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# 'Locking in' Desalination in the U.S.-Mexico Borderlands: Path Dependency, Techno-Optimism and Climate Adaptation

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ABSTRACT: Desalination (producing potable water from saline sources) has gained notoriety globally as climate change threatens water supplies. Strikingly, Arizona – a territory lacking coastal boundaries – has developed desalination proposals to augment water supplies, which imply leveraging relations with Mexico and/or expanding inland desalting. Utilising original data collected from interviews, participant observation, and archival sources, this research exposes the historical dynamics and discourses shaping Arizona's ambitions. The article reveals how Arizona's desalting pursuits are constructed around limited access to distant water sources and guided by the flaws in the Colorado River system. Case studies examined include the historically uneven trajectories of desalination proposals for the Sea of Cortez in Mexico, brackish water in Yuma, Arizona, and urban aquifer desalination in the Phoenix area. Following from the insights of political ecology, path dependency theory, and critiques of technologically optimistic ideology, the evidence points to how Arizona remains 'locked in' to this infrastructural commitment because of past policies, decisions, and tendencies. However, the Arizona case is not of interest only because it concerns largely unsuccessful, if consistent, attempts to diversify a supply portfolio, but also because desalination is marketed as a strategy aimed at avoiding dependence on large water transfers and centralised decision-making. Therefore, the evidence illustrates that desalination, in whatever form it takes, has been unable to alter deeply rooted institutional and political challenges; the Groundwater Management Act (a legal structure) and the Central Arizona Project (a mega-canal) are prime examples. The article's theoretical and empirical connections are useful for scholars, decision-makers, policy analysts, NGOs, and activists concerned about the possibilities for a sustainable society, because the historical analysis illuminates the flaws in managing resources with an overly optimistic orientation to technology that limits the vision for alternative infrastructure paradigms under the conditions of climate change. In other words, even when desalination is "just another tool in the toolbox", we argue it takes an outsized place in water planning discussions due to the significant financial and political commitments the technology requires. In so doing, desalination locks in new and sometimes long-standing path dependencies, based upon attempts to evade old ones.

KEYWORDS: Climate change adaptation technology, path dependency, political ecology of water, seawater and brackish water desalination, Southwestern United States and Mexican Borderlands

> *Desalinisation is a big answer to all of our problems in the West. (…) No one here is going to pay 50 times more for their water. When you're paying more for (…) your water than you are for your whiskey, you've got a serious problem. I do believe that is the answer to everything, is eventually you've got the ocean out there.*
>
> July 3, 2009 – Interview with an Arizona hydrologist whose career spanned work with the US Bureau of Reclamation, the Arizona Department of Water Resources, and the Central Arizona Water Conservation District (emphasis added).[1]

## INTRODUCTION: DESALINATION AND WATER SCARCITY IN THE AMERICAN BORDERLANDS

Desalination is a broad term referring to the removal of dissolved salts from saline, brackish, highly mineralised, or contaminated water (e.g. Curto et al., 2021). Based on well-publicised success stories in semi-arid and arid coastal regions of the world (e.g. the Arabian Peninsula, Israel, and California) (Megdal et al., 2012; McDonnell, 2014; Williams, 2018a), it is now part of a policy package (e.g. Saleth and Dinar, 2005) widely considered by decision-makers as an appropriate solution to drought because of its ability to provide growing populations with new freshwater (March et al., 2014; O'Neill et al., 2018; Williams, 2022). Increasingly, it is linked to proposals promoting various versions of 'green', 'circular', or 'blue' economies (Campero et al., 2022; O'Neill, 2022a). As the quotation opening this article shows, it is easily framed as an 'answer to everything': a technological innovation that can foment a combined social, economic, and ecological transition (O'Neill, 2022b; on technology's relation to the 'just transition' see also O'Neill and Schneider, 2022). And, with the technical progress made in recent years in the desalination sector (Fritzmann et al., 2007; Bundschuh et al., 2021), the technology of reverse osmosis is less expensive than it once was, providing an added economic rationalisation underlying desalination's appeal (March, 2015; Tubi and Williams, 2021). Desalination is then seen as viable, even 'drought-proof' technology, as, for example, private company representatives promoting the technology have remarked: "*These are certainly drought-proof water supplies*, but they are not being built for a specific incident or occurrence in time. These are projects that will provide a reliable water supply for half a century" (emphasis added)[2] (see also Knights and Wong, 2008; Bernabé-Crespo et al., 2019; Morgan, 2020).

Desalination is, of course, only part of the full suite of options available to solve water problems. Demand management – reducing use through efficiency – has become increasingly important. Rather than large-scale infrastructure like dams or desalination plants (on 'mega-projects', see Obertreis et al., 2016), demand management aligns with what some scholars call 'soft-path solutions', which try "to improve the productivity of water use rather than seek endless sources of new supply" (Gleick, 2003: 1526). Indeed, these 'paths', that is, the historical trajectories and policies for water, often have long-term effects. Scholars examining water policy reforms have shown that in "the absence of active and disruptive policy entrepreneurs" (Marshall and Alexandra, 2016: 679) 'path dependency' – institutional and policy patterns hindering innovation and adaptation (David, 2007; Djelic and Quack, 2007; Haydu, 2010) – can have detrimental socio-ecological impacts, promoting infrastructure and technology that may not be ideal for future needs. This is contrary to mainstream notions of 'progress' as achieved through technical innovation (Ingram and Fraser, 2006; Clarke and Flannery, 2020: 172-175). Path

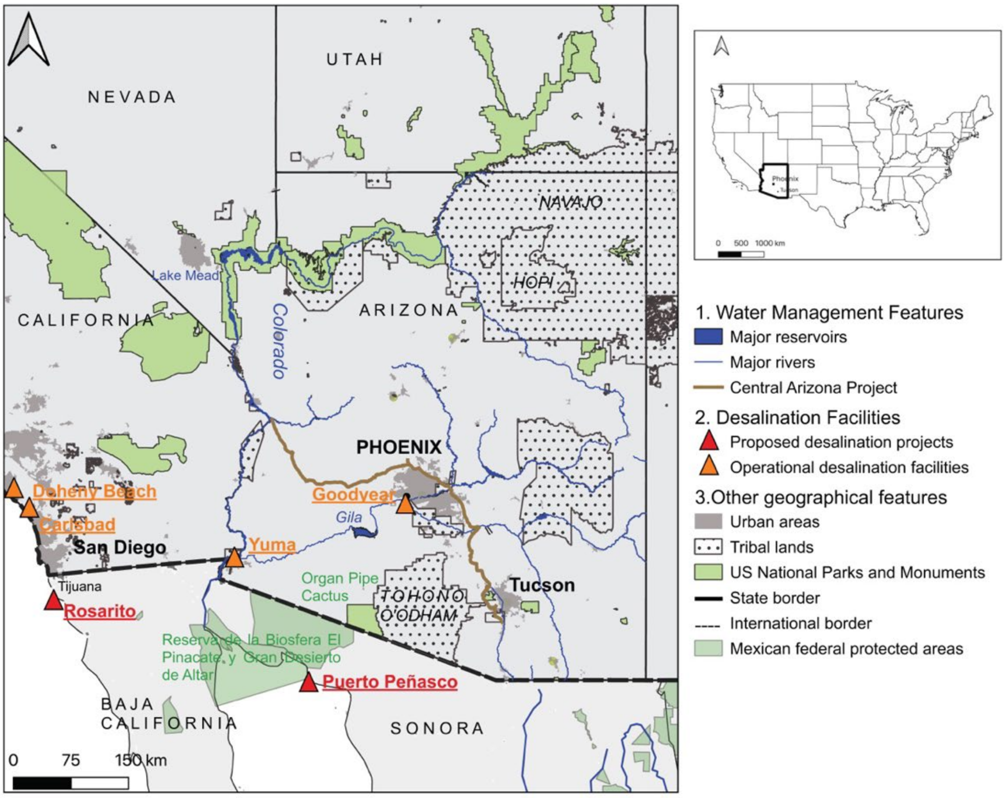
[1] This quote is from page 52 of the transcript, which can be found at the following link: https://library.cap-az.com/documents/about/oral-histories/Frank-Barrios-Transcript.pdf

[2] This quotation was sourced from a podcast interview that aired on August 8, 2015, where Scott Maloni, a vice president of the American desalination development firm Poseidon Water, discussed the possibilities of the technology in California. The interview can be found at the following link: https://menckenism.com/2015/08/10/realclear-radio-hour-podcast-water-politics/. The interview was part of the Bill Frezza *Real Clear Radio Hour* podcast. Maloni made nearly identical statements during an August 31, 2021 special report produced by *California Insider* and *The Epoch Times* – https://bit.ly/3MbOMXm

dependencies have been shown not only to lead to economic inefficiency (Harris, 2011), but also to ineffective conservation efforts (Teschner et al., 2013).

However, in the Southwestern American borderland region (Figure 1), an area affected by an ongoing drought of more than 20 years (Wilder et al., 2020), legislators as well as regional water delivery entities are continually (re)turning to seawater desalination despite the community and political tensions surrounding it (Williams, 2018a; O'Neill, 2023). For example, even after the recent failure of infrastructure development firm Poseidon Water, who tried to push a recent project through the regulatory process in the city of Huntington Beach (O'Neill, 2022b), California counts at least a dozen active or proposed plants. The largest of these is located in Carlsbad, San Diego County (Williams, 2018a; 2018b). Most recently, the Doheny Ocean Desalination Project in Orange County was approved in October 2022, lauded for its ecologically minded approach due to its proposed subsurface intake design (Water Manager at South Coast Water District, interview, July 1, 2020).[3]

Figure 1. Map of the Southwestern American borderlands, focusing on desalination facilities in Southern California, Arizona, and Northern Mexico.




Sources: USBR, 2007, 2012a; 2012b; Black and Veatch/Libra, 2020; US Census. *Note*: For both the desalination facilities in Mexico, various plans by government and consultancy firms discuss how it may be possible to create conveyance infrastructure to transport water north into the United States, although no final decisions on this have been made at the time of writing. Map © the authors.

[3] During the course of an interview with a South Coast Water District manager, it was explained that developing the desalination plant at Doheny Beach with an ecological orientation towards the impacts and design of the plant's infrastructure was a priority. At the same time, it was noted that a more eco-centric approach was facilitated by the geomorphology of the site itself, as opposed to, for example, Huntington Beach or Carlsbad, which have very different coastal characteristics. More about the Doheny project and its environmental impacts can be found at the following link: https://www.scwd.org/about/district_projects/doheny_ocean_desalination_project/index.php

Water in the Southwestern American borderland region comes principally from 'conventional' sources (Gandy, 2014: 12; Saurí et al., 2014): surface freshwater stored in reservoirs and conveyed via large-scale canals (e.g. Randle, 2021). Quite dramatically, though, the reservoirs have been declining (Powell, 2008; Wheeler et al., 2022). For instance, at the time of writing, Lake Mead (in Nevada), located on the Colorado River, only contains 27% of its capacity at 7.5 million acre-feet (MAF) (full capacity is 28.9 MAF).[4] One result of this has been that the United States Bureau of Reclamation (USBR), one of the most significant federal water managers throughout the region (O'Neill et al., 2016), has declared a 2023 'Tier 2' shortage. For the first time, those states who do not have 'senior', i.e. historically significant, water rights, will not have their usual allocation. In the context of this scarcity, technological uncertainty, and political contestation, the state of Arizona, located in the Colorado River Basin, is facing the largest cutbacks: they will lose 21% of their allocation (592,000 acre-feet).

Due to Arizona's low-priority status with regards to the Colorado River (e.g. Poupeau et al., 2019), and even though it is an inland state, this article explores the ways in which Arizona water managers regularly describe desalination as one of the 'next buckets of water' in their quest for water augmentation.[5] This presents an intriguing puzzle when one considers the historical cases elaborated, because desalination has been a largely unactionable preoccupation (for the United States anyway) since the height of the Cold War (O'Neill, 2020; Low, 2020). To be sure, there is a long history of mega-infrastructures and water transfers that have been at the core of Arizona water management, as this semi-arid state has been facing water scarcity since the infancy of its colonial development at the end of the 19th century (O'Neill et al., 2016; Curley, 2021). However, this article argues that the re-emergence of mega-project ambitions is linked to the contemporary drought context as well as to the historical relationship water managers and politicians have held with the technology of desalination. This relationship is the result of a combination of mechanisms: namely institutional memory, fixed capital costs, networks of contractual relations, and social power. In pointing to these mechanisms, the research herein elaborates upon the existing work on water politics and path dependencies of infrastructure that emphasise the importance of historical relations. Simultaneously, we find that a discussion of path dependency mechanisms must be coupled with a critical analysis of the discourses on desalination. In so doing, the notion of *techno-optimistic ideology* is mobilised to describe a condition that political economist John Barry has aptly called a belief in "technological abilities to solve problems of unsustainability while minimizing or denying the need for large-scale social, economic and political transformation" (2012: 3). This ideology is significant, as it further informs the attention that desalination continues to garner from policy elites, thereby maintaining it as a policy pathway (see also Harvey and Knox, 2012).

Drawing upon the recent research and theorising coming from sociology and human geography, our analysis is modelled after the work of critical political ecologists (e.g. Peet and Watts, 1993; Forsyth, 2004; Goldman et al., 2018). The concept of path dependency in particular will be valuable to scholars in these disciplines, as it remains less utilised than theories of 'fixes'. As geographer Joe Williams (2022) has recently commented in his review of the critical literature on desalination, path dependency is a crucial dynamic that is often mentioned, but less often fully developed in the scholarship. Empirically, this article contributes an original discussion to debates about the territorial dimensions at stake in Arizona's desalination projects, which often imply imported water sources (seawater from the Gulf of California, in

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[4] One acre-foot is roughly equivalent to 1.233 megalitres; one million acre-feet approximately equals 1233 km$^3$. The origin of the term has agricultural connotations. The unit is a convention native to the origins of modern – and specifically the western states' – American water law, which measures volumes of water in this way, referring to the amount of water necessary to cover one acre of land in one foot of water.

[5] This 'next bucket of water' discourse was prevalent in our analysis of news and other media. For example, a June 25, 2020 piece coming from Arizona State University quotes water policy analyst Susan Craig of the Morrison Institute for Public Policy: "If you're at any water meeting, ocean desalination always comes up as the next big bucket of water in Arizona". Our investigation corroborates this as well. See https://news.asu.edu/20200625-arizona-impact-new-asu-mapping-tool-shows-holistic-view-water-arizona

Mexico) (Mumme et al., 2017), but also small-scale (e.g. municipal brackish groundwater desalination plants) and larger inland facilities (e.g. the Yuma desalination plant). Indeed, water managers at every level of decision-making (municipality, county, state, federal government), and internationally (e.g. the proposed desalination plant in Puerto Peñasco in the Mexican State of Sonora) have managed to keep desalination alive through various discourses and actions, which are discussed in detail throughout the article.

In the following sections, we explain the methodological context of the research before moving into a more complete elaboration of the prior scholarship. We then unpack the path dependencies, discourses, and ideology surrounding desalination along the borderlands by discussing historical cases like the Central Arizona Project Canal, the Groundwater Management Act, the Yuma Desalter, plans to desalinate the Sea of Cortez, and inland desalination near Phoenix, Arizona. In so doing, we look at Arizona's ambitions and hesitations as they raise the two central issues discussed in the path dependency literature: (1) the 'locking-in' of an hydrosocial system to a technologically rooted trajectory emphasising the importance of fixed capital invested in large infrastructure projects (Palm, 2006; McEvoy and Wilder, 2012; McEvoy, 2015) and (2) the constraining of alternatives (Åhman and Nilsson, 2008; Howlett, 2009), which concerns sustainable water management and climate change adaptation (Rosenbloom et al., 2019; Al-Aghbari, 2021; Tubi and Williams, 2021). The theoretical and empirical connections made in this article will be useful for scholars, decision-makers, policy analysts, NGOs, and activists concerned about the possibilities for a sustainable society, by showing the flaws in managing resources with an overly optimistic orientation to technology that limits the vision for alternative infrastructure paradigms under the conditions of climate change.

## METHODOLOGICAL AND THEORETICAL CONTEXT OF THE RESEARCH PROJECT

### Materials and methods

This research emerged from the convergence of the authors' parallel initiatives on the politics of water. One author has been focusing on water conservation practices and policies in Arizona cities, and the other has been working on the politics of desalination from the Cold War to the present, focused on both local connections in and transnational connections with the American Southwest. For instance, archival research was conducted on the records of the Office of Saline Water, or OSW.[6] Both have a methodological background in the ethnography of public policies and mixed methods research.

Throughout 2022, the authors worked together to attend meetings on desalination and conservation (online and in-person) as well as various policy-related events (desalination was a topic of discussion due to recent elections in Arizona) to collect data that supplemented findings from initial archival and interview-based research (n = 64 in California; n = 76 in Arizona). These data were largely used to triangulate discursive patterns emerging from the recent and historical trends of interest in desalination in Arizona. Formative early findings were initially drawn from a content analysis of the Central Arizona Project (CAP) Oral History interviews,[7] which clarified the patchwork history of desalination in Arizona and its relations with Mexico. This article draws from research into this archive, which consisted of 38 interviews across 1251 pages of transcripts, conducted between 1999 and 2020 with various experts and politicians who shaped the management of the state's water.

Due to developments in the borderlands and Arizona's interest in desalination, the authors gathered an additional corpus of 248 *Arizona Republic* (one of the state's primary news outlets) articles by searching for qualitative phrases related to drought, water, and desalination. These search terms were

[6] The records of the Office of Saline are located in in the United States National Archives - https://www.archives.gov/research/guide-fed-records/groups/380.html

[7] These can be found at the following link: http://www.cap-az.com/about/history-of-cap/oral-histories/

used with the aim of understanding the trends in popular publications regarding the connection between the multi-decadal drought and desalination. The articles were selected from the most recent drought period (1999-2022).

Overall, this mixed-method strategy yielded a unique dataset that was appropriate to analysing the historical and contemporary dynamics of desalination in the region. And, while such an approach is consistent with past work on desalination, as well as on path dependencies and ideology critique (e.g. Vaughan, 2004; Bennett and Elman, 2006; Gunderson, 2017, 2022; Turley, 2021), we do not consider this work to be one of strict historical institutionalism, using the method of 'process tracing' (historical analysis reconstructing events and the activities of certain actors) that has been common to political science (e.g. Thelen, 1999). Instead, our approach is in line with interpretive sociology and critical political ecology, which does not aim to "unpack a causal story" (Turley, 2021; Song et al., 2022), per se, but rather aims to understand the pervasive logics by which policies and actions are undertaken (e.g. Burawoy, 1998; Dubois, 2009; Gandy, 2022).[8] This approach affords greater purchase on how path dependencies and ideologies are at work across the examined history.

## Conceptual approach: The political ecology of desalination, path dependency, and techno-optimism

This research is informed by the recent surge of interest in desalination across the social sciences and humanities. To date, the literature on the political ecology of desalination has dealt with Arizona (McEvoy and Wilder, 2012; Wilder et al., 2016), Texas (Hargrove and Heyman, 2020; Brannstrom et al., 2022; Heyman et al., 2022), and California (Williams, 2018a, 2018b; O'Neill, 2022c) when investigating the United States. Other notable analyses have also focused on desalination in Latin America (Campero et al., 2021; McEvoy, 2014), Spain (March et al., 2014; Swyngedouw and Williams, 2016; Bernabé-Crespo et al., 2019), England (Loftus and March, 2016), and Israel (Feitelson and Rosenthal, 2012), often raising questions regarding the uneven geography and the consequences of desalination's development (Wilder et al., 2016; Fragkou, 2018; O'Neill, 2022b, 2023).

The theoretical framework initially informing this research was that of 'technological fixes' (e.g. Harvey, 1981, 2001; O'Neill and Boyer, 2020). This is also due to the pervasive application and reworking of various notions of 'fixes', as well as geo- and technopolitics, within the literature on the political ecology of desalination (March, 2015; Williams, 2018b, 2022). Prominently, geographer David Harvey's discussions provide a useful starting point: the word 'fixes' evokes addiction, "the burning desire to relieve a chronic or pervasive problem" (Harvey, 2001: 24). In this tradition, Erik Swyngedouw and others have mobilised this term to discuss how a 'desalination fix' defers contemporary issues of legal, bureaucratic, and material constraints and mechanisms of path dependency to an undetermined future point, by which time 'innovation' will supposedly solve the issue. The point, of course, is that the underlying social and ecological problems are rarely resolved (e.g. Swyngedouw, 2013; Swyngedouw and Williams, 2016).

Therefore, the political ecology of desalination has emerged by taking politics seriously in a way that the technical literature on the topic rarely does (Williams, 2022). As prior work has shown, desalination first emerged in the world-system amidst the Cold War, during the so-called *Pax Americana* (Wallerstein, 1980). And it did so, not so much as a solution to the water scarcity problem per se, but as a solution to a series of geopolitical concerns. As Brian O'Neill (2020) and Michael Low (2020) empirically showed, the concern at the OSW was that the USA had lost the space race to the USSR and thus that its scientists and engineers had to double their efforts to conquer what new frontiers were left back here on planet Earth. The USA had an interest in promoting American expertise, as well as in establishing and maintaining its

[8] On an interesting use of how to better conceptualise methodology towards grasping tactics and strategies as modes of social praxis, see geographer Eric Perramond's work (2007).

diplomatic relations with the Middle East (Koch, 2022). In this way, the American Southwest borderlands have long been a kind of laboratory for technological innovation linked to political aims.

What is more, this has been a phenomenon that follows desalination wherever it travels. For example, geographer Naama Teschner and colleagues demonstrate that desalination was adopted in Israel not out of biophysical necessity but because the state needed a legitimate justification for uprooting the previous hydro-social regime characterised by institutional crisis. Therefore, social and political disruptions fueled by discontent over poor water management were deferred, because water became a 'neutral product', i.e. scientifically managed (Teschner et al., 2013: 100). Likewise, sociologist Samer Alatout (2008a, 2008b, 2009) has discussed these dynamics historically. Within the early Israeli state, competing conceptions of the national project were influential in constructing a dichotomous logic: water abundance/scarcity (see also Schmidt, 2017). Alatout argues that technocrats positing water scarcity as a central threat to the ethnonational political project saw the future of the state as a centralised network of water, electricity, and agricultural management. The solution then became the formation of a national subjectivity rooted in the ideas of 'new' engineers and experts producing efficient, responsible management (Alatout, 2008b: 50-51). It is no coincidence that transnational exchanges with Israel began quite early after state formation, as the United States' OSW endeavoured to build test facilities and exchange knowledge globally. What such examples show is that from seemingly disparate locales in the world-system, an ideology of techno-optimism rooted in an appeal to scientific expertise has long been present in the discourses surrounding desalting.

We propose that desalination can be critically read as arriving at a technological justification of the desire for 'abundance', what environmental historian Ruth Morgan has called the "allure of desalination" (2020). Indeed, its surplus nature is often discussed as a type of 'insurance plan' (Fieldnotes, February 2018, commission hearing for coastal permit). Sociologist Ryan Gunderson and colleagues (2019) have discussed these types of dynamics as involving a 'plan B logic', i.e. cases in which technological approaches are discussed as 'back-up plan to "Plan A"', which would involve serious consideration of a global economy predicated on extractive principles and gross domestic product (GDP) growth. Similarly to Harvey, Gunderson and colleagues argue that this has led to widespread optimism in technological applications to climate adaptation, or 'techno-optimism', which causes popular and institutional depoliticisation, thereby evading a confrontation with the possibility of social disruption that might be incited by reversing the political and ecological conditions of scarcity (Asayama and Ishii, 2017; Gunderson et al., 2019: 710; Gardezi and Arbuckle, 2020; Marquardt and Nasiritousi, 2021; O'Neill and Schneider 2022).

The notion of techno-optimism falls in line with research on infrastructure and the environment more broadly, which increasingly points to ideology as a political factor (Akhter, 2015; Crow-Miller et al., 2017; Anand et al., 2018). Indeed, the lineage of scholarship on infrastructure and planning suggests that climate adaptation technologies like desalination are not only reliant upon assessments and data to make their case to would-be adopters, but also on configurations of somewhat abstract representations, (techno)political desires, and material manifestations, which refer to an intellectual tradition that goes back at least to James Scott's work on 'high modernism' (1998). It is in this light that, rather than inspiring the necessary socio-environmental transformation, desalination helps to prop up the ideology of techno-optimism (Dentzman et al., 2016; Gunderson et al., 2019), relying on 'flat' (i.e. inattentive to social power and domination) assessments of the social (Gille, 2010).

At this point, a theoretical connection to path dependency can be made. In an early article on desalination discourses, geographers Jamie McEvoy and Margaret Wilder have explained that desalination is:

> an energy intensive, expensive technology with unintended side effects [and] the perception of 'limitless' water [that] undermines conservation efforts. And once built, fixed capital invested in a large infrastructure

> project creates a path dependency and reduces the flexibility of future generations to respond differently (2012: 355).

Clearly, the above discussion of techno-optimism shares key concerns around capitalist society's drive toward new 'limitless' resource frontiers and inflexibility toward alternatives. The concept is most frequently used to discuss how technologies, policies, and infrastructures tend to become 'entrenched' or 'locked in' in society (Arthur, 1989; Palm, 2006; Djelic and Quack, 2007: 163-4). Put differently, it suggests that early sequences of choices or processes "set in motion a course of events that becomes self-reinforcing over time" (Rosenbloom et al., 2019: 171). It describes how technologies can tend to exhibit a character of stabilisation to a specified policy path or historical trajectory.

More specifically, scholars of path dependency discuss the ways in which technologies, once sufficiently adopted and diffused through and across societies, tend to become 'bounded'. That is, the choices that can be made about which technology to use in the future become limited. As political scientist Michael Howlett has described, there is "an increasing weight of evidence from case studies of trajectories changing while being embedded in previous policy legacies so that their new form is not random or contingent, but *thoroughly influenced by and anchored in the old*" (2009: 250, emphasis added). Contrary to an uncritical free-market economics ideology, the concept of path dependency and the analysis of the history of science have shown that innovation occurring within market structures is constrained by historical context and principles that in turn structure the innovation, such that when

> (…) new technology is introduced to society as knowledge, drawing from a broad technological platform, [it] is developed and adapted to specific uses under the influence of market needs and government policies, [but] the same technological paradigms or trajectories can act as effective barriers for alternative technologies (Åhman and Nilsson, 2008: 84).

This problematisation of the notion that society is resplendent with a capacity for constant change and innovation reorients our gaze to the question of stubborn, persistent conditions engendering a certain inertia (Hannan and Freeman, 1984; Altman, 2000; Zantvoort, 2017). Deviations from the status quo can be difficult once certain patterns of practice and being are sufficiently socialised within historical context, sometimes called the 'memory' or 'learning' that occurs in an institution or organisation (e.g. Sehring, 2009; Turley, 2021).

The following sections marshal original evidence to show how thinking about path dependency and techno-optimistic ideology together in relation to desalination has important implications for how we assess the value of this technology for the future of societal adaptation to climate change and in relation to how relevant this type of solution might be for the southwestern American borderlands. This perspective is particularly instructive as we empirically consider Arizona's desalination agenda across the remainder of the article.

## THE PATH DEPENDENCIES OF DESALINATION IN THE SOUTHWESTERN AMERICAN BORDERLANDS

The succeeding sections aim to better understand the evolution of the optimism embodied by desalination in the unique geographical context of Arizona – a territory with no physical link to the ocean. In addition to bringing discussions of path dependency and techno-optimism together on the topic of desalination, the cases explored provide more empirical variety to existing research, for, as geographer Joe Williams has recently discussed, there remains a paucity of critical social research regarding inland desalination, or at least inland desalinated water transport (Williams, 2022). Arizona, and more broadly the southwestern American borderlands, are an important region for examining both inland and ocean desalting politics.

## Dependence on the Central Arizona Project

Briefly revisiting the history of the Colorado River water supply for farmers and cities is relevant to the arguments we develop. To begin, Arizona is a state with a semi-arid climate, receiving 20 to 50 inches – or 50 to 127 cm – of annual precipitation. It has little natural surface water and is known for wide open and sparsely populated rural areas as much as for its densely populated urban centres, particularly Phoenix (which, at 4.5 million inhabitants, ranks 5th in the United States in terms of metropolitan population) (Le Tourneau, 2022). Its combination of dense urban growth alongside tremendous agricultural production (among the US states, ranking second behind California in head lettuce, leaf lettuce, romaine lettuce, and cauliflower production, not to mention the state's reputation for cotton, almonds, alfalfa, and copper),[9] industrial production, and a boom-bust housing economy (Benites-Gambirazio et al., 2016) have led to groundwater depletion (Eastoe and Gu, 2016).

To be sure, Arizona's relationship to natural resources has been troubled. Since 1922, the year in which the Colorado River Compact was signed, (allocating the water of the entire river), Arizona has had an allocation of 2.8 MAF. In the 1940s, a mega-hydro project was conceived: the Central Arizona Project (CAP). The initial goal was to meet the needs of irrigated agriculture and the growing desert metropolises. In 1968, the Colorado Basin Project Act was signed by the U.S. Congress and the CAP took concrete shape. However, the construction was only made possible because of a $4.4 billion[10] interest-free loan from the federal government (Glennon, 1995; McCoy, 2019).

The CAP has further significance because it is Arizona's first major confrontation with "water-coal energy nexus" challenges (Curley, 2021). Two million megawatt-hours are used to deliver CAP water each year, relying entirely on fossil energy and strongly tied to colonial politics (Powell, 2018; Yazzie and Baldy, 2018). However, in 2019, the coal-powered Navajo Generating Station was closed as part of a shift to renewable energy (e.g. solar and hydroelectricity) in a context where extraction, energy resources, colonial capitalism, and Indigenous sovereignty issues are interlocked (Curley, 2023).

Today, Colorado River water supplied by the CAP serves 80% of the state's population. Furthermore, the sustainable management of groundwater since the 1980s relies on Colorado water for aquifer recharge (Bernat et al., 2020). The CAP and its related infrastructure, in both the physical and organisational sense, influences and constrains the entire operation of local water management. In fact, the cost of the CAP and the need to reimburse the federal government gave Arizona an incentive to promote not conservation but active water consumption. At the same time, CAP water is subsidised, especially for farmers who are being charged a mere $56 an acre-foot, an amount that is well below the market rate according to several reports (Cortinas et al., 2016). And so, the CAP has triggered a real addiction to a flow of 'cheap' water (O'Neill, 2020). Of further concern, the Drought Contingency Plan, signed by all the Colorado River Basin states in 2019, indicates that farmers will be charged $88 per AF in 2028, while $281 per AF will be charged to municipalities. The CAP is clearly a problematic hydrosocial fix (Swyngedouw, 2013; Hommes et al., 2022) that has caused institutional dependencies in the region, especially of a legal or contractual nature. Once seen as 'renewable' and 'infinite' (words that now appear as desalination adjectives), the CAP is now a tenuous solution. Enter desalination.

## Arizona's desalination dreams

Since the 1960s, Arizona has considered all kinds of options for securing its water supply. The first mention of desalination occurred in 1964, when the first Arizona Town Hall on water supply issues brought forward the idea. As the minutes of the meeting show: "Research should be continued into the possibility of the processing of saline water as a future solution to the regional water problem". The

[9] Reporting from the Arizona Farm Bureau speaks to some of these agricultural dynamics and the importance of agriculture to the state's economy. For example, see https://www.azfb.org/Article/5-Arizona-Agriculture-Facts-You-Cant-Live-Without

[10] All monetary amounts refer to US$.

Arizona Town Hall is a significant political event in the state each year and features a number of high-profile speakers and politicians, who try to assess a particular concern: water, urban poverty, economic growth, the housing market, etc. In the 1964 Town Hall, it is of further interest to note that while desalination was a topic of debate, stress was also placed upon the importance of water conservation and rainwater harvesting. The 1977 Arizona Town Hall program was entitled Arizona Water – The Management of Scarcity. During these talks, desalination was stated clearly as a solution to supplement existing water sources. However, in the next two Town Hall meetings focused on water management, in 1984 and 1997, the prospect of desalination disappeared completely, and instead the favoured policies concerned the combatting of groundwater depletion, such as through the use of groundwater recharge and banking. During this period, water conservation practices were much more discussed than in the 1960s and 70s, no doubt due to general environmental consciousness but also because of certain legal reforms specific to the state. Indeed, the enactment of the Arizona Groundwater Management Act (GMA) in 1980 marks a shift in Arizona's approach to water management; henceforth, it would be based on a degree of demand management, following a more global trend toward a soft path (Gleick, 2003; Brooks and Brandes, 2011; O'Neill et al., 2018). To be sure, 'water conservation' has become an umbrella expression to refer to these new water management strategies, more decentralised in terms of infrastructure and decision-making and inclusive of people's habits or behaviours regarding water (Saurí et al., 2014; O'Neill and Boyer, 2020; Boyer et al., 2021).

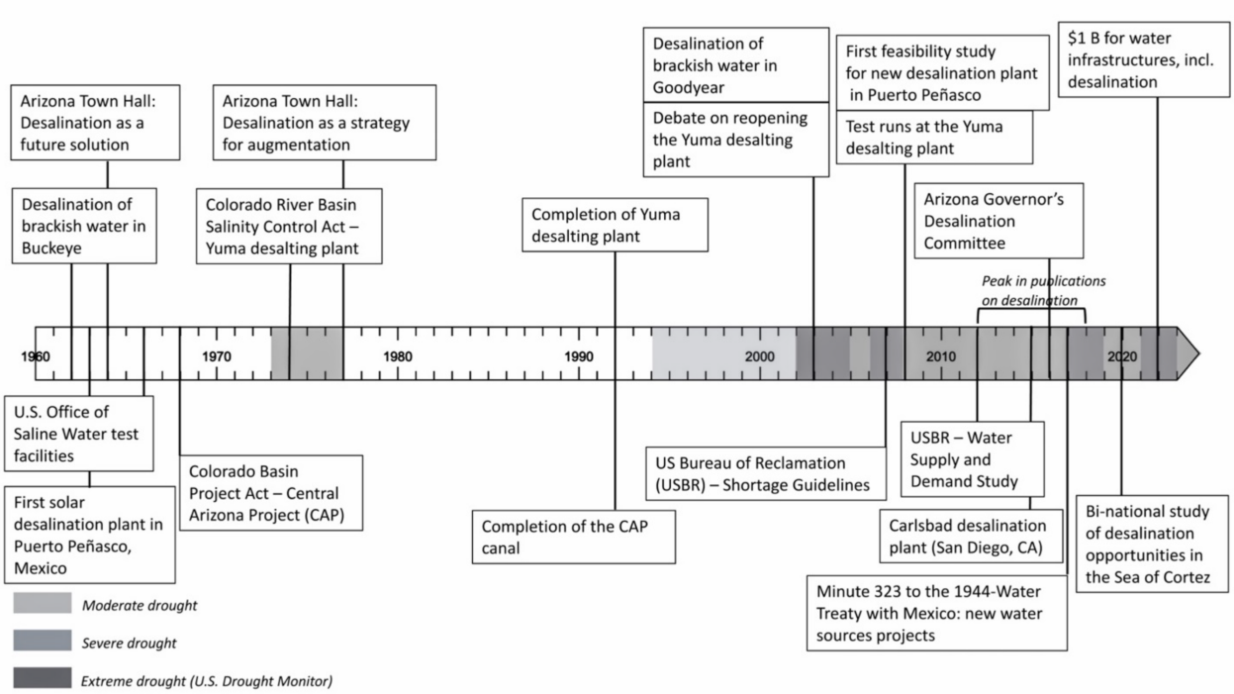
However, the context in which desalination re-emerges most strongly appears shortly after the most recent drought began on the Colorado River as a whole. According to the US Drought Monitor, from 2002 to 2005 an extreme or severe drought affected more than 80% of the region, with high risks of agricultural losses and shortages of water in reservoirs and wells creating water emergencies (Figure 2). At the same time, water managers at the federal and regional levels began calling for desalination as the solution to scarcity. In fact, as we were told throughout our fieldwork, there always is an imperative, even if unspoken among water professionals, that it is important to "never waste a crisis". Crises can become useful junctures, i.e. springboards to advancing a particular policy vision, as policy scholars have often noted (Keeler, 1993). In light of such issues, one long-time water management expert who worked on both the CAP and Arizona's desalination agenda mentioned the need to think about the 'big picture' in the following way:

> I don't have any belief that we're going to keep people from coming to the Southwest (…) so we need new water supplies. We're going to have to look at *big picture deals* like an ocean desalting plant. (…) A big plant, one that produces as much water as the Central Arizona Project does, a million and a half acre-feet per year, and use as much as you want to or need in the Sonora area, Hermosa, San Carlos, Nogales, San Luis, Port of Mexicali. Run some by pipe, if you need to, over to the western side of the Sea of Cortez or the eastern shore of Baja (…) Take the rest of it, a million-acre feet, up in an open canal, as cheap a pipe as you can get, and bring it up and dump it in the Colorado River just above Imperial Dam (emphasis added).[11]

As this expert states, these deals are the way of the future for Arizona. Indeed, any behavioural modification or means of working within the hydrological context of the region to reuse and conserve water seems foregone from the outset for these policy elites. The enduring interest in desalination as supply policy for the past six decades is visualised in Figure 2.

[11] Page 35-36 - Interview with Larry Dozier, conducted on July 9th, 2007 as part of the CAP Oral History project. The full interview transcript can be found at the following link: https://library.cap-az.com/documents/about/oral-histories/Larry-Dozier-Transcript.pdf

Figure 2. Timeline of the history of desalination in Arizona from 1960 to 2022.




Sources: 2012 United States Bureau of Reclamation Water Supply and Demand Study, 2010 Central Arizona Salinity Study, National Archives (College Park, Maryland), Record Group 380: Records of the Office of Saline Water. © the authors.

## Desalinating the Sea of Cortez, Part 1: A life support for the Colorado River

The proposed site for a new 'big deal', i.e. large-scale desalination facility is Puerto Peñasco (also called Rocky Point) in Sonora, Mexico. Now a growing tourist locality, it has long worked as a pilot site for desalination. Experiments funded by the US – in this case the University of Arizona (Koch, 2022) – have been conducted there since the 1960s, as can be seen in the archival photograph of a 1963 water management report produced by the OSW (Figure 3).

In 2008, with the technological progress made in the desalination sector and the worsening drought, the U.S. Trade and Development Agency and Sonora's state water commission ordered the first feasibility studies for a large-scale binational desalination plant in the Arizona-Sonora borderlands, to be located in Puerto Peñasco. These preliminary plans concluded that the plant could be constructed by 2011, with peak production to be reached by 2020. However, it is only in 2012 that the International Boundary Water Commission (IBWC) – the entity responsible for the application of water treaties between the United States and Mexico – signed an agreement on research exploring prospective binational desalination plants. Later, in 2014, another step forward for the official adoption of the projected Puerto Peñasco plant was taken through an agreement signed by the state governors of Arizona and Sonora to investigate desalination opportunities. The multiplication of statements and reports from various actors (federal agencies, states, regional water managers, counties, municipalities, etc) is explained by the fact that delivering desalinated water from Mexico to Arizona will require approval at multiple levels of government and robust intergovernmental cooperation.

Figure 3. Page 126 of 1963 *Saline Water Conversion Report.*

distillation preferable to other saline water conversion processes. In such cases, favorable economics indicate plant size not in excess of 50,000 to 100,000 g.p.d.

**MULTIPLE-EFFECT HUMIDIFICATION (SOLAR HEATED)**

An experimental solar energy multiple-effect humidification plant has been developed by the University of Arizona at its Solar Energy Laboratory of the Institute of Atmospheric Physics, Tucson, Ariz. (fig. 110 and 111). The plant was constructed to test the feasibility of using solar energy as a heat source in a humidification system which separates the collection of energy, evaporation of the salt water, and condensation of the product water. This separation permits multiple-effect operation. The Tucson pilot plant is described in the *Saline Water Conversion Report for 1962*.

Developmental work was continued during 1963. The modified pilot unit now has a new rectangular, vertical-finned tube condenser and a new circular-packed tower evaporator (fig. 110) in combination with doubleglazing, plastic solar collectors. The experimental plant operates at two effects and produces over one-third g.p.d. of fresh water per square foot of collector area.

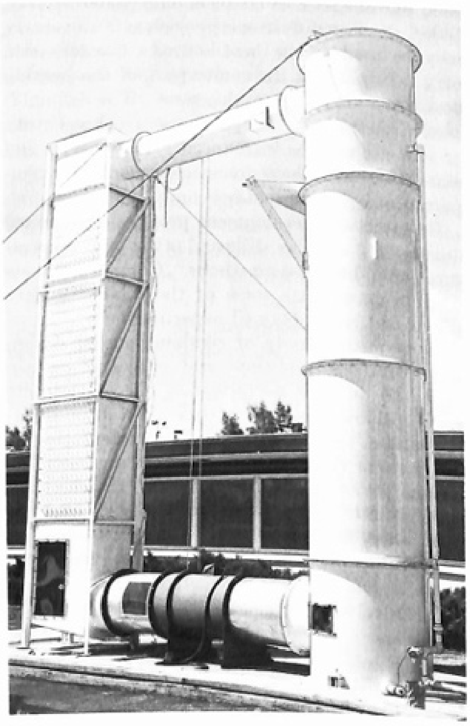


FIGURE 110.—Evaporator-condenser unit, Tucson experimental plant.

**HUMIDIFICATION—PILOT PLANT**

The University of Arizona, in cooperation with the University of Sonora, Mexico, has constructed a larger pilot plant at Puerto Peñasco, Sonora, Mexico, on the Gulf of California. Puerto Peñasco was selected as the site for the pilot plant because of its desirable meteorological conditions, its proximity to the experimental facility at Tucson, and the great need of the city of Puerto Peñasco for a supply of good water. The present 3,300 people of Puerto Peñasco pay $12 per 1,000 gallons for water; their entire supply, consisting of slightly brackish water (1,000 p.p.m. total dissolved solids), is trucked into the city's distribution system.

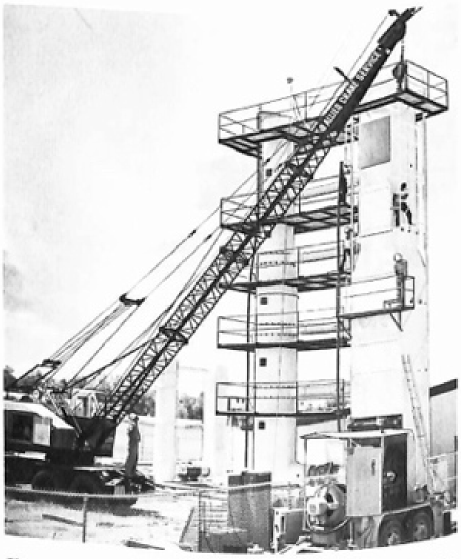


FIGURE 111.—Peñasco pilot plant evaporator-condenser unit (under construction at Tucson).

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Note: this report was published by the OSW in conjunction with the Department of the Interior. National Archives (College Park, Maryland), Record Group 380: Records of the Office of Saline Water – Office of the Assistant Secretary for Water Pollution Control/Office of Saline Water. Box No. 1 "Reports and Studies 1960-69". This image is in a folder marked as "Reports, Studies, and Tech. Papers 1963". The figures and text describe an experimental solar energy multi-effect humidification desalination plant that was constructed by researchers at the University of Arizona, notably Carl N. Hodges, and the University of Sonora.[12] Copy courtesy of the National Archives.

[12] More information on Hodges can be found at the following link: https://www.cedo.org/read/cedo-en/in-remembrance-of-carl-n-hodges/

Several publications of the time provide a deeper analysis of the different steps towards such a project and assessments of its socio-ecological impacts and pitfalls in terms of international water management (Ela and McEvoy, 2012; McEvoy and Wilder, 2012; Megdal et al., 2012; Wilder et al., 2016; Mumme et al., 2017; Hirt et al., 2017; Albrecht and Gerlak, 2022). These papers converge to show the potentially uneven distribution of costs and benefits of this expensive, energy-intensive technology and how it is likely to exacerbate existing social inequalities in the borderland region. Thus, as Hirt et al. (2017: 278) highlight, on top of shifting scarcity from the US energy sector to the Mexican one, there is a "troubling bilateral inequity inherent in a project that provides clean water to one country but leaves the wastes in another country", since brine residues will be discharged back into the ocean in a region which is a biodiversity hotspot (e.g. marine priority sites protected by the Mexican federal government and wetlands protected under the international Ramsar convention). If international desalination projects are often analysed as game changers in transboundary politics (Aviram et al., 2014) with a shift from conflict to potential cooperation, here the project relies on the significant socio-economic unbalance and uneven levels of development that characterise the American Southwest borderlands (Grineski and Collins, 2017).

In 2017, in the context of regional negotiations regarding the Drought Contingency Plan for the Colorado River required by the federal government, the US and Mexico amended the 1944 Water Treaty with Minute 323, entitled *Extension of Cooperative Measures and Adoption of a Binational Water Scarcity Contingency Plan in the Colorado River Basin*. This directed the creation of a Binational Desalination Work Group. Released in 2020, a study by an engineering consulting team concluded with similar results to those found in previous reports (Black and Veatch/Libra, 2020): a potential binational desalination project located along the Sea of Cortez is both technically and economically feasible; the main goal would be to transfer water to the Yuma-area hydraulic infrastructures (e.g. at the Morelos Dam on the border or at the Imperial Dam at the crossroads of the All-American Canal, the Yuma Aqueduct, and the Gila Riva) in exchange for Colorado River water; and the cost of desalinated water would range from $2,000-$2,200/AF for an exchange opportunity of 200,000 acre-feet a year. The report considers five different locations and diverse conveyance routes for a desalination plant on the coast of Sonora but does not go as far as making recommendations, as an Environmental Impact Statement will most likely later do so if the project comes to concrete existence. On the contrary, it highlights how such a project will require more minutes to existing water treaties, especially to make possible the construction of a framework through which binational exchanges of water could eventually occur (Wilder et al., 2016; Mumme et al., 2017). Furthermore, the grey literature produced on this project shows that the promotion of a US-Mexico desalination project relies on the success of Carlsbad in California for the technological aspects and on the example of the Israel-Jordan agreement signed in 2015 on the Red Sea-Dead Sea project for the hydro-diplomatic dimensions it implies (Megdal et al., 2012).

Thus, Arizona's desalination dreams are not only limited to ocean desalination itself. Rather, due to the fact of it being a landlocked state, ocean desalination goes with an ambitious conveyance infrastructure in the form of pipelines or canals to bring the water to some suitable location where Arizona can take control of it. This perspective is informed by geopolitical concerns and the pre-existing policies and infrastructure at the disposal of decision-makers.

### Desalinating the Sea of Cortez, Part 2: Bypassing the Colorado River shortage?

There have been a number of very recent events that continue to give shape to discussion of desalinating the Sea of Cortez. In January 2022, in his last State of the State address, Arizona's outgoing Republican governor announced $1 billion for water infrastructure management, explicitly pushing for the implementation of the long-considered large-scale desalination plant on the northern shore of the Sea of Cortez in Mexico to sustain Arizona's growing economy. For him, it is time for the dream to become reality:

> Now, with resources available in our budget, a relationship with Mexico that we have built and strengthened over the last seven years, and the need clear – what better place to invest more? Instead of just talking about desalination – the technology that made Israel the world's water superpower – how about we pave the way to make it actually happen?[13]

In the aftermath of this, the Israel-based desalination firm IDE Technologies actually presented to the state of Arizona its very own desalination project in Puerto Peñasco, along with a pipeline that would pump the desalinated water into Arizona through Organ Pipe Cactus National Monument to a water distribution facility tied into the CAP at Lake Pleasant, north of Phoenix. The IDE Technologies plans outline how it could serve Arizona directly, with bypasses from the main pipeline to serve users interested in purchasing desalinated water, which raises the question of a new private actor in a complex, largely public, and bureaucratic water system.

One player considering going it alone to secure its water supply is the City of Tucson in Pima County, which is the most dependent in Arizona on CAP water: 80% of its water supply comes from the Colorado River. Due to this dependency, it began to consider unconventional water supplies in the early 2000s. For example, the opening of the *Tucson Water Plan 2000-2050,* released in 2004, starts by making a link between acquiring new sources and the challenge of urban growth:

> There may be a theoretical limit on the number of people who can sustainably reside in the Tucson area. To expand beyond this limit is to cross the critical threshold from a community growing with sustainable water resources to one that depends on gradual resource depletion.

In this document, the municipality develops diverse strategies for pushing this limit as far as possible. It states:

> The currently improbable sources of supply might include the desalinization of sea water, weather modification to increase local precipitation, watershed modification to increase runoff and basin recharge, and of course iceberg harvesting among others. Where the practical end of the spectrum grades into the improbable is not clear and cost may not be a limiting factor if there is a great enough need (p.122).

However, in 2012, Tucson's plan to acquire "improbable sources" was updated in light of the publication by the USBR of the *Colorado River Basin Water Supply and Demand Study*, illuminating the multiple means of articulation across scales in the system. Thus, Tucson Water explains:

> Statewide efforts have continued to explore developing a seawater desalination facility in partnership with a coastal community in the United States or Mexico that has higher-priority rights to Colorado River water. Under such a potential agreement, Tucson could, in partnership with others, provide funding to the coastal community to desalinate seawater for use in that location in exchange for more Colorado River water to import to the Tucson area through the CAP. If this type of arrangement were to occur, it would likely be many decades out. Tucson Water continues to participate in these discussions to take advantage of this potential opportunity if and when it occurs (p.31).

Beyond the dependencies of multiple cities on the Colorado River infrastructure, further connections can be made at the regional and county scales. As Colorado River water cutbacks were implemented in 2019, Pima County decided to take the lead in asserting its position on the potential of seawater desalination, no longer in terms of exchange within the Colorado River system but rather to supply Tucson directly. By 2021, the Pima County Public Works Administration had published a study reworking the report by the Binational Desalination Work Group to assess how a pipeline from the projected desalting plant on the shore of the Sea of Cortez in Sonora could benefit Tucson. For the scenario of a projected population of 1.5 million, a drop to 6 inches (152.4 mm) in annual rainfall, and no more Central Arizona Project water

[13] The full Arizona State of the State Address – 2022 by Gov. Doug Ducey can be found here: https://azgovernor.gov/governor/files/2022-arizona-state-state-address

delivery, the study considers that 90 million gallons (over 340 million litres) of water per day – 100,813 acre-feet per year – would need to be imported to maintain current groundwater levels and supply the urban area. Therefore, the plan envisions a 196-mile (315 km) pipeline, operated by 5 pumps for a total elevation lift of 3,853 feet (1174 m) from Southern Sonora to the Southern Avra Valley Storage and Recovery Project (SAVSRP) near Tucson, where CAP water is currently being recharged into the aquifers. The construction cost estimate for the desalination plant and pipeline is $4.1 billion.[14] This project's financial analysis assumes Federal grant funding for 50% of the capital cost and the remaining debt to be paid over 50 years. However, the cost could add up to $60-90 per month to the typical Tucson-area inhabitants' water bill (Wieduwilt, 2021). Not only would this plan require transnational agreements, but also agreements at the level of municipal intrastate governance.

The grey literature on these projects reveals the path dependency implied by the highly complex management of the Colorado River Basin that was put in place in 1922 and, even if amended, it has never deeply transformed. While desalination is often a strategy to avoid dependence on large water transfers and centralised decision-making (March, 2015; Williams, 2018b), the above case examples bear out how a plant in Sonora would, on the contrary, be part of one more large water importation project: that of transporting water over 168 miles (270 km) to Arizona. Furthermore, water supply deficits could reach 335,800 acre-feet a year in Arizona and 112,700 in Northern Sonora (Black and Veatch/Libra, 2020), and so the solution of a water desalination plant in Puerto Peñasco seems to be both a very expensive and highly complex drop of water in the bucket needed to face demand in this fast-growing arid region of North America.

### Inland desalination in Yuma, Arizona: Path-dependency and geopolitics of the borderland

The other large-scale desalination project that Arizona is envisioning is inland and deals with agricultural brackish run-off: the re-opening of the Yuma desalting plant. The Yuma territory in particular has long been seen as part of the 'big-picture' plan for Arizona:

> …it's just a shame when everybody is looking for new water supplies and desalinisation is the technology they're all looking at and here sits a fully capable desalinisation plant, the largest in the United States if not the largest of its type in the world, with brackish water all over the place, and we're not operating it. It just seems like a shame. It's a waste of a resource, in a time when we're all looking for new water, that it's not cranking out water.[15]

In 2007, as drought was severely affecting the functioning of the Colorado River system, the USBR released for the first time its *Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead*, which is the starting point of the debate on 'reopening' (moving it out of idle status and possibly expanding its capacity) the existing Yuma desalination plant, located in the Imperial Valley at the border between California, Arizona, and Mexico. The Yuma Desalting Plant was created in 1974 by the Colorado River Basin Salinity Control Act. Indeed, in 1944, the Mexican Water Treaty allotted to Mexico a guaranteed annual quantity of 1.5 MAF of water from the Colorado River. But in the 1960s, Mexico filed a formal complaint against the US, claiming that the water quality was too poor, notably because of saline agricultural return flows to the river. As a result, the federal government authorised the construction of a facility whose sole purpose was to desalinate Colorado River water and brackish agricultural run-off. However, while lauded in the archives, it also indicates that it was, in a sense, a disproportionate reaction. As long time Arizona water expert Ed Hallenbeck has attested:

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[14]For example, this was reported in the news in Tucson, Arizona at the following link: https://tucson.com/news/local/subscriber/a-4-1-billion-desalination-plant-the-wave-of-pima-countys-future/article_5c3d6548-f1a7-11eb-97de-d7966c7779ea.html

[15] Page 32 - Interview with Larry Dozier, conducted on July 9th, 2007, as part of the CAP Oral History project. The full interview transcript can be found at https://library.cap-az.com/documents/about/oral-histories/Larry-Dozier-Transcript.pdf

> The desalting plant? It solved the problem politically. It threw money at it and solved it in a political sense. I was a little bit frustrated towards the end; it didn't seem to be a great deal of interest in people divvying up their various budgets throughout the Bureau in order to operate it. And in that case, it still holds. And you try and get the money to run the desalting plant today; everybody says it costs too much. Well, we pretty well knew that back when we were building it. It took care of the political anxiety of Mexico, and I think at that time that was one of [the] things they were shooting for.[16]

Here, we can understand the Yuma desalination project as an attempt to fix a political and legal dependence (the Treaty with Mexico) by focusing only on water quantity delivery in an inland hydro-bureaucratic context (Molle et al., 2009).

Completed in 1992 at a cost of $280 million, the Yuma project was ultimately a disappointment; it operated only at one-third capacity for one year and then was shut down (idle status) because of higher Colorado River flows – allowing larger releases from Lake Mead to Mexico, among other operational considerations. The plant is now mostly an onsite water treatment research facility called the Water Quality Improvement Center, managed by the US Bureau of Reclamation. Its focus is on analysis of inland brackish water, and it is surrounded by a canal and lettuce fields. The site is a veritable amalgamation of the complex tensions surrounding water management in Arizona and speaks to the history of path dependence in the region (Figure 4).

Figure 4. January 22, 2020 – The Yuma Desalter, Yuma, Arizona.

Note: The desalination plant is in the back left-hand side of the image. While it is common in this region to see landscapes combining industrial sites, agriculture, and water canals, such as can be seen in this image, the Yuma desalting site is remarkable for its convergence of industrial agriculture, water resource management, and energy infrastructure in a single locale. Image © Brian F. O'Neill

[16] Page 4 – Interview with Ed Hallenbeck, conducted on July 8, 2004, as part of the CAP Oral History Project. The full interview transcript can be found at https://library.cap-az.com/documents/about/oral-histories/Ed-Hallenbeck-Transcript.pdf

However, the initial failure of the Yuma desalter did not spell its demise. Press articles from the *Arizona Republic* show that in 2003 and 2005, expectations were high for technological improvements that could allow the functioning of inland desalination plants. One example, in July 2003, states that "Arizona water managers hope that advances on the [California] coast will eventually filter to inland plants that will treat brackish groundwater and salty sewage". In 2005, Secretary of Interior Norton's *Water 2025 – Preventing Crises and Conflicts in the West* initiative made funding available to begin conducting pilot projects in Yuma, which would work on improving desalination technologies to make them more affordable and accessible. Part of these discussions involved not only the technological feasibility of revamping the Yuma desalter, but how it could help aid the political tensions between river basin users (USBR, 2012b) – a known ambition for desalination at the basin scale (Williams, 2018a; Bernat and Megdal, 2022).

More recently, the most commonly discussed model for how the Yuma project could be reapproached is not only to treat brackish water for delivery to Mexico, but to cut back on Arizona's withdrawals from Lake Mead. The impact of this indicates a level of broader structural thinking on the part of Arizona's water management experts, in the sense that they are concerned about the entire river basin, but also indicates that they realise Arizona (given its low priority on Colorado River water) has the most to lose when the basin system is suffering. As such, by limiting withdrawals from Lake Mead, looming shortages can be reduced.

As might be expected, the reopening of the Yuma desalination plant has had opposition from environmental groups on both sides of the border for some time. In 1975, when the Yuma site was first selected and some foundations were being laid for future completion of the project, the US began draining salty agricultural runoff to the Cienega de Santa Clara, near the Sea of Cortez on the Mexican side, eventually creating the largest remaining wetland in the Colorado River delta. This marsh now supports endangered bird and fish species and is protected both at the Mexican federal level and internationally (by the Ramsar Convention). Therefore, despite its human-made nature, conservation groups fear that if the water currently flowing to the wetland is desalinated, it would threaten the very existence of the Cienega, which the Yuma Desalter helped create in the first place (Zengel et al., 1995; Fleck, 2016). On that matter, several test runs were conducted in 2008 and 2010-2011; the results showed that the plant could operate while maintaining artificial ecological flows and produce desalinated water at a cost roughly estimated to be in the range of $400-$500 an acre-foot (Desalination Committee, 2018). Getting the plant to operate at full capacity is calculated to have a cost of approximately $70 million in 2022 dollars, which is roughly comparable to other large-scale facilities that have been observed in California. If the Yuma desalting plant is to re-open to maintain Lake Mead levels, investment efforts would have to be shared amongst all Colorado River Basin states and Mexico, since the binational Drought Contingency Plan signed in 2019 is now in effect (USBR, 2019).

What the history so far shows is that desalination does not really offer a decentralised source of water, independent from river basin politics, despite what popular commentators might claim. Instead, it has become increasingly clear that desalination is a contributor to the American Southwest's path dependency on the Colorado River system. Indeed, as described by political scientist Jacob Hacker, path dependence processes are common in politics and policymaking, because "policy creates or encourages the creation of large-scale organisations with substantial set-up costs [and] embodies long-lived commitments upon which beneficiaries and those around them premise crucial life and organisational decisions" (Hacker, 2002: 55). The Yuma desalter continues to feature in policy proposals that attempt to solve a multitude of issues that have arisen in the Colorado River basin.

**Brackish aquifer desalination in the metropole: The path dependencies of groundwater exploitation**

In 2019, a study by the Governor's Water Augmentation Council concluded that desalination of local brackish groundwater was an important water strategy available to Arizona. The logic behind this position involves the elaboration of multiple methods for desalting, notably including brackish groundwater.

Various reports and media discussions on the topic of utilising saline groundwater have been emerging since the early 2000s. Notably, a *Central Arizona Salinity Report* (2006: 17) states that there are "over a million tons of salt accumulating in the Phoenix Metropolitan Area" and "that managing salinity is required for the long-term sustainability of Arizona". As consultants on the issue have remarked, it would seem like a win-win situation to advance brackish groundwater desalination projects (Montgomery and Associates, 2008, 2019). Brackish water has a composition of 1000 to 10,000 mg/L of total dissolved solids, which makes it distastefully salty and unpotable, as it often goes with high levels of contaminants such as nitrates and arsenic (Tidwell et al., 2018). In Arizona, soils and groundwater are degraded by natural and anthropogenic causes of salinity, as is often the case in arid regions (Afonso et al., 2004; Lashkaripour and Zivdar, 2005). Moreover, those processes are accelerated in times of drought, notably through increased evaporation and diminution of groundwater replenishment rates. In Northern Arizona, high salinity levels are due to ancient and natural salt deposits. In Central and Southern Arizona, however, they are mostly caused by the multiple agriculture irrigation cycles (Eden, 2011; Anning et al., 2018). By 2016, the CAP ordered an updated report to assess the availability of recoverable brackish groundwater throughout the state (Montgomery and Associates, 2008, 2019). The study describes a largely untapped resource of approximately 600 MAF of water. In the Diné (Navajo) and Hopi reservations on the Little Colorado Plateau, the same report estimates that brackish groundwater resources could represent up to 200 MAF. In the Phoenix area, aquifers contain approximately 185 MAF of recoverable brackish water, and in the Yuma area, 50 MAF of groundwater could be treated by the Yuma desalting plant on top of the desalination of surface water and agricultural run-off.[17]

As with ocean desalting, the region has been pursuing brackish desalination in various forms since the 1960s. For example, in 1962, the Town of Buckeye, in the vicinity of Phoenix, built the first municipal-level desalination plant in the U.S. to treat groundwater. Buckeye sits on a waterlogged area where brackish water needs to be pumped from areas of dewatered wells to avoid a rising water table that would damage local agriculture (Boyer and Bernat, 2020). The plant was shut down in 1988 because of high operation costs. But today, the City of Buckeye (as it has been renamed) is considering a new facility that would be able to provide potable water for the city (Strategic Plan, 2020). Similarly, the City of Goodyear, located nearby, runs a small-scale desalination plant to provide water to municipal users. This reverse-osmosis drinking water treatment plant was first built for lack of anything better (Interview – May 22, 2019, Goodyear's Water Resources Manager), as the municipality was only relying on low-quality groundwater supplies until 2022. Indeed, Goodyear could not access its CAP water allocation (11,000 acre-feet) until the recent completion of a surface-water treatment plant. One can already see the irony of a general situation where the CAP is seeking to diversify water users' portfolio by looking at desalination, while locally, the only municipality in Arizona with the technology is relieved to finally have access to CAP.

Despite these mixed successes, the desalination of brackish groundwater poses three main issues in Arizona. The first is that it is a non-renewable resource, considered as such by the Groundwater Management Act. The Governor's Water Augmentation Council even states that brackish groundwater should be considered as groundwater and "should continue to be regulated as it currently is". Groundwater in Arizona is subject to significant regulation, particularly within the framework of Active

[17] A map of the brackish water resources in Arizona estimated by Montgomery and Associates can be found here: https://new.azwater.gov/news/articles/2018-12-01

Management Areas delineated around large urban areas (Phoenix, Tucson, Flagstaff, Nogales, etc) and irrigated agriculture. In these areas, the goal is to reach what is called 'safe yield' so that withdrawals do not exceed the recharge rate, and eventually to eliminate pumping from the aquifers (Colby and Jacobs, 2007). As Arizona has experienced risks associated with overexploitation in the past, especially land subsidence and deterioration of water quality, water managers since the 1980s have focused all their efforts on diverting water users from groundwater, always aiming at finding renewable replacements, of which the CAP is the largest so far. Given the fact that safe yield is hard to reach – it is supposed to be achieved in 2025 – in a semi-arid environment with low replenishment rates stricken by drought, the question of investing in desalination plants for treating highly regulated and limited amounts of water is an important one.

The second issue is the one of brine concentrate produced by the desalination of brackish water in an environment already challenged by salinity. In such a context, the salts have to be removed from the water cycle. However, neither of the three most common methods of brine management – evaporation ponds, deep-well injection in isolated aquifers, or sewer disposal – are sustainable if large quantities of brine are generated; they are either too physically expansive (i.e. the cost of the land in an urban environment would be too high), or non-existent in Arizona due to local geology, or chemically affect the wastewater treatment facilities. In Goodyear, for now, the city has to mix brine concentrates with regular wastewater in order to be able to store it in its wastewater treatment facility. As such, this raises unanswered questions not just regarding the cost of the desalinated water itself, but especially of the other forms of treatment that will be needed to maintain the quality of the aquifer.

That said, Goodyear, with the USBR, has been conducting a pilot project to treat the brine concentrate through a constructed wetland (Central Arizona Salinity Study, 2010). Experiments have demonstrated that plants which normally thrive in salty conditions are able to absorb salts and other contaminants (Tosline, 2019). If the final project is completed, brine concentrate will be mixed with groundwater in the artificial wetland and effluents will be finally discharged to the Gila River (Chakraborti et al., 2022). Based on the plan, called *From Brine to Beautiful*, planners are envisioning the wetland becoming a recreation area for Goodyear residents and also tourists, providing a perennial water supply as part of a river restoration plan for the Gila River.[18] As Goodyear is one the fastest-growing cities in the US (US Census, 2022), the size of the wetland would have to reach 45 acres to be able to treat the increased brine concentrate produced by the desalination of local brackish groundwater. This project is promising at a city scale of 165,000 inhabitants, but it would be an economic and ecological challenge to scale up regionally. For large-scale brine management, the last *Central Arizona Salinity Study* (2010) recommends the construction of a pipeline to Yuma to discharge the Phoenix-area-produced brine into the ocean. The report considers this solution to be "the most environmentally friendly" one.

Especially given the brine disposal challenges for inland desalination, the third issue with large-scale brackish groundwater recovery is the cost. Even though brackish water treatment is often considered to be cheaper than seawater desalination, reports assessing potential sites for brackish groundwater all calculate that such production would cost from $600 to $1200 an acre-foot of water (Desalination Committee, 2018), which is between 10 and 20 times more than CAP water. With water cuts on the CAP system, water users are turning back to aquifers, in which many have stored water. Putting the brackish groundwater to use is another turning point in the direction of groundwater exploitation, in a context where institutions such as the Arizona Department of Water Resources have gained power, legitimacy, and social recognition in sustainable groundwater management and are presented as institutional arrangements able to avoid the mistakes of the past.

Table 1 summarises the above discussion of the case studies of the uneven trajectories of desalination proposals for the Sea of Cortez in Mexico, brackish water in Yuma, Arizona, and urban aquifer

[18] For more information on this, see the following link: https://static.sustainability.asu.edu/giosMS-uploads/sites/22/2015/01/Goodyear-Wetland-Brief.pdf

desalination. Following from insights in political ecology, path dependency theory, and critiques of technologically optimistic ideology, the evidence presented points to how Arizona remains 'locked in' to this infrastructural commitment because of past policies, decisions, and tendencies. The historical relationship water managers and politicians have held with the technology of desalination are the result of a combination of mechanisms across the case studies, but it is clear that institutional memory, fixed capital costs, networks of contractual relations, and social power continue to be significant factors.

Table 1. Summary of cases, desalination technology type, and water amounts, as well as relevant organisational context and path dependencies.

| Case | Desalination type | Organizations | Path dependency type | Description |
|---|---|---|---|---|
| Puerto Peñasco Desalination plant | Seawater<br>Reverse osmosis<br><br>100,000 to 200,000 AFY (Binational Water Commission)<br><br>1 million AFY (IDE Technologies) | *Fed. level*:<br>- Trade & Development Agency<br>- IWBC<br>- Binational Desalination Work Group (DCP)<br>*State level*:<br>- Sonora Water Commission (Mex.)<br>- Arizona Mexico Commission<br>- CAP<br>- State of AZ (ADWR; Gov.)<br>*Regional level*:<br>- Pima County<br>- Southern Nevada Water Authority<br>*Private*:<br>- IDE Technologies | Power and vested interests<br><br>Formal and informal contracts | The distribution of power makes it beneficial for some actors to work for the existence of their institutions +institutions are reproduced through the support of elite groups.<br><br>Can be costly to change and have large barriers to exit. There is a natural preference for honoring contract rather than breaking them. |
| Yuma Desalination Plant | Brackish surface water<br>Reverse osmosis<br><br>70,000 AFY | *Fed. Level*:<br>- USBR<br>*State level*:<br>- State of AZ (Governor's Water Augmentation Council)<br>- Central Arizona Project<br>*Regional level*:<br>- Southern Nevada Water Authority<br>*Municipal level*:<br>- The Metropolitan Water District of Southern California | Socio-ecological memory<br><br>Large fixed costs | History of management and accumulated knowledge can generate institutional inertia<br><br>Make the continuation of an established infrastructural pattern a less expensive option than creating new patterns |
| Municipal Groundwater Plants | Brackish aquifers<br>Reverse osmosis<br><br>91,000 AFY | *State level*:<br>- State of AZ (GMA; Governor's Water Augmentation Council)<br>*Municipal level*:<br>- Goodyear, Scottsdale, Buckeye | Learning effects | A correct way of addressing problems has been established, decisions follow an already experienced path |

Sources: referenced grey literature reports and studies; see also Turley (2021).

## CONCLUSIONS: IS DESALINATION JUST ANOTHER TOOL IN THE TOOLBOX?

Due to Arizona's low priority access to the Colorado River, and even though it is an inland state, this article explored the ways in which Arizona water managers have historically described and continue to discuss and attempt to implement desalination as one of the necessary tools to face shortage situations. And the context of climate change has provided a new justification for resurrecting and expanding the implementation of this technology. The desalination projects we examined are considered on several scales: large-scale infrastructures with regional and international implications that would relieve the tensions of the Colorado River Basin system, but also smaller and localised infrastructures supported by cities, in particular the suburbs with strong demographic growth on the edge of the Phoenix metropolis. To these ends, desalination is framed as both a regional climate adaptation tool but also as an urban climate change adaptation strategy.

Recently, desalination found its way back into public view as a core issue in the political debate during the election campaign for the Arizona Governor's seat. Republican candidates insisted that "desalination is the future", as notably stated on candidate Kari Lake's website in February 2022. However, during a press conference held in front of the State Capitol, Bruce Babbitt, the former Arizona Governor and former Secretary of the Interior who passed the GMA in 1980 and is known for his ecocentric ideas, stated as a response to these ambitious announcements that "desalination will not be an answer to Arizona's water crisis in the next generation". This occurred as part of Babbitt's support of a bill that would allow for the regulation of groundwater in rural parts of the state and tends toward a focus on water conservation strategies rather than augmentation. The positions taken on desalination could therefore be the object of the ongoing political polarisation typical of the current American context, which comes on top of the existing tensions between water augmentation and water conservation, between the hard path and the soft path that may be chosen for climate change adaptation. The risk of this approach is that discourses and projects involving water desalination obscure the range of alternatives, implemented at the local scale, to adapt the region and especially the cities to a warmer world with less water. Solutions such as water recycling, rainwater harvesting, greywater harvesting, drip irrigation, and other water-conserving devices are less-advertised, perhaps largely disregarded aspects of the water manager's proverbial toolbox.

Indeed, reflecting on the historical events surrounding desalination in and around the American Southwestern borderlands and the contemporary popular discussions of the topic, one often sees it spoken of in what appear to be conservative terms, even if they are slightly inflammatory ones. "We need more tools in the damn toolkit", as California Governor Gavin Newsom exasperatedly declared about the failed Huntington Beach project.[19] What this article has endeavoured to show, though, is that even when desalination is "just another tool in the toolbox", the historical and contemporary evidence point to the fact that desalination continually takes an outsized place in water planning discussions, due to the significant financial and political commitments the technology requires. In so doing, desalination quite often has the effect of locking in a 'hard' path dependency, even when the push to promote it seems to be based on attempts to evade old political, legal, and institutional structures.

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[19] This quote has made the rounds on various newswires and is a sentiment that also can be seen in the discourse in Arizona as well. See, for example: https://www.mercurynews.com/2022/04/29/newsom-desalination-project-should-be-approved-we-need-more-damn-tools-in-the-toolkit/

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