flooding, each of which may be "solved" (and future risks mitigated against) by implementing new management regimes, including introducing new technologies.[2] Importantly, however, transformational adaptations made in response to a specific crisis do not eliminate hydrosocial risk altogether, but fundamentally reposition it.

What sorts of changes do acute crises bring about, and what sorts of new risks might lie in their wake? What does "avoiding," "overcoming," or "resolving" a hydrosocial crisis mean in terms of recasting social connections and relationships of power? And to what extent might over-reliance on a centralized solution expose farmers to further risk? Writing on water management in Australia, Hindmarsh (2012:1132) highlights an "increasing failure of traditional, largely technical, planning, and policy approaches to address interrelated socio-environmental issues at the local level." He calls for a "liberation of social knowledges," especially those tied up in "place-based local communities currently neglected in water planning despite these communities most often comprising the fabric of the social infrastructure of water planning and management" (Hindmarsh 2012:1132). Policymakers, as Ostrom argues (Ostrom 1990, Ostrom et al. 2003), frequently propose solutions that call for either strong governmental regulation and oversight or a privatization of water resources to tie management to market forces. Lessons from these models, she asserts, show that "... neither the state nor the market is uniformly successful in enabling individuals to sustain long-term, productive use of natural resource systems" (Ostrom 1990:1). Rather, effective polycentric governance of water will need to take into account histories of successful community management of hydrological systems, alongside regulatory and market-led elements (Ostrom et al. 2003, Lankford and Hepworth 2010, Pahl-Wostl et al. 2013). It is with this idea in mind that we highlight the experiences and narratives of farmers, irrigators, and others who negotiate their lives with water in the region. We next provide a brief conceptual overview of risk, crisis, and hydrosociality before discussing post-crisis risk in Langhorne Creek.

## CONCEPTUAL BACKGROUND

To clarify the discussion, it is important to define some of the key terms. The concepts of risk and risk management have been normalized within environmental hazard research and practice to refer to specific frameworks that quantify the likelihood of detrimental consequences. For example, Kaplan and Garrick (1981:12) define risk as “the ‘possibility of loss or injury’ and the ‘degree of probability of such loss,’” and go on to note that while hazards exist as a source, “risk includes the likelihood of conversion of that source into actual delivery of loss, injury, or some form of damage.” Social theorists have developed that bounded concept to recognize that risk is now pervasive across modern society and is constantly experienced and responded to, often without explicit acknowledgement or definition (Beck 1992). In doing so, the ability to conceptually constrain the fluid concept of risk is challenged, with risks having both “objective elements of consequence and likelihood tied to real events within any society or system, as well as subjective elements related to people’s knowledge, perceptions and cultural experiences” (Bardsley and Knierim 2020:504). Thus, risk management is a social-ecological process that extends beyond the ability to mitigate the likelihood or consequences of a defined and bounded hazard, to become a constant reflexive reorganizing of societal structures and systems to live with and minimize negative change.

Boin et al. (2018:24) represent crisis as “a *threat* that is perceived to be existential in one way or another... No disaster has materialized just yet, but the prospect is imminent.” Accelerating risks relating to water access or degradation clearly fall within this category, as in the cases of drought and groundwater salinity discussed here, which are seen to pose an abnormal threat to the viability of agricultural production and the people and communities dependent upon it. Periods of crisis may presage disaster or they may be averted (Shaluf et al. 2003). Although a specific water crisis bounded in time and space may pass, the ongoing goal of water security is resilience: “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions” (United Nations Office for Disaster Risk Reduction 2009:24). Thus, hydrosocial resilience is a way of being with water that accounts for exogenous and endogenous risks in the ongoing interplay between people and environment.

Water crises are rarely reducible to simple causes. As Trimble et al. (2022) state, they are “complex problems that usually occur due to a combination of factors (e.g., ecological, climate, economic, governance), and involve multiple actors with different perspectives, who generally are affected unequally by the water problem.” Crisis often stems from a disjuncture between expectations and reality: a predictive failure, complicated and compounded by several natural and social moving parts. Crises of water access and management, such as those dealt with here, emerge from a “dialectical relation between water and society” in which “water and society make and remake each other over space and time” (Linton and Budds 2014:170). Hydrosociality is a concept well suited to illuminating key points of social change and complexity when it comes to resource management, focusing as it does on relationships of power: “how, and therefore whose, decision making shapes the hydrosocial system and what impact this has on political and material inequity” (Wesselink et al. 2017:6). For that reason, understanding water-society relationships is crucial to understanding risks of water access, management, and ecosystem health, as well as the emergence of specific crises within systems and places (e.g., Mark et al. 2017, Goldman and Narayan 2019, Haeffner and Hellman 2020, Jackson and Head 2020, McCulligh et al. 2020).

Hydrosocial theory draws together elements of water resources and their use, technological change, and social processes (Dunham et al. 2018, Ross and Chang 2020). It holds that there are continuous and ongoing interactions between those elements, with risks managed and transformed in response to both endogenous and exogenous drivers of change (Kinzig et al. 2006, Jackson and Head 2020). Some of that change will be incremental, but as Kates et al. (2012:7156) note, transformational adaptations also occur via irregular social-ecological changes: “those that are adopted at a much larger scale or intensity, those that are truly new to a particular region or resource system, and those that transform places and shift locations.” Transformational adaptation, as in response to specific crises, can bring about transformation and translocation of risk. We are indebted to the work of Ulrich Beck and others (e.g., Beck 1992, Giddens 1999, Beck et al. 2003), who show how processes of modernization, by offering technocratic and institutional solutions to risk, can bring about ever more complex and unintended risks. Such modern systems may indeed prove less flexible and resilient, and more vulnerable to breakdown, than previous systems (Tierney 2014, Boin et al. 2018). As hydrosocial systems reach limits of exploitation, attempts at mitigating risk become major drivers of decision-making and action. Risks are not eliminated altogether by transformational adaptations but are transferred or articulated elsewhere within the system. As Beck et al. (2003:17) note, “Rather than focusing on and resolving the crises, the established processes of ‘crisis resolution’ set off new chain reactions ... that further jam those mechanisms and set off even more turbulence, which has by this point become predictably unpredictable.” While the immediate challenges generated by risks such as water availability, salination, pollution, or floods may be reduced through targeted technological interventions with sociopolitical support, those modern solutions generate new types of risk that are less easily defined or managed.

Even with strong individual and collective engagement, high levels of community trust, and concerted effort to respond to common concerns, management of “first-order” risks can result in the emergence of new “second-order” side-effects (Beck et al. 2003:14). Those consequential risks may be less immediately obvious, hidden behind technological, financial, bureaucratic, or political barriers, and therefore, largely beyond the means of any single community to understand or respond to directly (Mercer et al. 2007, Bardsley et al. 2018, Alexandra and Rickards 2021, Seidl et al. 2021, Kumar et al. 2022). This situation, we will show, is relevant to the example we offer from research in Langhorne Creek: as modern technologies and associated hegemonic power and procedural structures are deployed to respond to water resource concerns relating to groundwater degradation and drought, hydrosocial systems are fundamentally transformed, generating new risks with potentially significant ramifications. What is required, therefore, is a perspective that accounts for the complexity and ever-changing dynamism of hydrosocial risk by acknowledging that any changes to practice and policy will expose a water community to new risks, which must be examined reflexively and managed in turn (Beck and Lau 2005).

## METHODS

We draw upon empirical and ethnographic findings acquired during fieldwork during 2021–2022 with farmers and irrigators in Langhorne Creek. This research involved documenting recollections of water scarcity, water crises, and concerns for the region's resilience to future crises as part of the three-year project "Hydrosocial Adaptations to Water Risk in Australian Agriculture." The research was undertaken to address a core question on the relationship between hydrosocial adaptations and water risk management with approval from the University of Adelaide's Human Research Ethics Committee (approval H-2021-009). As anthropologists and geographers, we abide by the Code of Ethics of the Australian Anthropological Society and the Code of Professional Conduct of the Institute of Australian Geographers and strive to uphold principles of ethical research at all times. Research involved on-farm, semi-structured, "walk-and-talk" and "drive-and-talk" interviews (Drew et al. 2022) with 20 vignerons, regional industry bodies, government agencies, and water experts. Participants represented a broad cross-section of wine business types in the district, including small-scale growers, family and independent wineries, and representatives of larger, cross-regional corporations. They ranged in age, with several involved in farming in the district for many decades.

Interviews were recorded, transcribed, and analyzed thematically. Quotations are used here with pseudonyms (selected by the authors) to guide the discussion, with the exception of Karlene Maywald, Chair of the National Water Commission, who gave consent to be identified by name. All participants were provided with project information, were informed of their rights to withdraw from the project at any stage, and signed forms confirming their free, prior, and informed consent to participate in the project. Importantly, several key participants requested that early results be shared so that they could respond with feedback to support or contest the study's initial findings; this was a welcome invitation because the sharing of research insights was part of the project's design. The provocations of the present discussion, especially those regarding the transformation and potential for maladaptation to risk, were conveyed at three key meetings in 2022 attended by a range of research participants, industry personnel, and government officials. At each event (be it a convening of the region's basin management committee, a gathering of water security professionals and interested parties, or the annual meeting of grape growers and wine producers in Langhorne Creek) the research insights were upheld as reflecting the concerns, perspectives, and conclusions reached by the people that live and work in the region.

## RESULTS

Part of the reason that a focus on social issues relating to risk management was well received by stakeholders is that water-related risk, from unpredictable weather and rainfall to the concerns of ground- and surface-water security, is recognized as being crucial to the viability of agricultural livelihoods in the region. As the "driest State on the driest continent," the story of South Australian agriculture is dominated by concerns of access to water resources, punctuated by climatic cycles and the ever-looming threat of drought (Williams 1992, Sendziuk and Foster 2018). Issues relating to water access and quality in Langhorne Creek have reached a critical point on several occasions. Below, we emphasize two significant hydrosocial crises afflicting the region during the last 50 years, i.e., groundwater degradation and drought, and describe the range of factors that contributed to these critical moments and the community responses to them. First, however, we provide a brief geographical and social-historical context to the region.

Langhorne Creek lies in the rain shadow of the southern Mount Lofty Ranges, on the alluvial floodplain of the Angas and Bremer rivers. These are small, seasonal rivers flowing from the relatively high-rainfall uplands of the hills into Lake Alexandrina, a broad, shallow, coastal lake fed by the Murray River and outflowing into the Southern Ocean at the very end of the extensive MDB system (Fig. 2). The region forms part of the country of the Ngarrindjeri people (Hemming et al. 2017), but, from the mid-19th century onward, was colonized by European farmer-settlers, who saw great farming potential in the rich floodplain landscape. Since then it has seen a range of agricultural and pastoral uses, including cereal cropping, market horticulture, orchards, dairy cattle, sheep, and viticulture; the latter was always present, but is now the dominant agricultural land use (Verrier 1977, Smith and Ragless 1986, Angas Bremer Water Management Committee and Sim 2004, Sim and Muller 2004, Skinner et al. 2023).[3]

Early on, settlers recognized the precarity of water resources in the district. Flow volumes and water quality in the Angas and Bremer rivers were matters of concern at various times through the 19th century (Angas Bremer Water Management Committee and Sim 2004). Water access and management along these creeks was also a focus of community, legal, and political debate, as farmers sought governmental support for irrigation dam development and, when it was not forthcoming, built their own infrastructure to direct floodwaters through their properties (Verrier 1977, Smith and Ragless 1986, Angas Bremer Water Management Committee and Sim 2004). This system required significant coordination between neighboring landholders as the surface water, an important common resource, progressed from one property to the next. The integrated, community-level hydrosocial system remains in place even as most of the district's irrigation water is now drawn from other sources (Skinner et al. 2023). Regional cooperation and collaboration, as well as willingness to seek governmental support, are recurring themes in overcoming water crises in more recent years (Shalsi et al. 2019, 2022). As we discuss below, however, these strengths are coming under increasing threat by a recasting of social relationships and a scalar repositioning of risks.

### 1970s–1980s: groundwater overextraction and degradation

During the 20th century, farmers in the Angas Bremer basin increasingly made use of groundwater for irrigation. In the 1950s, the district was connected to mains electricity, enabling the use of electric bore pumps to access the subsurface aquifer much more efficiently and cheaply than previously (Harris 1993, Angas Bremer Water Management Committee and Sim 2004; Howles, *unpublished report*: http://www.angasbremerwater.org.au/documents/ABhowlesPpr.pdf). A new ability to irrigate year-round, rather than rely on winter rains and flooding from high river flows, enabled farmers to rapidly increase crop plantings and production, especially of lucerne (*Medicago sativa*) for stock fodder (Waterhouse et al. 1978). With increased irrigation and expanding area under crop, groundwater resources rapidly came under strain, and by the late 1960s, high extraction rates had increased salinity in some areas to the extent that bore water could no longer be used to water stock (Harris 1993). The South Australia Department of Mines and Energy was engaged to undertake a hydrogeological study of Angas Bremer basin groundwater, producing the influential "Waterhouse Report" (Waterhouse et al. 1978). This report confirmed what many farmers already knew experientially: extraction was depleting the aquifer much more quickly than it could be replenished through natural recharge.

Even before the Waterhouse Report was released, local farmers and politicians had begun to investigate the possibility of "prescribing" the water resource and introducing closely controlled licensing, thus limiting its exploitation. In the late 1970s, a committee made up of irrigators and government experts was formed, which was a precursor to the Angas Bremer Water Management Committee. Through its recommendations, in 1981, the Angas Bremer basin was declared a "Proclaimed Wells Area" under the South Australia 1976 *Water Resources Act* (K. L. Muller, *unpublished manuscript*: http://www.angasbremerwater.org.au/documents/WIEC%20Full%20paper.pdf; Fig. 2). At this time, an estimated 26,600 ML of water, more than four times the estimated natural recharge rate, was being drawn annually from the aquifer (Shalsi et al. 2019). In some parts of the region, increasing salinity rendered much of the water unsuitable for irrigation (Waterhouse et al. 1978; Howles, *unpublished report*: http://www.angasbremerwater.org.au/documents/ABhowlesPpr.pdf).

Understanding the need for a collective solution to the growing collective crisis of basin degradation, irrigators rallied the farming community and lobbied government to support drastic cuts to Angas Bremer basin licensing allocation. However, reaching consensus on a solution proved challenging. In April 1987, a community meeting was held to discuss a proposed strategy to cut water licenses. Farmers and Committee members present at the time recalled a fiery session, during which many irrigators reacted to the proposal with hostility. At the heart of these tensions lay differences in risk perception among irrigators: the varied ability or willingness to perceive the present situation as an emerging *crisis* demanding immediate action. Crucial to the Committee's role, then, was working alongside other farmers to understand the scale of the worsening problem. Another meeting was called a month later, providing further explanation of the hydrogeological situation (Harris 1993). As the scope of the problem became apparent, community consensus was gained in support of the Committee's proposals. According to Dennis,

> *Some of the policies that were developed by that committee were pretty harsh. And that's when we had to win the community over. The community played a part in it - the strong leadership in the community, seeing your own problem and discerning: "We're gonna fix it."*

In October 1987, the first Angas Bremer Basin Management Plan was set in place. Under this plan, the total volume of groundwater committed under license decreased by approximately one-third, bringing it in line with irrigators' actual highest annual declared water use over the previous three-year period. In turn, irrigators could trade their existing groundwater allocations for licenses to extract MDB water from Lake Alexandrina, with incentives offered to use that water to "artificially recharge" the Angas Bremer basin aquifer (Bjørnlund 1995). The uptake of this scheme was slow at first because of the high initial costs of setting up private pipelines from Lake Alexandrina and the low market price for lucerne and potatoes, which were key irrigated crops at the time (Angas Bremer Water Management Committee and Sim 2004:31). Nevertheless, by 1991, aquifer extraction had halved (Bjørnlund 1995), and, for the time being, it seemed that the water crisis in the Angas Bremer basin had been overcome.

**2000s: the Millennium Drought**

The "fix" of the groundwater crisis was both policy based (the implementation of MDB licenses) and technology based (the development of new pipelines and artificial aquifer recharge). Altering the hydrosocial landscape generated new possibilities for irrigation expansion. Newfound confidence in water supply coincided with a significant export-led boom period for Australian wine from the early 1990s onward (Anderson and Aryal 2015). Rising grape prices led many farmers to plant new vineyards or expand their existing vineyards. Langhorne Creek also became a target of external investment from managed investment schemes taking advantage of government tax incentives for vineyard planting and from large winemaking companies with holdings across multiple states and regions, who could invest in private pipeline infrastructure to draw water from Lake Alexandrina. The overall area planted to vines expanded rapidly, further encouraged by the implementation in the 1990s of a legal Geographical Indication framework for Australian wine labeling and marketing, which facilitated promotion of the region in its own right (Johnson and Robinson 2013).[4] This rapid expansion of vineyards, catalyzed by changes to water regulation, generated significant new risks: a reliance on Lake Alexandrina and the MDB to quench the region's greatly increased water needs.

Around the turn of the 21st century, southeastern Australia entered a prolonged period of lower-than-average rainfall, often referred to as the Millennium Drought (Cai et al. 2014). Low rainfall and high extraction for agriculture and urban use across the MDB meant that flow rates in the Murray River declined significantly. The water level in Lake Alexandrina dropped well below sea level, and levels of salinity and acidification increased dramatically (Stone et al. 2016; https://www.environment.sa.gov.au/topics/river-murray/dry-conditions/millennium-drought). For farmers in Langhorne Creek, now heavily reliant on irrigation from the lake, this was experienced as an acute crisis. As we drove around his large farm on the shores of Lake Alexandrina, Bruce painted a picture of this dire situation.

> *The water went back and back and back until [the surface of the lake] was 1.2 m below sea level and we had 2000 acres [809 ha] of drifting sand off the point, and the Boggy Lake out here, we could drive down the center of it. First thing we did was put a 3-km channel out across the point and into the lake. And then that got too low, the sand drift just filled the end of it up...*

As lake water dwindled and became unusable, farmers began to rely upon bore water once more, forcing the aquifer, again, into rapid decline. The optimism that had followed groundwater licensing turned to hydrological and climate-related anxiety. Many people, anticipating a bleak future, walked away from the land. Another farmer, Peter, told us that during that period, he did not think Langhorne Creek "would exist in anywhere near the same form in ten years' time." Across the MDB, a sense of helplessness and alienation resulted in a marked increase in rates of depression and suicide (Bryant and Garnham 2013, 2014, Wheeler et al. 2018). One participant, an ecologist involved with basin planning, told us that this was particularly marked in dairy farming communities that were already suffering from deregulation and corporate consolidation.

> *Everyone was on suicide watch ... The drought hit and they got no support at all. They were left hanging. You know, dairy wasn't very sexy and had been deregulated. They weren't seen as worth it, you know? This is where political connections become so incredibly important when you're dealing with wine.* (Tammy)

In response to the broad and prolonged drought, the South Australia government announced a number of infrastructure projects to mitigate water supply problems across the state, including a major desalination plant on Adelaide's metropolitan coastline. However, it was in the towns and irrigation communities such as Langhorne Creek, reliant on Murray River inflows into the Lower Lakes, that low flows were felt most severely. As one participant recalled, the condition of Lake Alexandrina placed significant pressure on the government: "it was dry everywhere: all the way down the lake!"

In Langhorne Creek, community experience dealing with the groundwater crisis of previous years, including engaging scientific experts and both formal and informal pathways to negotiate solutions with government, placed the region in good stead to deal with the drought crisis. The farmers we talked to, as well as other stakeholders who worked with them during this period, spoke of a proactive attitude from a community already primed by years of collaborative water management discussions. Karlene Maywald, the Minister for the River Murray and Minister for Water Security at the time, told us that the Water Committee and the Langhorne Creek community more generally, were highly engaged in seeking solutions.

> *I was doing public meetings so regularly, I think I was doing them every week ... I would turn up to the football club here at Langhorne Creek, and there'd be three to five hundred people there. And incredibly respectful, intelligent questions from an engaged audience that wanted to know more, and who willingly engage with the government officials also after the meeting, and engage with me down the pub after the meeting as well, where you got the real story.*

As a community, Maywald told us, Langhorne Creek irrigators presented a more-or-less unified front, participating in deliberative discussion with government representatives and decision makers in search of solutions for the region. But just as important as the discussion that took place within formal frameworks of "consultation" was the ability of community members to speak frankly and directly to politicians outside these frameworks.

> *When it's out of that formal environment, you have real conversations that you need to have ... And so it was the conversations with the leaders in the community afterwards at the pub that were really, really important.* (Karlene Maywald)

Ultimately, the Angas Bremer Water Management Committee, in alignment with several major commercial growers, put forward a proposal to tap into and greatly expand a government-funded scheme to provide water for agricultural irrigation to Langhorne Creek directly from the Murray River. The Creeks Pipeline Company (CPC; http://www.creekspipelineco.com.au/index.htm), funded in part through private capital investment, opened in late 2009. The CPC also made use of existing infrastructure, plugging into the private pipelines delivering MDB water allocations from Lake Alexandrina.

Drought conditions across the MDB persisted roughly until mid-2010 (http://www.bom.gov.au/climate/updates/articles/a010-southern-rainfall-decline.html). Throughout the drought years, governments at state and federal levels sought to establish new frameworks for water management. A key component was the 2007 *Commonwealth Water Act,* which legislated establishment of the MDB Authority as an independent statutory agency, and in 2012, the whole-of-basin MDB Plan came into effect (https://www.mdba.gov.au/water-management/basin-plan). The MDB Plan includes a range of measures and mechanisms ("sustainable diversion limits," local subcatchment water resource plans, and government water purchases from license holders) aimed at ensuring equity for water users across the basin and providing "environmental flows" to protect downstream ecosystems, including South Australia's Coorong and Lower Lakes area. The mounting water crisis in Langhorne Creek, exacerbated by years of drought, had thus been circumvented by a number of interconnected factors: the infrastructural fix of a major new pipeline, improvement in rainfall and river flows as the drought broke, and the instigation of a new hydrosocial order that tied Langhorne Creek much more intimately to the broader MDB. The subsequent dependability of the CPC's delivery of relatively high-quality water, including into areas that previously lacked access to adequate surface and groundwater, has meant that the Murray River water has become the most significant source of irrigation water for Langhorne Creek (Angas Bremer Water Management Committee 2022). Again, a techno-governmental fix to a hydrosocial crisis has sparked confidence among farmers and investors, and the region is experiencing a renewed expansion of irrigation-intensive horticulture and vegetable production facilitated by the pipeline scheme.

## DISCUSSION: POST-CRISIS RISK

Researchers and observers, as well as the farmers and irrigators we spoke to, pointed to cooperation and cohesion among stakeholders in Langhorne Creek as a key hydrosocial element facilitating the introduction of policy and infrastructure beneficial to long-term water sustainability (Harris 1993, Trezona 2005, Cuadrado-Quesada and Gupta 2019, Shalsi et al. 2019, Cuadrado-Quesada 2022, Shalsi et al. 2022, Skinner et al. 2023). Highlighting the genuine success of collective action, Shalsi et al. (2019, 2022) found that high degrees of community cooperation and participation correlated with exceptional water management outcomes. We, too, found that social cohesion shaped by well-respected community members aligned in response to specific risks helped to foster a view of water as a common good, rather than simply a resource for individualistic exploitation. Proactive, community-driven negotiations helped to integrate emplaced social knowledge and local perspectives into solutions. Participatory decision-making, involving input and ownership at a community level, was crucial to responding to crisis (Bardsley and Rogers 2010, Van der Linden et al. 2015, Eaton et al. 2021, Cuadrado-Quesada 2022). Langhorne Creek has, to date at least, provided a model of this response "done right." As we would argue, however, the reordering of hydrosocial relations stemming from the implementation of solutions like the CPC in the wake of crises has important future ramifications. These ramifications include potential exposure to a range of new risks emerging from the solution itself, requiring a reflexive and adaptive approach (Hurlbert and Mussetta 2016, Pearson and Bardsley 2022, Trimble et al. 2022).

As a result of the management directions taken in the wake of groundwater and drought crises, the Langhorne Creek region is now almost wholly reliant upon MDB flows for irrigation, largely through the CPC (Angas Bremer Water Management Committee 2022). This transition mitigates or bypasses several existing hydrosocial problems in the region, but in so, doing generates a range of other risks. There are inherent dangers associated with an overdependence on one source, and the region is now exposed to risks relating to flow rates affected by upstream extractions, climate fluctuations, and management policy across the broader MDB. There are also risks associated with a scalar shift in focus. This risk landscape is multivalent but includes those risks relating to the water itself (e.g., its supply and quality), structures of water governance (e.g., policies and frameworks that regulate extraction and usage locally and across the MDB), and community cohesion (e.g., cooperation and engagement of Langhorne Creek irrigators), all of which were highlighted at various times by our participants. We next discuss some key emergent hydrosocial risks and the way they relate to one another.

**Water and governance risks**

The interconnectedness of the MDB system means that actions taken by upstream water users can have significant downstream ramifications. At the very end of this vast riverine system, Langhorne Creek irrigators are reliant on whatever water is permitted to flow downstream and are thus directly affected by all upstream decisions and actions, as well as weather patterns affecting the entire basin. Processes of climate change, now recognized largely as a by-product of the technologies and socioeconomic arrangements of modernity (Beck 2016), must now be considered by local farmers in terms of their effect on the entire MDB, rather than only their local manifestations in the Angas Bremer basin. Implementation of the CPC occurred at a time when drought was giving way to a wetter climatic phase, bringing increased flows through the MDB and refilling the Lower Lakes. There has not yet been another significant drought period to test the resilience of Langhorne Creek's new water regime. New levels of recognition of climate change impacts and the ongoing inability to establish effective MDB governance systems is generating new concerns for farmers.

> *We're exposed ... especially people that haven't got a groundwater license. If the River Murray turns to a point where our water allocations are capped year after year after year, or if the salinity rises, we'll go back to using groundwater ... and we'll bugger [ruin] it again. That's the longer term impact of the River Murray failing, the longer term impact for this area is that the Angas Bremer aquifer will fail.* (Dennis)

Overarching policy and governance decisions around water extraction and trade, structured by the whole-of-basin MDB Plan, reverberate across the basin in different ways. The plan aims to provide equity of water access for irrigators, other water users, and environmental purposes through a range of mechanisms, but the machinations of water allocation and distribution for irrigators across all basin jurisdictions represents a notoriously treacherous political minefield (Alexandra and Rickards 2021). The result is a hydrosocial landscape of great complexity, which some irrigators have been better positioned to exploit than others (Hamilton and Kells 2021, Wheeler 2022). During the Millennium Drought, this complexity and impersonality compounded the distress caused by the physical effects of the drought itself. Participants noted that their own autonomy, and that of the local community, were increasingly constrained by the moral and political economies of agribusiness and regulatory governance. Langhorne Creek was spared some of the worst social impacts of the drought, partly as a result of the relative importance of the region and the political influence of its farmers and wine producers (*unpublished manuscript*). However, as new hydrosocial arrangements build distance between farmers and decision-making processes, the sense of agency and autonomy felt by individuals and communities over their own fate diminishes. This situation has flow-on effects on resilience in the face of future problems.

**Risks to community cohesion**

The response of the community to salinity and water security problems in the Angas-Bremer region has been framed as an example of collective action "overcoming the tragedy of the commons" (Shalsi et al. 2019, 2022). The collective action in the irrigation community's own push for enforced restrictions on their own ability to extract groundwater, for the sake of the ongoing long-term sustainability of the region, was integral to overcoming the immediate crisis of aquifer degradation. Subsequently, community support for the private-public CPC scheme drawing water from the main flow of the Murray River was also key to ensuring water access during the Millennium Drought. It would seem that the conditions of hydrosocial crisis foster an imperative for community unity: as Cuadrado-Quesada (2022:39) notes of water management in the Angas Bremer basin, "crisis often provides the impetus for people to come together to create possible solutions to address pressing concerns." However, community-driven engagement requires deliberate and conscientious effort to maintain, especially in the face of governance structures that are becoming (in our participants' views) more complex and centralized, and thus, further removed from the grassroots level.

An ongoing trend toward corporatization has been exacerbating a decreasing sense of community ownership over decision-making and governance in farming generally and viticulture especially. Langhorne Creek's vineyard boom from the 1990s onward was driven largely by an influx of corporate producers, who had identified the region, with its newfound MDB water licensing regime, as ripe for investment. Although large multiregional and multinational wine companies provide significant employment and other economic benefits, they have been less active than other farmers and irrigators in local affairs. As Tammy told us, "Corporates just don't have the same kind of [local] connectivity. If there's problems, corporates can move, they just write it off." Bodies like the Angas Bremer Water Management Committee have largely consisted of smaller scale farmers with long personal and family histories in the district. Now, a decrease in the agency of these farmers relative to the influence of larger corporate actors and increasing bureaucratization is contributing, in the views of some of our participants, to their detachment from decision-making processes. Participants reported that some community members, feeling a diminishment of agency over decisions, have disengaged from participatory processes altogether. In other words, a scalar shift in economic and governance focus away from Langhorne Creek and toward the interjurisdictional MDB is mirrored in a shift in social engagement as local farmers report much less sense of ownership over water management issues as non-local companies become increasingly influential.

A growing disconnection between community and governance processes in agricultural relations is not limited to Langhorne Creek or the MDB. Rather, it is built into the fabric of an agribusiness political economy itself, one of increased corporate consolidation and a regulatory apparatus that favors the hegemony of competitive productivism in the hydrosocial realm (Sojamo et al. 2012, Lawrence et al. 2013, Ioris 2017). Water plays a significant role within this neoliberal paradigm: as "modern water," it becomes quantified, measured, and licensed – a resource brought into the service of production (Linton 2014). Through this process, it is also commodified. Across the MDB, progressive unbundling of water entitlements from land titles has seen the rapid development of a water market, permitting license holders to trade allocations across vast geographical distances, which, in many cases, has favored the interests of larger entities with diversified holdings and a sophisticated ability to "play the system" (Kiem 2013, Wheeler et al. 2014, Seidl et al. 2020*a,b,* Hamilton and Kells 2021, Wheeler 2022). The effects of this shift on resilience to future crises is yet to be seen.

## CONCLUSION

The physical, social, and political relationships of Langhorne Creek with respect to water and irrigation, i.e., its hydrosocial characteristics, have altered significantly over the course of decades. Immediate, critical issues of groundwater degradation and drought were overcome through decisions and actions intended to reconfigure water management and use to secure a water supply from the broader MDB and to greatly reduce pressure on the local aquifer. However, much as these developments have been successful in overcoming specific periods of crisis, such solutions expose the region to other risks. Tying the region more intimately to the broader MDB system has meant the replacement of local risks with exogenous risks over which the community has less influence. The great hydrological and socioeconomic complexity of large systems such as the MDB means that there is great potential for any given decision to have unforeseen and geographically uneven consequences. For local water communities such as Langhorne Creek, risk has the potential to manifest in ways almost entirely exterior to their individual or communal influence.

The case study of Langhorne Creek provides insight into issues that affect communities everywhere struggling with water basin management and transformation in response to climate change, overextraction, and other pressures. Water security frequently involves a strategic recasting of relationships and governance arrangements around large and interjurisdictional bureaucracies, a process that potentially lessens the effectiveness of flexible community-level organization on water matters, diminishes local ownership, and threatens the very social resilience that empowers crisis-averting action to be taken in the first place. In the case of Langhorne Creek, as elsewhere, existing risks are not necessarily overcome by transformative change in response to crisis but are repositioned or replaced by the sorts of risks inherent to large, complex modern hydrosocial systems: big government and big business. In response, there is increasing urgency to build reflexivity into environmental, water, and natural resource management planning everywhere. This process involves recognizing the myriad, compounding, and dispersed risks tied up in the relations of complex physical, social, and political-economic processes, including the overarching threat of climate change. More than this, however, it includes an emphasis on polycentric governance that prioritizes the emplaced social knowledge situated within communities. Crisis can unify communities, but resilience to future challenges depends on maintaining this cohesion during the relaxation of a post-crisis period. A community that is less engaged in the first place is less able to coalesce in times of need.

Attention must be focused maintaining, over time, the sorts of active, emplaced relational community networks that will enable effective and ongoing influence over regional affairs. Periods of crisis may engender cohesion and cooperation as people rally together to find solutions, but "success" during these moments relates, we believe, to deeper relationships of emplaced commitment, trust, and care. It is this fabric that has enabled Langhorne Creek's ability to respond to pressing, unifying crises. Solutions to the drought and groundwater crises have involved a degree of divestment of community ownership and agency over local matters. An unintended consequence of this situation may be ossification of community flexibility and leadership in future decision-making, and decreased ability for key individuals and community groups to exert effective political agency. If, or rather, when the region faces another water resource crisis, the resilience of these hydrosocial structures will again be tested. For Langhorne Creek and other regions, then, we must recognize the crucial and sometimes underacknowledged role of community well-being in adapting to complex challenges. Formal and informal networks and relationships of community activism and decision-making should be supported beyond the pressing moments of urgency during ecological crisis, especially when broader forces of political economy and structures of governance have rendered such relationships less powerful than they once were.

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[1]We use these names contextually: "Langhorne Creek" in relation to the district generally, and "Angas Bremer" when discussing the aquifer and basin catchment.

[2]In Australia, for example, the extended drought in the first decade of the 21st century provided a catalyst to implement the Murray-Darling Basin Plan in 2012, a national agreement providing for shared responsibility and management of this system in its entirety (https://www.mdba.gov.au/water-management/basin-plan).

[3]Water is a key element of contemporary wine grape growing in Langhorne Creek. As well as the obvious significance of access to water for irrigation, low rainfall and low humidity lessen pressure from pests and grape vine diseases such as mildews. Proximity to the lake and the ocean beyond is also important for their moderating climatic influence, lessening frost risk in spring and extreme heat events in summer. Provided that one can get enough water to the vineyard, participants asserted, it is an ideal place to grow grapes.

[4]This designation was developed following the 1994 Australia-European Community Agreement on Trade in Wine. The Langhorne Creek Geographical Indication came into effect in October 1998 (https://www.wineaustralia.com/labelling/register-of-protected-gis-and-other-terms/geographical-indications/langhorne-creek).

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**Data Availability:**

*The data and code that support the findings of this study are available on request from the corresponding author, W. S. None of the data are publicly available because they contain information that could compromise the privacy of research participants. Ethical approval for this research study was granted by the University of Adelaide's Human Research Ethics Committee, approval H-2021-009.*

## LITERATURE CITED

Abel, N., R. M. Wise, M. J. Colloff, B. H. Walker, J. R. A. Butler, P. Ryan, C. Norman, A. Langston, J. M. Anderies, R. Gorddard, M. Dunlop, and D. O'Connell. 2016. Building resilient pathways to transformation when "no one is in charge": insights from Australia's Murray-Darling basin. Ecology and Society 21(2):23. https://doi.org/10.5751/ES-08422-210223

Alexandra, J., and L. Rickards. 2021. The contested politics of drought, water security and climate adaptation in Australia's Murray-Darling basin. Water Alternatives 14(3):773-794. https://www.water-alternatives.org/index.php/alldoc/articles/vol14/v14issue3/644-a14-3-7

Anderson, K., and N. R. Aryal. 2015. Growth and cycles in Australia's wine industry: a statistical compendium, 1843 to 2013. University of Adelaide Press, Adelaide, Australia. https://doi.org/10.20851/austwine

Angas Bremer Water Management Committee. 2022. Angas Bremer irrigation management zone 2021–2022 annual report. Angas Bremer Water Management Committee, Strathalbyn, Australia. http://www.angasbremerwater.org.au/documents/Irrigation%20Annual%20Report_Angas%20Bremer%202021-2022.pdf

Angas Bremer Water Management Committee and T. Sim. 2004. Angas Bremer regional history. Angas Bremer Water Management Committee, Strathalbyn, Australia. http://www.angasbremerwater.org.au/documents/Bremer_history.pdf

Bardsley, D. K., and A. Knierim. 2020. Hegel, Beck and the reconceptualization of ecological risk: the example of Australian agriculture. Journal of Rural Studies 80:503-512. https://doi.org/10.1016/j.jrurstud.2020.10.034

Bardsley, D. K., E. Palazzo, and M. Pütz. 2018. Regional path dependence and climate change adaptation: a case study from the McLaren Vale, South Australia. Journal of Rural Studies 63:24-33. https://doi.org/10.1016/j.jrurstud.2018.08.015

Bardsley, D. K., and G. P. Rogers. 2010. Prioritizing engagement for sustainable adaptation to climate change: an example from natural resource management in South Australia. Society and Natural Resources 24(1):1-17. https://doi.org/10.1080/08941920802287163

Beck, U. 1992. Risk society: towards a new modernity. Sage Publications, Thousand Oaks, California, USA.

Beck, U. 2016. The metamorphosis of the world: how climate change is transforming our concept of the world. Polity Press, Cambridge, UK.

Beck, U., W. Bonss, and C. Lau. 2003. The theory of reflexive modernization: problematic, hypotheses and research programme. Theory, Culture and Society 20(2):1-33. https://doi.org/10.1177/0263276403020002001

Beck, U., and C. Lau. 2005. Second modernity as a research agenda: theoretical and empirical explorations in the 'meta-change' of modern society. British Journal of Sociology 56 (4):525-557. https://doi.org/10.1111/j.1468-4446.2005.00082.x

Bjørnlund, H. 1995. Water policies and their influence on land uses and land values. the Angas-Bremer proclaimed region: a case study. Property Management 13(2):14-20. https://doi.org/10.1108/02637479510083771

Boelens, R., J. Hoogesteger, E. Swyngedouw, J. Vos, and P. Wester. 2016. Hydrosocial territories: a political ecology perspective. Water International 41(1):1-14. https://doi.org/10.1080/02508060.2016.1134898

Boin, A., P. 't. Hart, and S. Kuipers. 2018. The crisis approach. Pages 23-38 *in* H. Rodríguez, W. Donner, and J. E. Trainor, editors. Handbook of disaster research. Second edition. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-319-63254-4_2

Bozzola, M., and T. Swanson. 2014. Policy implications of climate variability on agriculture: water management in the Po River basin, Italy. Environmental Science and Policy 43:26-38. https://doi.org/10.1016/j.envsci.2013.12.002

Bryant, L., and B. Garnham. 2013. Beyond discourses of drought: the micro-politics of the wine industry and farmer distress. Journal of Rural Studies 32:1-9. https://doi.org/10.1016/j.jrurstud.2013.03.002

Bryant, L., and B. Garnham. 2014. Economies, ethics and emotions: farmer distress within the moral economy of agribusiness. Journal of Rural Studies 34:304-312. https://doi.org/10.1016/j.jrurstud.2014.03.006

Cai, W., A. Purich, T. Cowan, P. van Rensch, and E. Weller. 2014. Did climate change-induced rainfall trends contribute to the Australian Millennium Drought? Journal of Climate 27 (9):3145-3168. https://doi.org/10.1175/JCLI-D-13-00322.1

Connor, J., K. Schwabe, D. King, D. Kaczan, and M. Kirby. 2009. Impacts of climate change on lower Murray irrigation. Australian Journal of Agricultural and Resource Economics 53(3):437-456. https://doi.org/10.1111/j.1467-8489.2009.00460.x

Cuadrado-Quesada, G. 2022. Governing groundwater: between law and practice. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-030-92778-3_3

Cuadrado-Quesada, G., and J. Gupta. 2019. Participation in groundwater governance - outlining a path to inclusive development. Water Policy 21(5):1050-1064. https://doi.org/10.2166/wp.2019.209

Drew, G., W. Skinner, and D. K. Bardsley. 2022. The 'drive and talk' as ethnographic method. Anthropology Today 38(3):5-8. https://doi.org/10.1111/1467-8322.12725

Dunham, J. B., P. L. Angermeier, S. D. Crausbay, A. E. Cravens, H. Gosnell, J. McEvoy, M. A. Moritz, N. Raheem, and T. Sanford. 2018. Rivers are social-ecological systems: time to integrate human dimensions into riverscape ecology and management. Wiley Interdisciplinary Reviews: Water 5(4):e1291. https://doi.org/10.1002/wat2.1291

Eaton, W. M., K. J. Brasier, M. E. Burbach, W. Whitmer, E. W. Engle, M. Burnham, B. Quimby, A. Kumar Chaudhary, H. Whitley, J. Delozier, L. B. Fowler, A. Wutich, J. C. Bausch, M. Beresford, C. C. Hinrichs, C. Burkhart-Kriesel, H. E. Preisendanz, C. Williams, J. Watson, and J. Weigle. 2021. A conceptual framework for social, behavioral, and environmental change through stakeholder engagement in water resource management. Society and Natural Resources 34(8):1111-1132. https://doi.org/10.1080/08941920.2021.1936717

Enqvist, J. P., and G. Ziervogel. 2019. Water governance and justice in Cape Town: an overview. Wiley Interdisciplinary Reviews: Water 6(4):e1354. https://doi.org/10.1002/wat2.1354

Fragaszy, S. R., R. McDonnell, and A. Closas. 2021. Creating a hydrosocial territory: water and agriculture in the Liwa Oasis. Journal of Political Ecology 28(1):286-308. https://doi.org/10.2458/jpe.2369

Giddens, A. 1999. Risk and responsibility. Modern Law Review 62(1):1-10. https://doi.org/10.1111/1468-2230.00188

Goldman, M., and D. Narayan. 2019. Water crisis through the analytic of urban transformation: an analysis of Bangalore's hydrosocial regimes. Water International 44(2):95-114. https://doi.org/10.1080/02508060.2019.1578078

Götz, J. M., and C. Middleton. 2020. Ontological politics of hydrosocial territories in the Salween River basin, Myanmar/Burma. Political Geography 78:102115. https://doi.org/10.1016/j.polgeo.2019.102115

Haeffner, M., and D. Hellman. 2020. The social geometry of collaborative flood risk management: a hydrosocial case study of Tillamook County, Oregon. Natural Hazards 103:3303-3325. https://doi.org/10.1007/s11069-020-04131-4

Hamilton, S., and S. Kells. 2021. Sold down the river: how robber barons and wall street traders cornered Australia's water market. Text Publishing, Melbourne, Australia.

Harris, B. 1993. Recovering degraded groundwater in the Angas-Bremer basin through community action. AGSO Journal of Australian Geology & Geophysics 14(2-3):167-176. https://d28rz98at9flks.cloudfront.net/81346/Jou1993_v14_n2-3_p167.pdf

Hemming, S., D. Rigney, S. L. Muller, G. Rigney, and I. Campbell. 2017. A new direction for water management? Indigenous nation building as a strategy for river health. Ecology and Society 22 (2):13. https://doi.org/10.5751/ES-08982-220213

Hindmarsh, R. 2012. "Liberating" social knowledges for water management, and more broadly environmental management, through "place-change planning." Local Environment 17 (10):1121-1136. https://doi.org/10.1080/13549839.2012.729564

Hurlbert, M., and P. Mussetta. 2016. Creating resilient water governance for irrigated producers in Mendoza, Argentina. Environmental Science and Policy 58:83-94. https://doi.org/10.1016/j.envsci.2016.01.004

Ioris, A. A. R. 2017. Agribusiness and the neoliberal food system in Brazil: frontiers and fissures of agro-neoliberalism. Routledge, Milton, UK.

Jackson, S., and L. Head. 2020. Australia's mass fish kills as a crisis of modern water: understanding hydrosocial change in the Murray-Darling basin. Geoforum 109:44-56. https://doi.org/10.1016/j.geoforum.2019.12.020

Johnson, H., and J. Robinson. 2013. The world atlas of wine. Seventh edition. Mitchell Beazley, London, UK.

Kaplan, S., and B. J. Garrick. 1981. On the quantitative definition of risk. Risk Analysis 1(1):11-27. https://doi.org/10.1111/j.1539-6924.1981.tb01350.x

Kates, R. W., W. R. Travis, and T. J. Wilbanks. 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. Proceedings of the National Academy of Sciences 109(19):7156-7161. https://doi.org/10.1073/pnas.1115521109

Kiem, A. S. 2013. Drought and water policy in Australia: challenges for the future illustrated by the issues associated with water trading and climate change adaptation in the Murray-Darling basin. Global Environmental Change 23(6):1615-1626. https://doi.org/10.1016/j.gloenvcha.2013.09.006

Kinzig, A. P., P. Ryan, M. Etienne, H. Allison, T. Elmqvist, and B. H. Walker. 2006. Resilience and regime shifts: assessing cascading effects. Ecology and Society 11(1):20. https://doi.org/10.5751/ES-01678-110120

Kirby, M., R. Bark, J. Connor, M. E. Qureshi, and S. Keyworth. 2014. Sustainable irrigation: How did irrigated agriculture in Australia's Murray-Darling basin adapt in the Millennium Drought? Agricultural Water Management 145:154-162. https://doi.org/10.1016/j.agwat.2014.02.013

Kumar, S., P. Leith, C. Garcia, and R. Adhikari. 2022. Expectations of water futures and hydrosocial change linked to irrigation development in Tasmania, Australia. Geoforum 129:107-117. https://doi.org/10.1016/j.geoforum.2022.01.009

Lankford, B., and N. Hepworth. 2010. The cathedral and the bazaar: monocentric and polycentric river basin management. Water Alternatives 3(1):82-101. https://www.water-alternatives.org/index.php/alldoc/articles/vol3/v3issue1/71-a3-1-5

Lawrence, G., C. Richards, and K. Lyons. 2013. Food security in Australia in an era of neoliberalism, productivism and climate change. Journal of Rural Studies 29:30-39. https://doi.org/10.1016/j.jrurstud.2011.12.005

Linton, J. 2014. Modern water and its discontents: a history of hydrosocial renewal. Wiley Interdisciplinary Reviews: Water 1 (1):111-120. https://doi.org/10.1002/wat2.1009

Linton, J., and J. Budds. 2014. The hydrosocial cycle: defining and mobilizing a relational-dialectical approach to water. Geoforum 57:170-180. https://doi.org/10.1016/j.geoforum.2013.10.008

Mark, B. G., A. French, M. Baraer, M. Carey, J. Bury, K. R. Young, M. H. Polk, O. Wigmore, P. Lagos, R. Crumley, J. M. McKenzie, and L. Lautz. 2017. Glacier loss and hydro-social risks in the Peruvian Andes. Global and Planetary Change 159:61-76. https://doi.org/10.1016/j.gloplacha.2017.10.003

McCulligh, C., L. Arellano-García and D. Casas-Beltrán. 2020. Unsafe waters: the hydrosocial cycle of drinking water in Western Mexico. Local Environment 25(8):576-596. https://doi.org/10.1080/13549839.2020.1805598

Mercer, D., L. Christesen, and M. Buxton. 2007. Squandering the future—climate change, policy failure and the water crisis in Australia. Futures 39(2-3):272-287. https://doi.org/10.1016/j.futures.2006.01.009

Ostrom, E. 1990. Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9780511807763

Ostrom, E., P. C. Stern, and T. Dietz. 2003. Water rights in the commons. Water Resources Impact 5(2):9-12. https://www.jstor.org/stable/wateresoimpa.5.2.0009

Pahl-Wostl, C., C. Vörösmarty, A. Bhaduri, J. Bogardi, J. Rockström, and J. Alcamo. 2013. Towards a sustainable water future: shaping the next decade of global water research. Current Opinion in Environmental Sustainability 5(6):708-714. https://doi.org/10.1016/j.cosust.2013.10.012

Pearson, R., and D. K. Bardsley. 2022. Applying complex adaptive systems and risk society theory to understand energy transitions. Environmental Innovation and Societal Transitions 42:74-87. https://doi.org/10.1016/j.eist.2021.11.006

Ray, P., S. Wi, A. Schwarz, M. Correa, M. He, and C. Brown. 2020. Vulnerability and risk: climate change and water supply from California's Central Valley water system. Climatic Change 161:177-199. https://doi.org/10.1007/s10584-020-02655-z

Ross, A., and H. Chang. 2020. Socio-hydrology with hydrosocial theory: two sides of the same coin? Hydrological Sciences Journal 65(9):1443-1457. https://doi.org/10.1080/02626667.2020.1761023

Seidl, C., S. A. Wheeler, and A. Zuo. 2020*a*. High turbidity: water valuation and accounting in the Murray-Darling basin. Agricultural Water Management 230:105929. https://doi.org/10.1016/j.agwat.2019.105929

Seidl, C., S. A. Wheeler, and A. Zuo. 2020*b*. Treating water markets like stock markets: key water market reform lessons in the Murray-Darling basin. Journal of Hydrology 581:124399. https://doi.org/10.1016/j.jhydrol.2019.124399

Seidl, C., S. A. Wheeler, and A. Zuo. 2021. The drivers associated with Murray-Darling basin irrigators' future farm adaptation strategies. Journal of Rural Studies 83:187-200. https://doi.org/10.1016/j.jrurstud.2020.10.048

Sendziuk, P., and R. Foster. 2018. A history of South Australia. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/9781139196352

Shalsi, S., C. M. Ordens, A. Curtis, and C. T. Simmons. 2019. Can collective action address the "tragedy of the commons" in groundwater management? Insights from an Australian case study. Hydrogeology Journal 27:2471-2483. https://doi.org/10.1007/s10040-019-01986-1

Shalsi, S., C. M. Ordens, A. Curtis, and C. T. Simmons. 2022. Coming together: insights from an Australian example of collective action to co-manage groundwater. Journal of Hydrology 608:127658. https://doi.org/10.1016/j.jhydrol.2022.127658

Shaluf, I. M., F. Ahmadun, and A. Mat Said. 2003. A review of disaster and crisis. Disaster Prevention and Management 12 (1):24-32. https://doi.org/10.1108/09653560310463829

Sim, T., and K. Muller. 2004. A fresh history of the lakes: Wellington to the Murray mouth, 1800s to 1935. River Murray Catchment Water Management Board, Strathalbyn, Australia.

Skinner, W., G. Drew, and D. K. Bardsley. 2023. "Half a flood's no good": flooding, viticulture, and hydrosocial terroir in a South Australian wine region. Agriculture and Human Values 40:549-564. https://doi.org/10.1007/s10460-022-10355-w

Smith, W. B., and M. Ragless. 1986. Bleasdale 1850–1986: incorporating the Bleasdale family history and a continuation of the Bleasdale story from 1950. Bleasdale Vineyards, Langhorne Creek, Australia.

Sojamo, S., M. Keulertz, J. Warner, and J. A. Allan. 2012. Virtual water hegemony: the role of agribusiness in global water governance. Water International 37(2):169-182. https://doi.org/10.1080/02508060.2012.662734

Stone, D., D. Palmer, B. Hamilton, C. Cooney, and L. Mosely. 2016. Coorong, Lower Lakes, and Murray Mouth water quality monitoring program 2009–2016: summary report. South Australian Environment Protection Authority, Adelaide, Australia. https://www.epa.sa.gov.au/files/12070_cllmm_final_2016.pdf

Taing, L., C. Chang, S. Pan, and N. P. Armitage. 2019. Towards a water secure future: reflections on Cape Town's Day Zero crisis. Urban Water Journal 16(7):530-536. https://doi.org/10.1080/1573062X.2019.1669190

Tierney, K. 2014. The social roots of risk: producing disasters, promoting resilience. Stanford University Press, Stanford, California, USA. https://doi.org/10.1515/9780804791403

Trezona, R. 2005. A regional approach to environmental stewardship through EMS, in Langhorne Creek. Australian and New Zealand Grapegrower and Winemaker 495:56.

Trimble, M., T. Olivier, L. A. P. Anjos, N. Dias Tadeu, G. Giordano, L. Mac Donnell, R. Laura, F. Salvadores, I. M. Santana-Chaves, P. H. C. Torres, M. Pascual, P. R. Jacobi, N. Mazzeo, C. Zurbriggen, L. Garrido, E. Jobbágy, and C. Pahl-Wostl. 2022. How do basin committees deal with water crises? Reflections for adaptive water governance from South America. Ecology and Society 27(2):42. https://doi.org/10.5751/ES-13356-270242

United Nations Office for Disaster Risk Reduction. 2009. 2009 UNISDR terminology on disaster risk reduction. United Nations Office for Disaster Risk Reduction, Geneva, Switzerland. https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

Van der Linden, S., E. Maibach, and A. Leiserowitz. 2015. Improving public engagement with climate change: Five "best practice" insights from psychological science. Perspectives on Psychological Science 10(6):758-763. https://doi.org/10.1177/1745691615598516

Verrier, P. D. 1977. "The town that welcomes floods": a brief history of Langhorne Creek and its school. P. D. Verrier, Langhorne Creek, Australia.

Waterhouse, J. D., J. A. Sinclair, and N. Z. Gerges. 1978. The hydrogeology of the Angas-Bremer irrigation area. Department of Mines and Energy, Adelaide, Australia.

Wesselink, A., M. Kooy, and J. Warner. 2017. Socio-hydrology and hydrosocial analysis: toward dialogues across disciplines. Wiley Interdisciplinary Reviews: Water 4(2):e1196. https://doi.org/10.1002/wat2.1196

Wheeler, S. A. 2022. Debunking Murray-Darling basin water trade myths. Australian Journal of Agricultural and Resource Economics 66(4):797-821. https://doi.org/10.1111/1467-8489.12490

Wheeler, S. A., A. Loch, A. Zuo, and H. Bjornlund. 2014. Reviewing the adoption and impact of water markets in the Murray-Darling basin, Australia. Journal of Hydrology 518(A):28-41. https://doi.org/10.1016/j.jhydrol.2013.09.019

Wheeler, S. A., A. Zuo, and A. Loch. 2018. Water torture: unravelling the psychological distress of irrigators in Australia. Journal of Rural Studies 62:183-194. https://doi.org/10.1016/j.jrurstud.2018.08.006

Williams, M. 1992. The changing rural landscape of South Australia. Second edition. State Publishing, Cowandilla, Australia.