frontiers in Water

ORIGINAL RESEARCH
published: 11 October 2021
doi: 10.3389/frwa.2021.735018

Who Governs at What Price? Technocratic Dominance, Ways of Knowing, and Long-Term Resilience of Brazil's Water System

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Technocratic decision making has been long criticized for dampening participation and limiting the range of adaptive choices through its overreliance on infrastructure-based solutions. There has been growing attention to how technocratic approaches shape long-term resilience of water systems, especially under the threat of climatic change impacts. In Brazil, even under its highly decentralized and participatory water management system, technical expertise and science-based decisions have been often promoted as a desirable mechanism to insulate governance outcomes from the country's prevailing clientelistic and rent-seeking politics. Yet, Brazilian river basins continue to struggle with long-standing problems (such as universal access to sanitation) and increasing challenges for guaranteeing water provision under recurrent drought. In this study, we examine how technocratic insulation, different ways of knowing (WoKs), and participatory governance shape long-term resilience in one of Brazil's most important river basins, the Piracicaba-Capivari-Jundiaí (PCJ). By taking an in-depth look at how the PCJ River Basin's governance system responded to the 2014 Brazilian water crisis, we seek to understand how planning decisions in the aftermath of the crisis were influenced by different actors, and how the outcomes of those decisions are likely to shape long term resilience. Based on 27 in-depth interviews with members of the PCJ River Basin Committees, we show how a distinct preference for infrastructure-based solutions to deal with on-going and upcoming challenges may be unsustainable under climate change as the basin's traditional technocratic approach failed both to insulate its decisions from politics and to explore adaptive water management solutions that might be key to shape long-term resilience.

Keywords: water governance, infrastructure, ways of knowing, path-dependence, climate vulnerability, drought, technocracy, water policy

OPEN ACCESS

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Water and Human Systems, a section of the journal Frontiers in Water

Received: *01 July 2021*
Accepted: *10 September 2021*
Published: *11 October 2021*

Citation:
Almazán-Casali S, Puga BP and Lemos MC (2021) Who Governs at What Price? Technocratic Dominance, Ways of Knowing, and Long-Term Resilience of Brazil's Water System. Front. Water 3:735018. doi: 10.3389/frwa.2021.735018

INTRODUCTION

While Brazil has plenty of freshwater, more than 70% of the country's runoff is concentrated in the Northern region, home to a small part of the population [Agência Nacional de Águas (ANA), 2018]. In contrast, the southeast, where 40% of the population lives, is endowed with only 7% of total runoff (Getirana, 2016). As a result, megacities such as São Paulo invest large amounts of resources

in the procurement and management of water but are often under water stress (Kelman, 2015). Historically, metropolises worldwide have followed the "hydraulic paradigm" in which access to water and sanitation mostly relies on built infrastructure to store, treat and move water to where it serves both the population and industry (Molle et al., 2009; Bakker, 2014). In São Paulo, the crown jewel of this system is the Cantareira System, a set of four reservoirs and tunnels responsible for providing water to more than 10 million people in the São Paulo Metropolitan Region (SPMR) (Leão and De Stefano, 2019). This model has ensured a relatively good level of water security for the metropolitan region, relying on water transfers from other basins especially the Piracicaba-Capivari-Jundiaí River Basin (PCJ) and more recently from the Paraíba do Sul River Basin (PDS) (Lemos et al., 2020). However, the existing infrastructure and management practices are no guarantee for satisfying the metropolis' increasing demand for water, nor is the process of water allocation accomplished without conflict. Tensions between the SPMR and the PCJ came to a head during the 2014–2015 water crisis when the region experienced the worst drought on record. Conflict arose over water storage in Cantareira reservoirs when several downstream cities ran out of water. Cities dependent on water released from the Cantareira system suffered significantly more than those relying on water from smaller tributaries or their own water storage infrastructure. Moreover, the participatory river basin committees in the PCJ were powerless to stop the São Paulo State government from invoking emergency measures that re-centralized decision-making and rationed water at high social costs in a process widely recognized as lacking transparency, participation, and legitimacy (Empinotti et al., 2019; Quintslr et al., 2021). These extraordinary measures were a painful reversal of a decades-long process of decentralization started in the 1990s with the Brazilian water reform.

Extreme events pose significant challenges to any governance system, exposing its gaps and flaws. The 2014–2015 water crisis is a salient example of the hydraulic paradigm's limitations for dealing with increased uncertainty about the timeliness and magnitude of precipitation in the region (Gleick, 2003; Getirana, 2016). The overlap of low rainfall with high temperatures led to a rapid depletion of water in the Cantareira System and threatened to collapse the system. The crisis also exposed the limitations of existing operational rules and management practices controlling water flows across the PCJ basin. Because extreme events may sometimes create a window of opportunity for institutional innovation to change an established political pathway (Kingdon, 1995; Meijerink, 2005; Biggs et al., 2008), a possible consequence of the 2014–2015 extreme drought could have been a significant change in the water management approach in the region. These changes could have included, for example, favoring alternatives related to ecosystem services, nature-based solutions, water-demand management, and cultural measures, all options already existing in small scale across the system. Rather, the water crisis led to renewed efforts to expand the dominant hydraulic model instead of embracing innovations or pursuing options akin to an adaptive governance approach.

One explanation for this outcome is that water policy is characterized by periods of continuity rather than dramatic changes (Ingram and Fraser, 2006). Once a particular policy begins to follow a specific route, the political cost of reversing it becomes too high, generating a hard path-dependence almost impossible to overcome (Marshall and Alexandra, 2016). Indeed, some choices along the path reduce the range of future choices, making alternative paths less likely over time and possibly creating lock-ins (Crow-Miller et al., 2017). Large, high-cost, infrastructure projects such as dams, tunnels, canals, and water transfer systems are good examples of decisions that anchor water management paths for decades at a time. Another related explanation is that different ways of knowing (WoKs) can critically affect water policy decisions by limiting the pool of policy alternatives deemed appropriate and desirable, creating a different kind but not less intractable path-dependence as decision-makers continuously choose alternatives from a restricted set of options. WoKs can be defined as a dynamic process in which actors interpret the different components and relationships within a policy realm and make sense of them (Schneider and Ingram, 2007). A WoK influences how a decision-maker perceives an issue, determines whether the issue is a priority, and what are possible solutions to address it. For example, under a certain WoK, a decision-maker may deem water scarcity as a priority issue that is best addressed by investing in large infrastructure projects, rather than reducing water demand. Different WoKs can foster or constrain policy changes by influencing the perceived level of ambiguity surrounding the issues considered as important and the range of solutions contemplated to address them (Brugnach and Ingram, 2012). It is therefore important to understand the WoKs held by those who make water policy decisions and how those WoKs influence responses to extreme events.

This paper examines how different WoKs held by Brazilian water managers, combined with the historical hierarchies of different types of technical expertise, contribute to perpetuating a technocratic governance model to address water challenges.

First, we provide our theoretical framework highlighting how WoKs interconnect and shape governance outcomes. Next, we present the example of the PCJ basin in the aftermath of the 2014–2015 water crisis, and how different WoKs in the basin have shaped decision-making and outcomes. Lastly, we discuss the challenges faced by this prevailing model and offer some reflections about what can be done.

AN OVERVIEW OF BRAZILIAN WATER GOVERNANCE

Like most Latin American countries, in the 1990s Brazil transitioned from a state-centered to a more decentralized water governance approach (Formiga-Johnsson and Kemper, 2005). The Brazilian Water Law (1997) enacted a governance system based on Integrated Water Resources Management (IWRM) principles aimed at balancing water resources protection with achieving ecological, social, and economic needs through the integrated management of water and land use (Engle, 2011).

The new law designed a system encompassing the multi-level characteristics of water management, introducing new tools, organizations such as river basin organizations (RBOs) and water agencies. It also introduced new integrated scales of governance at the sub-regional and intra-state levels to tackle the challenges of water availability and use in Brazil. The new participatory and decentralized governance system succeeded at introducing a new diversity of technical experts with different WoKs to the water governance space.

Historically, in Brazil, water governance has relied mostly on the expertise of engineers (Marques, 2000; Barraqué et al., 2008). Brazilian engineers are the biggest supporters of large infrastructure and public works as the primary strategy for dealing with longstanding and emerging water governance issues (Roman, 2017). Preference for infrastructure-centered solutions constitutes the core of an engineering WoK that has dominated Brazilian water governance for decades. The great level of influence enjoyed by engineers, locally and generally known in Brazil as *técnicos,* can be partially attributed to the technocratic insulation process created by major political and administrative reforms starting in the 1950s but reaching their apex in the 1970s and 1980s (Nunes and Geddes, 1987; Buckley, 2017). Through these processes, the Brazilian government presumably sought to insulate decision-making from the irrationality and rent-seeking of party politics (Nunes and Geddes, 1987; Lemos et al., 2020) in favor of a new model based on scientific evidence and expertise.

While the outcomes of technocratic insulation can at times be positive (Nunes and Geddes, 1987; Lemos and De Oliveira, 2004), in Brazil's natural resource governance it fundamentally depended on the values and frames espoused by these technocrats and the diverse networks of which they were part (Lemos, 1998). The creation of the modern Brazilian state combined elements of authority, hierarchy, control, and patrimonialism shaped by the belief the government should promote the isolation of its political decisions in favor of greater rationality (Nunes and Geddes, 1987). This belief was widespread during the military dictatorship and incorporated the modernist ideas of planning and policymaking (Lemos, 1998). Technocratic bureaucracies emerged from this process, which, by invoking the "neutrality" of technical knowledge, shaped distinct sectoral policies (Marques, 2000; Abers and Keck, 2013).

However, critics of technocratic governance highlight its political and operational implications. For example, Radaelli (1999) argues that the denial or repulsion of politics does not necessarily mean more efficient decisions. The politicization of issues may generate more conflicts, but "frees policies from the trap of technocracy and makes room for a more benign utilization of expertise" (Radaelli, 1999, p. 770). Scholars also highlight the fundamental incompatibilities between technocratic approaches and facing the complexity of natural resource governance (Pahl-Wostl et al., 2010). In Brazil's water governance, dislike of political interference at times negatively interacted with popular participation and transparent decision-making in RBOs, often characterizing decisions from government and technical agencies as superior to all others (Abers and Keck, 2013; Lemos et al., 2020). Favoring technocratic decisions, however, failed at producing evidence-based policies, and rather gave rise to politics-based evidence. Using politics-based evidence, policy opponents often tried to influence policy outcomes by disguising their political preferences as technical issues. As a result, "political struggles over different substantive outcomes are waged as if they were conflicts over technical issues" (Abers and Keck, 2013, p. 43).

In the case of Brazilian water governance, technical experts akin to an engineering WoK found natural allies in politicians who favored visible and politically profitable infrastructure solutions. The strength of this alliance, however, depends on the issue at hand, where temporary alliances may arise or dissolve with changing political circumstances (Lemos, 1998). As mentioned before, the outcomes of technocratic insulation in great part depend on the values and networks created to push for different solutions (Blyth, 2002; Lemos and De Oliveira, 2004). In this context, technocratic insulation can yield both positive and negative outcomes relative to water governance. During the 2014 crisis, for example, although *técnicos* prevailed in many of the decisions on what to do, they failed to insulate the process from political intervention as the crisis progressed. Rather, during the crisis, politics challenged both the participatory and the technocratic systems, at times opening the opportunity for contestation even if in the end technical approaches prevailed.

WAYS OF KNOWING, ADAPTIVE MANAGEMENT, AND SOLVING CRISES

Actors in a governance setting have different values, beliefs, perceptions, backgrounds and use different heuristics and rationale to assess issues at hand (Ingram and Fraser, 2006). Understanding how water problems and solutions are framed, assessed, and proposed by water managers is crucial to assess governance outcomes (Feldman et al., 2006; Ingram and Fraser, 2006; Brugnach, 2017). Actors can portray an issue in a certain way to advocate a given course of action, thereby limiting options to be considered. Through politics, actors can use their framing power to select which aspects of the problem to focus on and which should be set aside (Morrison et al., 2017; Quintslr et al., 2021). Thus, how each problem is defined, framed, and represented, is inherently linked to the different WoKs of actors involved in decision-making and can significantly affect policy outcomes. Usually, different WoKs are associated with an implicit set of values and priorities that inform the different narratives actors use to explain the phenomena they experience. People can have multiple WoKs as social interactions reinforce or challenge certain elements of a particular WoK (Gerlak and Mukhtarov, 2015). As issues emerge and are interpreted, some WoKs might gain more traction than others, creating a shared dominating understanding or marginalizing others (Lejano and Ingram, 2009). Not surprisingly, different WoKs might lead to different proposed solutions to a given problem or challenge. However, the pool of solutions considered might not be drastically different had another WoK become dominant, but the way in which alternatives are weighted will vary. Those discrepancies can result in markedly different policy preferences when, for example, choosing between solutions such as a bold reforestation program or expanding water transfer systems. Other factors that play a determinant role in advancing a WoK include power

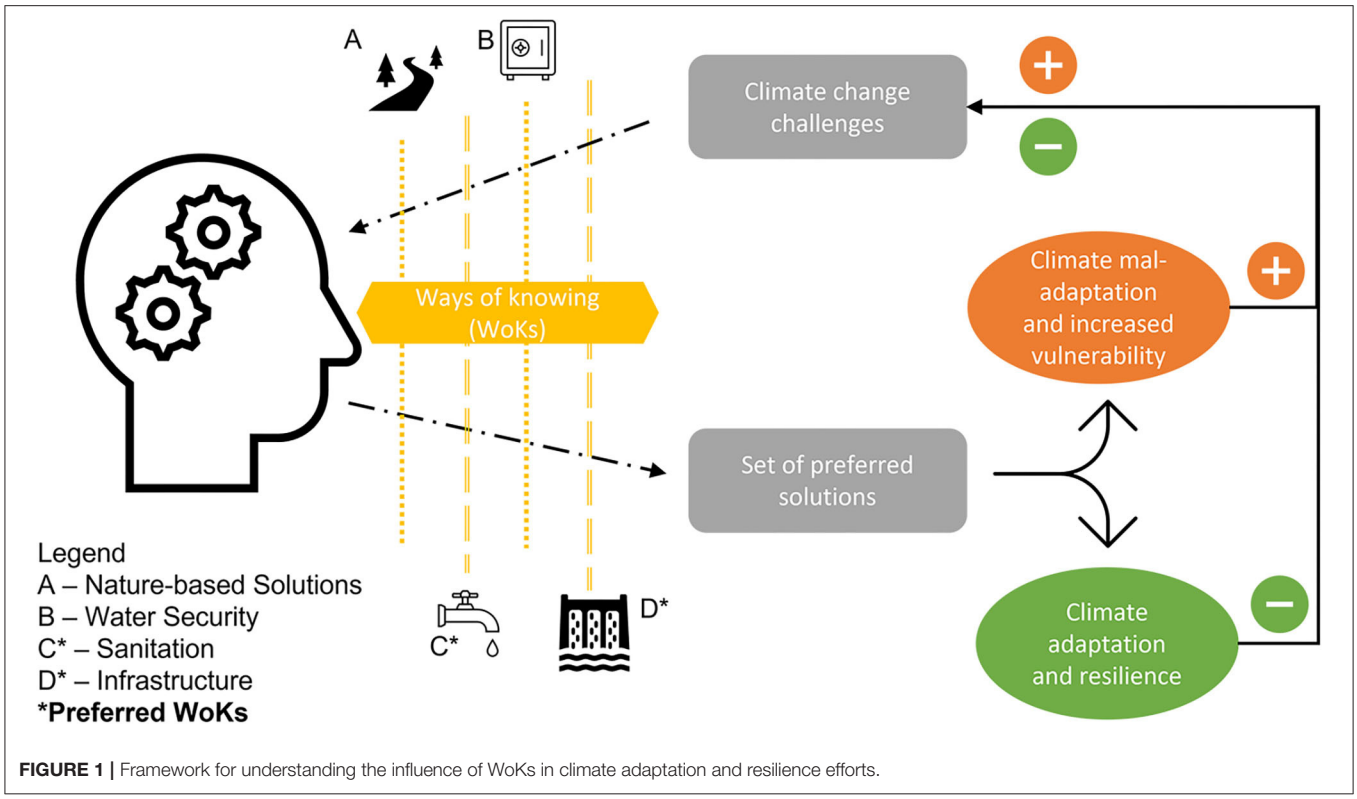

FIGURE 1 | Framework for understanding the influence of WoKs in climate adaptation and resilience efforts.

asymmetries and the epistemic legitimacy of actors, both of which are receiving growing attention in environmental governance literature (Meijerink, 2005; Brisbois and de Loë, 2016; Morrison et al., 2019).

Assessing the different discourses through the WoKs lense is useful to understand the different values and concepts shaping policy outcomes (Gerlak and Mukhtarov, 2015). **Figure 1** presents an actor-centric framework of how WoKs inform efforts to tackle climate change issues. An actor's WoK serves as a filter through which climate issues are perceived and interpreted, identifying the most and least pressing issues. Although an actor may hold different WoKs at the same time, some WoKs may hold more sway over an actor's decisions at any given time (see preferred WoKs in **Figure 1**). For example, an individual favoring a WoK akin to IWRM may perceive changes in rain patterns as a major threat to the steady and reliable provision of water. The appropriate ways of tackling priority issues will also be influenced by the actor's WoK. Actors using an IWRM WoK may deem increasing overall water storage capacity as the best way of tackling uncertainty over rains. Alternatives that reduce water demand or increase water storage capacity through spring protection programs may be deemed too slow or insufficient to deal with the magnitude of challenges related to reliable water supply. In this sense, different WoKs help determine overarching policy preferences. Policy preferences, in turn, can greatly impact a system's ability to cope with climate issues, either increasing its resilience or vulnerability (Kallis et al., 2009).

Ways of Knowing, Adaptive Management, and Building Adaptive Capacity

Different scholars advocate for more adaptive governance systems, such as those established by the Adaptive Management (AM) approach, both as a superior way to govern natural resources and as particularly adept to respond to uncertain climate change impact. According to Folke et al. (2005) AM is a systematic process of continuous improvement of management policies and practices through learning the results of implemented practices. The process incorporates uncertainty through social learning and knowledge co-production between policymakers and scientists (Walters, 1997). Adaptive frameworks also emphasize the need of including a broad range of stakeholders, including different perspectives beyond the technical and scientific, especially when these stakeholders are the ones likely to shoulder the brunt of negative impacts in these highly uncertain contexts (Funtowicz and Ravetz, 1991).

In water governance, especially under the uncertainty of climate change impact, AM involves transforming the way water managers view problems and act, focusing on the learning process as a crucial element for promoting adaptive capacity while embracing uncertainty (Kochskämper et al., 2021). The IPCC defines adaptive capacity (AC) as 'the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities or to respond' (IPCC, 2014, p. 118). AC includes the resources needed to cope with disturbances, such as infrastructure, information,

institutions, and capital (economic, social, and environmental) (Nelson et al., 2007). Adaptive capacity is core to both vulnerability and resilience paradigms, but scholars still struggle with creating and implementing metrics to access it (Engle, 2011; Siders, 2019). Both AM and AC frameworks posit that technical knowledge-use through water governance is likely to build more adaptive capacity and to increase the resilience of governance systems (Medema et al., 2008). Those adaptive forms of management aim to overcome failures of traditional regimes by integrating multiple resource uses and governance levels with a dynamic decision-making process that considers uncertainty and various forms of knowledge (Engle, 2011). However, while the conceptualization of these new forms has advanced, their practices and implementation are still lacking (Medema et al., 2008; Pahl-Wostl, 2009; Brugnach, 2017). Scholars have also discussed the compatibility and relationship between existing IWRM and AM (Engle, 2011; Fritsch, 2017), with a few proposing a broader interpretation of the IWRM framework that expands the role of alternative narratives and WoKs as an avenue to balance the weight of technical experts and a focus on technocratic solutions (Mukhtarov and Gerlak, 2014). In this conceptualization, increasing the role of alternative WoK in decision-making may facilitate effective transitions to AM practices.

Moreover, several authors have explored the role of knowledge and technical experts in upholding existing practices and blocking the introduction of AM practices (Kehler and Birchall, 2021). There is also growing attention paid on how different processes of knowledge co-production may enhance collaboration (Mach et al., 2020), especially connecting multiple WoKs (Brugnach, 2017). For example, research on subsiding deltas across Asia, Europe, and the U.S. emphasizes, among other factors, the role of technical experts in maintaining a path-dependence on technocratic approaches that exacerbate, rather than mitigate, delta subsidence (Seijger et al., 2017). However, in post-socialist Uzbekistan, attempts from technocrats to introduce IWRM were received with distrust by the central government who perceived the move as an attempt to hollow out their power to manage water (Hamidov et al., 2020). In addition to knowledge, empirical research has documented how differing perspectives on uncertainty between scientists and practitioners of different sectors have influenced decision-making and contributed to tensions between actors engaged in water management (Höllermann and Evers, 2017). Acknowledging the tensions created by the interaction of different WoKs and expertise is key for building agreements that reflect common collective goals and mutually acceptable solutions (Brugnach, 2017). In this context, finding common solutions is challenging given the ambiguity surrounding issues and possible solutions (Brugnach and Ingram, 2012), which can be attested by the relative lack of robust empirical evidence of expected outcomes of adaptive water management, either positive or negative.

In such contexts, a few frameworks have emerged that acknowledge that water governance should embrace uncertainty rather than try to repeal it (Döll and Romero-Lankao, 2017). Many of these frameworks also highlight the benefits of learning and experimentation in situations of crisis (Farrelly and Brown, 2011). For example, emergency situations may align a need for change with an increased willingness of policymakers and the general population to accept new ideas and the creation of new political channels and arenas (Lach et al., 2005). Moreover, although built infrastructure is necessary, it is often not enough; under the threat of climate change impact, it is very likely that coping with either uncertain or non-stationary scenarios will require a more flexible approach to water management (Milly et al., 2008). Such approaches should explicitly consider current path-dependence and allow for experimentation to foster adaptive management solutions. Some scholars suggest that handling extreme events and hydrological variability should involve three "I"s: institutions, infrastructure and information (Hall et al., 2014). For instance, there is a growing recognition that nature-based solutions (green infrastructure) can be a good complement (or alternative) to gray infrastructure in water-related issues, including because of the flexibility they offer when compared to public works (Cohen-Shacham et al., 2016; Seddon et al., 2020).

METHODS

Our analysis relies on primary and secondary documentary data to understand the structure and general functioning of the planning process at the PCJ Committees: the unified decision-making body grouping the river basin committees in charge of each river in the PCJ basin. We comprehensively reviewed information available on the PCJ Committees official website (Comitês PCJ, 2021), the PCJ Executive Agency's official website (Fundação Agência das Bacias PCJ, 2019), the State of São Paulo's Water Plan (Plano Estadual de Recursos Hídricos) for 2016–2019 and 2020–20230, and the PCJ Committees' master planning documents (Plano de Bacias) for 2010–2020 and 2020–2035 (see **Supplementary Table B** for a list of reviewed documents). Our analysis of the Plano de Bacias focused on the investment projects defined as priority for the basin in the past and for the next few decades. Information from these sources was categorized using broad topics such as planning priorities, perceived challenges, and preferred solutions to contextualize the issues being discussed in the Committees. We also participated, as observants, of dozens of committee and technical group meetings throughout 2014–2016, and between October and December 2018. Data and observations collected from these meetings helped us to understand how the Committees and its institutional bodies work and supported our background description of how different WoKs interact with each other in setting up and making decisions within the Committees. We also identified, downloaded, and coded news articles and other media from national and local news outlets such as Folha de São Paulo, Estado de São Paulo and Correio Popular to document the water crisis and the political machinations influencing decision-making at the PCJ basin level.

The PCJ Committees comprise a deliberative body, a Secretariat, an Executive Agency, and several technical chambers (Fundação Agência das Bacias PCJ, 2019; Comitês PCJ, 2021).

The technical chambers and the Executive Agency play a crucial role in informing planning decisions at the Committees. Technical chambers are also the main arenas where members of the Committees analyze, debate, and elaborate policies or

programs to address basin issues before presenting them to the deliberative body of the Committees. Meanwhile, the Executive Agency functions as the Committees' knowledge producer, being responsible for creating and diffusing technical knowledge and providing technical assistance for program implementation (Member of the Executive Agency, personal communication, 2018). When first created, the PCJ Committees faced great challenges in terms of sanitation infrastructure, flood control, pollution, and water flow disruptions. In the past 20 years, the basin has achieved remarkable progress in terms of sanitation infrastructure and sanitation access. However, there are still increasingly pressing challenges, both in terms of water quantity and quality. Defining the strategies to address these issues falls primarily on the technical chambers most closely related to each individual issue (Comitês PCJ, 2021). When issues fall within the jurisdiction of multiple technical chambers, the Committees tends to form *ad hoc* groups to work collaboratively across technical chambers (PCJ Committee Member, personal communication 2018).

We collected information about Committee members' perceptions of the planning process and governance priorities through in-depth semi-structured interviews with members of the PCJ Committees and Technical Chambers between September to December 2018. The PCJ governance bodies currently have 600 members representing government agencies, local governments, water users, and representatives of civil society. However, only a minority of current members actively participate during regular meetings organized by the twelve different technical chambers or the Committees' Plenary sessions (Member of the Secretariat, personal communication, 2018). Interviewees were selected snowballing from introductory interviews with key informants at the PCJ Committees and Chambers until no new names were suggested. We invited 35 potential interviewees representing the different water users and types of technical experts active in the Committees, with 27 accepting the invitation. Our interviewees were highly active in the PCJ Committees, and some have been involved since the Committees' creation. Twenty of our respondents are male and seven are female. We interviewed 14 water users, five government representatives, four representatives of civil-society, and four unaffiliated members. We believe the interviewees spoke candidly about interview topics. They were generous in sharing their experiences at the PCJ Committees, their opinions on how the Committees are tackling challenges, and their perceptions of the decision-making process at the Committees. Out of the 27 interviewees, 11 have engineering backgrounds while 16 have training in a variety of disciplines including biology, social sciences, and education. In section Results below, we compare how participants at the PCJ Committees perceive the basin's challenges and their potential solutions based on different WoKs.

All interviewees were transcribed, translated, and coded using NVivo software. Interviews focused on committee members' perceptions on the basins' primary challenges faced currently, potential solutions to those challenges, perceptions about the 2014–2015 water crisis, flexibility of the Committees' planning process, primary sources of information guiding interviewee's decisions, perceptions about influential groups and individual participating in the Committees, and general perceptions about climate change. We performed a two-stage content analysis of in-person interviews. In the first stage of analysis, we coded interviews to identify the main themes arising from our conversations with PCJ Committee members. We used a deductive approach to develop a set of coding categories broadly corresponding to our interview protocol topics. We then added coding categories to reflect the richness and specificity of topics available in the data taking advantage of the flexibility of the deductive coding approach (Saldaña, 2021). Our interview protocol is presented in **Appendix A** of the **Supplementary Material**. During the second stage of our analysis, we reviewed coded interviews to identify the narratives that reflect interviewees' WoKs, particularly in terms of how the basin's issues should be addressed. For this analysis, we focused primarily on the themes relating to the 2014–2015 water crisis, perceptions of climate change, and potential solutions to the basin's challenges.

RESULTS

Figure 2 presents the sub-themes identified as the basin's main challenges and potential solutions, other relevant themes can be found in **Supplementary Table C**. Throughout our interviews, water security came up as the most critical challenge for the basin. Other relevant issues include an expressed need to improve the basin's meteorological monitoring and information systems, issues of water quality, the appropriate distribution of responsibilities, and issues with increasing participation at the Committees. However, there was no general agreement on which solutions have the largest potential to address the issue coupled with persistent challenges and broader governance goals. **Table 1** summarizes identified WoKs in terms of their main proponents in the PCJ Committees, the kind of solutions they gravitate toward, the level of influence each WoK holds in the Committees, and ancillary narratives that support the use of each WoK. Several interviewees, primarily those from large sanitation companies, industrial users, and government agencies favored the construction of new reservoirs and the water transfer system from other basins as the best, and potentially only, solutions. Meanwhile, interviewees from local municipalities, researchers, environmental education projects, rural and natural water resources expressed concerns about the effectiveness of new reservoir systems. We also encountered divided opinions about climate change, its relation to the 2014–2015 water crisis, and potential ways of coping with it (see details below). These topics are all deeply intertwined with one another and clearly informed by individuals' WoKs. **Supplementary Table A** provides a detailed summary of the qualitative data supporting these findings.

Data from the interviews overwhelmingly support the importance of WoKs for selecting solutions to deal with challenges currently affecting the PCJ basin. The PCJ Committees are a space where different WoKs coexist, and different actors can participate in all areas of the Committees. Yet, participation

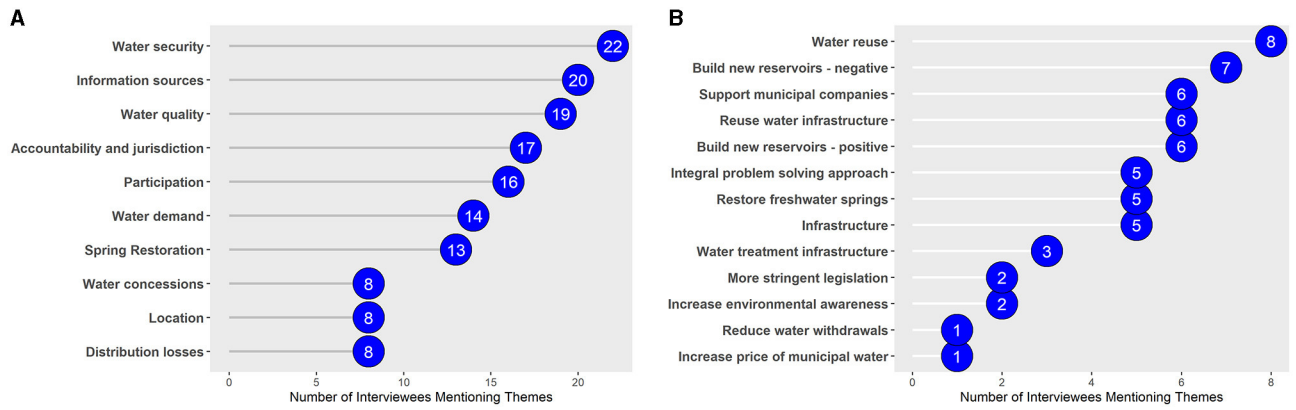

FIGURE 2 | Interview themes related to the basin's challenges **(A)** and potential solutions **(B)**.

TABLE 1 | Ways of knowing and their main features.

WoK	Integrated water resources approach	Environmental approach
Advocates	Primarily engineers, local politicians, water state agencies	Ecologists, environmentalists, biologists, social scientists, NGOs.
Water	Water as a commodity	Nature as water producer
Preferred solutions	Gray infrastructure: reservoirs, water transfer systems	Green infrastructure, experimentation through pilot programs, nature- based solutions
Kind of knowledge	Rational/cartesian/engineering approach	Multiple sources of knowledge
Level of influence	High overall	Low overall, except for the rural/environmental sector
Frameworks	IWRM, Water Security (narrow view)	Water security (broader view), Adaptive management, Nature-Based Solutions
Ancillary narratives	Infrastructure as only reliable way to achieve water security	Infrastructure is necessary but not sufficient. Water should be seen as an outcome from ecological processes.

does not translate to all ideas having the same weight or credibility. During the meetings, it became increasingly clear that there is an unspoken hierarchy for which kinds of solutions are considered as the most legitimate in terms of water management, with engineering solutions ranked highly (see **Supplementary Table A** for more detail).

> "We are perhaps one of the largest and most active groups in the public sphere. Not all groups have the same spotlight and media presence. In general, we work elaborating public policy recommendations for local governments, representatives, and other high-level decision makers." -Member of Professional Association of Sanitation Engineers
>
> "The group of technical experts from SABESP is very strong. The group from the water sanitation company in Campinas is strong too. They have an office with experts dedicated to their water sustainability plans. They have political influence that we cannot even dream off." -Water Sanitation Company Employee

The prevalence of the hydraulic solution is often noted by members of the PCJ Committees that hold other WoKs. For example, an interviewee pointed to the predominance of engineering approaches as part of the culture of the water sanitation company they collaborate with.

> "The issue of climate change now emerged from the crisis of 2014. It is recently perceived here as a limiting factor of water resources. That's because the water company is an engineering company, 99% of the coaching staff are engineers, mainly civil engineers. You do not have the mindset and vision to relate engineering, the environment, and water resources. In the company's long history, I am the first biologist to assume the position of environmental manager at the company. It is one thing I'm breaking that paradigm." -Water Sanitation Company Employee

The dominance of engineers does not imply that environmental ideas are absent from the Committees. In general, the members of the Committees publicly support initiatives for water resources conservation and restoration (see **Supplementary Table A**). Nuances over the extent of this support arise in the different technical chambers. Members of the Committees more connected to the rural and environmental education sectors have an agenda closely linked to conservation and environmental initiatives, placing great emphasis on programs such as payment for ecosystem services and nature-based solutions.

Regarding climate change perceptions and its influence on the decisions taken by members of the PCJ Committees, all of them acknowledge that climate change impact projections imply the basin will face more extreme events and more uncertainty. However, interviewees' opinions differ regarding the cause of

climate change disruptions and its connection to the water crisis, with some expressing disbelief in anthropogenic climate change. When talking about climate change, most interviewees referred to expected uncertainty about rain patterns, and lamented the loss of stable or "predictable" rain. The overall perception is that climate change will make rain patterns more or less intense throughout the years, with the expectation that it will cause disruptions to water supply. Although interviewees shared a sense of being unable to alter the causes of climate disruptions, they disagree on how best to cope with them.

> "Weather events are our major challenge. The great challenge is understanding climate change. What we know is that here, in the PCJ, rain patterns are different, more intense or less intense, and we are losing that average that existed throughout the years. Now we are always at the extremes of too much or too little rain. This is forcing us to revise our planning, but because we have not yet managed to accurately identify changes, we still don't have metrics to monitor these extreme conditions." -Member of Executive Agency
>
> "Noting the extreme weather events in the world, what are they doing? Dams, dams for you to offset the climate anomalies." -Water Sanitation Company Employee

Meanwhile, members in charge of water allocation and monitoring decisions are staunch supporters of infrastructure-based initiatives, including to deal with climate change. These preferences are heavily informed by professional expertise and its accompanying WoK. As a result, disagreements arise over the priority and potential benefits associated with different solutions, greatly affecting the likelihood that a particular solution will be pursued. Everyone participating in the PCJ Committees agrees that nature-based solutions have a place in the portfolio of management strategies at the Committees' disposal. However, environmental approaches are rarely considered as the best solution, particularly against the big challenges like climate change. For some, environmental solutions can provide, at best, marginal gains. Therefore, they cannot be the main strategy pursued by the Committees. The following quote from a large sanitation company employee perfectly sums up this perspective.

> "Climate change is happening, but my opinion is very different from many others. What we must do is prevention and that means infrastructure. Because with the changes, the reservoirs are not only for drought mitigation but also for flood control. The engineering vision imposes itself a bit because engineers are very pragmatic. We (engineers) need to be a little more like poets and social engineers. Solutions cannot be at either extreme. Neither do away with all the infrastructure nor just only plant trees. We have to find a balance to address the environmental issues and also the infrastructure issues. Environmentalists are here to stay, so you have to find that balance. We still have *eco-chatos*[1] on the PCJ Committees, as well as very *Cartesian*[2] engineers. I think there has been a change of vision in the Committees and now we need to find the balance between the environmental and the pragmatic." -Water Sanitation Company Employee

It is worth noting the association the informant makes between an environmental agenda and poetry, evoking a sense of idealism, in contrast with an engineering agenda and pragmatism. This contrast exemplifies how environmental solutions are construed as less appropriate from a problem-solving perspective. Under the engineering WoK, infrastructure projects aimed at increasing water production capacity will fare better than environmental solutions despite their potential for water retention. Preference for engineering solutions is reinforced by a positive feedback loop between existing built infrastructure and the increasing complexity of new projects. Existing infrastructure requires technical experts capable of managing it. In turn, these technical experts will pursue solutions they are familiar with to address existing and arising issues, creating the need for more technical experts like them to handle infrastructure in the future. This dynamic creates barriers for technical experts associated with other WoKs as they seek to advance their agendas. In the interviews, these barriers are cited as one of the reasons for the lack of innovation and out-of-the-box thinking in the Committees as different perspectives can rarely gather enough support and resources to establish large scale projects.

Despite these barriers, alternatives to engineering approaches continue to gain recognition and support in the Committees, at least in terms of brainstorming. Financial resources for projects implemented by the Committees in the foreseeable future are still expected to primarily fund infrastructure projects. Those advancing alternative perspectives view the increased ability to propose their ideas as the result of a long engagement process on their part that is slowly, but surely, changing the dominant perspectives and culture at the PCJ Committees. Respondents highlight the cultural change in terms of the creation of dedicated technical chambers and increasing resources for nature-based projects. Several interviewees commented on the difficulty of convincing who they described as "traditional engineers." However, they also highlight that through constant participation in technical chambers focused on rural and natural resource issues they have been able to create a space for different agendas to gain a foothold.

> "It was a turning point, a quiet revolution within the Committees. We now have working groups focused on stream restoration that include different Committee members. They are addressing deeper issues within each area of expertise related to reforestation, sewage treatment, watershed recovery. We elaborated the first master plan for water springs. The approach of the group: our reservoir is not the Cantareira, but here on the ground." -Member of Agricultural Water Users

The water crisis was a tipping point toward recognizing the seriousness of future water availability challenges. Not surprisingly, Committee members tend to rely on their technical expertise when thinking of potential solutions. About half of interviewees (14) mentioned the need to increase built

[1]Eco-chato is a disparaging term for someone who constantly directs the conversation to environmental issues similar to the English common expression "broken record".

[2]Cartesian is an adjective used in Brazilian Portuguese to describe an individual who is extremely rational and methodical.

infrastructure to tackle climate change, a kind of solution with which they are very familiar. Those advocating for expanding built infrastructure consistently mentioned the need to increase water storage and transfer capacity as the obvious and most reasonable strategy. In this sense, responses to the water crisis and the acknowledgment of climate change are consistent with the planning culture at the PCJ Committees, which is deeply informed by the WoKs of the engineers that populate it.

Data from participant observation of Committee meetings and the interaction between participants supports our finding that overreliance on one type of technical expertise (or one WoK) may ultimately increase vulnerability to climate change as it limits the experimentation and active learning required for adaptive management. During meetings despite the participatory nature of the PCJ Committees, which provides opportunities for different technical experts, and their WoKs, to introduce new perspectives, potential solutions, and alter how an issue's priority is determined, there was little evidence that such ideas have a path to take hold. Although the work and engagement from actors advancing different WoKs continue to gain footholds in the PCJ Committees, the tension between traditional and emerging WoKs can be observed in the day-to-day activities of the PCJ Committees, during long-term planning processes, and in the aftermath of a crisis. For now, discussions observed during these meetings suggest that the engineering WoK will continue to prevail in the foreseeable future.

DISCUSSION

The multiple WoKs identified during our analysis are consistent with WoKs previously described in the broader water management literature. One particularly prominent WoK corresponds to traditional management strategies with a focus on engineering solutions akin to the IWRM framework. This WoK tends to dominate water management spaces focused on technical and economic solutions (Giordano and Shah, 2014; Gerlak and Mukhtarov, 2015; Brugnach, 2017). In partial opposition to the first WoK, we identified another WoK that grants a larger emphasis to environmental solutions and pays more attention to broader concepts of water security (Gerlak and Mukhtarov, 2015) and the social value of water in line with the work of Ingram and Oggins (1990), which highlights water's relevance as a community good vital for security and self-determination.

Throughout Brazil's drive to decentralize water governance, technical experts, and their WoKs have critically participated and influenced RBOs. However, basin organizations have struggled to foster broad participation and balancing power asymmetries that favor technical solutions (Lemos et al., 2020). As a result, WoKs attuned to engineering solutions remain prominent throughout Brazilian basin organizations. Part of this prominence stems from the fact that a large percentage of Committee members are engineers and they have consistently been part of the Committees since their creation. In the PCJ basin, the main proponents of the engineering WoK are the technical experts from water sanitation companies and some government agencies. Water sanitation companies, especially the state-owned companies, hold a great deal of influence and power despite just being a water user. The heuristics used to categorize issues into technical chambers are, to a great extent, informed by the WoKs held by Committee members. This is one mechanism through which WoKs contribute to reinforcing established patterns, a dynamic in line with common criticisms levied at technocratic IWRM approaches (Mukhtarov and Gerlak, 2014). Technical experts that have a large presence or influence at the Committees will have a greater capacity to designate the basin's most pressing issues as challenges that fall primarily under their jurisdiction. Key issues are then discussed primarily in technical chambers dominated by these technical experts, where proposed solutions will likely correspond to their WoK: a lock-in process similar to the one observed in delta subsidence (Seijger et al., 2017). Likewise, having jurisdiction over priority issues grants technical experts an advantage to secure most of the Committees' financial resources to implement solutions.

Water sanitation company employees occupy leadership roles in the Committees' deliberative body and key technical chambers. Meanwhile, most high-level actors in state agencies have a lot of practical authority, ensuring that their agendas are followed as a state policy (Abers and Keck, 2013). Technical experts from other areas of expertise have progressively become more engaged at the PCJ Committees, but there are still significant barriers for greater participation. These experts are usually affiliated with NGO's, Civil Society, and Municipal governments, groups that tend to have smaller budgets and capacity to participate in multiple arenas of the PCJ Committees.

Yet, because of the dominance of the engineering WoK, the extent to which solutions stemming from relatively new WoKs will impact the basin's overall policy approaches is limited. Success will partly depend on the extent to which recent events and perceptions of climate change continue to influence Committee members' approach to the basin's challenges. For example, pilot nature-based projects have been recently funded by the PCJ Committees. Similarly, discussions about rural water production, spring restoration, and small-scale water reservoirs, to name a few, have become more common.

As a participatory body, the PCJ Committees provide ample opportunity for actors holding different WoKs to engage with each other as they try to advance their preferred management approaches and solutions. These debates influence what is ultimately included in the basin's planning documents as priority policies. It is therefore important to understand the links between the different WoKs present in the Committees and current perceptions about the basin's challenges and the long-lasting effects of the water crisis. For example, despite the challenges, technical experts akin to other WoKs have managed to establish some projects. The PCJ RBO runs a modest watershed restoration and protection program, and is developing others addressing water demand reduction, nutrient load reduction, and environmental education. These programs are a testament to the hard work and perseverance from technical experts holding WoKs akin to environmental issues and adaptive management. Arguably, part of these experts' success would lie in their ability to frame initiatives as a different kind of infrastructure

(green infrastructure) that can effectively complement existing infrastructure, particularly in rural or otherwise underserved areas of the basin. Interviewees representing alternative WoKs often referred to the need and difficulty of convincing more established members of the PCJ Committees of the benefits of new approaches. Part of this difficulty stems from the perception that alternative approaches to water management, particularly nature-based approaches, are not only less effective but idealistic. The characterization of environmental approaches as idealistic puts them at a disadvantage when trying to convince technical experts focused on finding pragmatic solutions under considerable financial constraints.

Different perceptions regarding the efficacy of environmental solutions also helps understand why, despite agreement over the risks and uncertainty presented by climate change, technical experts double down on their preferred approaches. For those holding an engineering WoK, the water crisis appears to have reinforced the belief in the need to expand the built infrastructure in the basin as the only viable option to increase water security. The tendency to rely on familiar solutions highlights the limitations of learning opportunities supposed to be facilitated by polycentric governance systems (Walters, 1997) and the role of technocratic approaches in limiting AM (Kehler and Birchall, 2021). Nonetheless, the crisis seems to have helped broaden the acceptance of nature-based and adaptive management approaches with groups that are not traditionally associated with an engineering WoK.

With time, the modest rural, environmental education, and nature-based programs included in the 2020–2035 basin plans may provide valuable proof-of-concept to increase the respect and credibility of these approaches. Setting the PCJ basin on a path toward adaptive management depends on recognizing the ambiguity around policy options (Brugnach and Ingram, 2012) and achieving a greater balance between the different agendas and WoKs coexisting in the PCJ River Basin. Preventing catastrophic consequences of future rain pattern disruptions may well depend on the basin's capacity to understand the complementarity of different approaches, a challenging feat. Helping non-traditional understandings of the basin's problems achieve equal footing with established views is one of the key steps to achieve this. Increasing the importance of non-sanitation water agendas in the PCJ could create opportunities for proposing, designing, and planning for flexible solutions that address multiple agendas at the same time. This can come from the recognition that the problems assailing the PCJ River basin have consequences for all water users and that solutions for these problems can address more than one agenda at a time. This would be in line with advancing a more holistic view of the IWRM framework that can lead to implementing successful AM practices (Medema et al., 2008; Mukhtarov and Gerlak, 2014; Fritsch, 2017). Expanding the pool of viable solutions, both in political and technical terms, can give rise to new approaches. For example, nature-based solutions can address needs in the sanitation sector as well as environmental ones and are gaining adherents in different parts of the world.

CONCLUSIONS

The 2014–2015 water crisis failed to ignite the changes many hoped would transform the governance of the PCJ river basin's water management strategy toward long-term resilience. Rather the hydraulic WoK once again prevailed. The PCJ Committees have not deployed ambitious nature-based solutions programs and social marketing campaigns, or programs aimed at reducing water consumption greatly depend on the Committees' partners, particularly municipalities, for success. Rather, many members of the PCJ Committees look toward the construction of large new reservoirs, an inter-basin water transfer system, more sophisticated water treatment plants, and water loss reduction programs as the main avenues to increasing water security. This reliance on traditional infrastructure solutions is a common feature of a narrow view of IWRM.

Decision-makers in water governance tend to choose strategies they are familiar with and feel confident about having the technical expertise required to manage them. This is understandable given the high stakes and perceived risks posed by climate change. Incentives to invest in experimental approaches are lower when infrastructure solutions have generally proved successful at achieving a narrow definition of water security understood simply as maximizing water supply. In this sense, the way in which the most influential technical experts conceptualize problems and judge potential solutions, or their WoK, is one of the pillars upholding the overreliance on traditional infrastructure solutions. Although it is true that river basins worldwide need to expand their water supply to deal with current and future demand, there are potential risks associated with these projects when considering climate change impacts. For example, climate change erodes our ability to estimate future water availability based on historical data alone. In the case of the PCJ basin, decision-makers may be under or overestimating rain pattern disruptions, potentially increasing rather than decreasing their vulnerability to climate change. Some potential risks include increased flooding risk for the cities near new reservoirs, intensification of nutrient load pollution issues, water supply disruptions and intraregional conflict that arise from extreme events jeopardizing water transfers between the PCJ and the Paraiba do Sul basin. The focus on infrastructure solutions may prove to be an example of maladaptation if and when another water crisis (either extreme floods or drought) occurs.

Planning in a deeply uncertain world requires flexibility to adjust for changing conditions, giving more room for adaptation in an iterative process of social learning. Arguably, decentralized and participatory institutions facilitate social learning by creating arenas where different actors and different WoKs can interact with each other. However, the introduction of new WoKs and the increased participation of different technical experts and social actors have not translated into the implementation of a diverse set of strategies to deal with the basin's challenges. Members of the PCJ Committees perceive low participation from less dominant voices as an issue that requires immediate attention. We argue that the PCJ Committees need not only increase the variety of voices and expertise in the Committees

but actively elevate the validity of alternative WoKs and fight bias and misconceptions about non-engineering water management strategies. Our research also contributes to the literature that advocates overcoming the prescription that participation alone is sufficient for fostering AM. Exchanging information and co-creating knowledge does not influence governance outcomes without recognizing the different asymmetries (structural, institutional, and power) that permeate such relationships. In the case of the PCJ, problems and issues are framed, voices heard, and solutions considered in an institutional environment that reflects historical and structural asymmetries reinforcing them in an institutional lock-in. Challenges faced by the PCJ River Basin, although informed by the Brazilian context, are a familiar story for many regions of the world. Climate change will increase the pressure drivers over freshwater resources, requiring new WoKs. Breaking the infrastructure path-dependence will require additional measures, in addition to increasing participation and decentralizing governance systems. Close attention needs to be paid to the voices and expertise that hold sway over the decisions that will determine future adaptation strategies.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because access to data is restricted to protect participant privacy and confidentiality. Access to de-identified interview codes may be available upon request with permission from study participants. Requests to access the datasets should be directed to Stefania Almazán-Casali, salmazan@umich.edu.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board (IRB) Health Sciences and Behavioral Sciences (HSBS) at the University of Michigan. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

SA-C and BP conceived the manuscript, collected, analyzed the data, and wrote the manuscript. ML supervised the study and contributed valuable comments to the manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

ML's work was supported by the National Oceanic and Atmospheric Administration (NOAA–Grant NA10OAR4310213/Great Lakes Integrated Sciences and Assessments). SA-C's work was supported by the Consejo Nacional de Ciencia y Tecnología (CONACyT).

ACKNOWLEDGMENTS

We want to extend our gratitude to the Comitês das Bacias Hidrográficas dos Rios Piracicaba, Capivari e Jundiaí (CBH-PCJ), the Agência PCJ, and Consórcio PCJ for their time and helpful insights that made our research possible. We would also like to thank Dr. Tadeu Malheiros from the University of São Paulo for facilitating introductions with members of the CBH-PCJ.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frwa.2021.735018/full#supplementary-material

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