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Water insecurity in the Global North: A review of experiences in U.S. colonias communities along the Mexico border

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Abstract

Since the late 1970s, the term “colonias” (in English) has described low-income, peri-urban, and rural subdivisions north of the U.S.-Mexico border. These communities are in arid and semi-arid regions—now in a megadrought—and tend to have limited basic infrastructure, including community water service and sanitation. Recent scholarship has demonstrated how colonias residents experience unjust and inequitable dynamics that produce water insecurity in the Global North. In this review, we explain why U.S. colonias are an important example for theorizing water insecurity in the United States and beyond in the Global North. Tracing the history of water infrastructure development in U.S. colonias, we show how colonias are legally and socially defined by water insecurity. We draw on the published literature to discuss key factors that produce water insecurity in U.S. colonias: political exclusion, municipal underbounding, and failures in water quality monitoring. We show that water insecurity had led to negative outcomes—including poor water access, risks to physical health, and mental ill-health—in U.S. colonias. We present four possible approaches to improving water security in U.S. colonias: (1) soft paths & social infrastructure for water delivery, (2) decentralized water treatment approaches, such as point-of-use, point-of-entry, and fit-for-purpose systems; (3) informality, including infrastructural, economic, and socio-cultural innovations; and (4) political, policy, and law innovations and reforms. At the same time, we reflect seriously on how water security can be ethically achieved in partnership and aligning with the visions of U.S. colonias residents themselves.

This article is categorized under:

Human Water > Water Governance

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1 | INTRODUCTION

U.S. colonias are low-income, peri-urban, and rural subdivisions located on the northern side the U.S.-Mexico border. This arid and semi-arid region contains the Sonoran and Chihuahuan Deserts, is characterized by a warm and dry climate, and is experiencing a rapidly intensifying current megadrought—the worst in 1200 years (Williams et al., 2022). Colonias communities are legally defined by their lack of basic infrastructure, including water systems, wastewater disposal, stormwater control, paved roads, and trash collection. Residents, predominately Mexican and Central American immigrants, work in agricultural wage labor, skilled trade labor, and the informal economy (Vélez-Ibañez, 2004). While U.S. colonias have a long history of settlement, activism, and self-advocacy to secure better living conditions and water services (Arizmendi & Ortiz, 2004; Dolhinow, 2010; Donelson & Esparza, 2016; Jepson, 2005; Jepson & Brannstrom, 2015), water insecurity in U.S. colonias rose to the attention of national news, scholars, and policymakers only in the 1980s (Korc & Ford, 2013; Parcher & Humberson, 2009; Ward, 2010). Today, as many as 1 million people (Vélez-Ibañez & Heyman, 2017) live in an estimated 1800+ colonias in Texas, 154 colonias in New Mexico, 104 colonias in Arizona, and 35 colonias in California as determined by the USDA and HUD criteria (e.g., Alvarez-Smith, 2009; Rowles et al., 2020).

In this focused review, we trace the history of water infrastructure development in U.S. colonias. We begin with the history of water infrastructure and water insecurity. Here we define water insecurity as, the inability “to access and benefit from affordable, adequate, reliable, and safe water for wellbeing and a healthy life” (Jepson, Budds, et al., 2017). We then consider how research in U.S. colonias can contribute to broader efforts to theorize water insecurity globally. While the water situation might be considered as a market failure, a problem of economies of scale, or “benign neglect,” we argue that the literature indicates that three core structural factors produce water insecurity in U.S. colonias: political exclusion, municipal underbounding, and inadequate water quality monitoring. Moreover, scholarship demonstrates how water insecurity in colonias communities produces negative outcomes, including physical and mental ill-health. We then conclude by examining four broad approaches suggested in the literature to advance water security in U.S. colonias.

2 | U.S. COLONIAS: A HISTORY OF WATER INSECURITY ALONG THE U.S.-MEXICO BORDER

Colonias are located on the northern side of the U.S. border in the four U.S.-Mexico border states: Texas, New Mexico, Arizona, California, as shown in Figure 1. Most scholars trace U.S. colonias' origins to the Bracero program (1942–1964),

Colonias Distribution in Four Border States

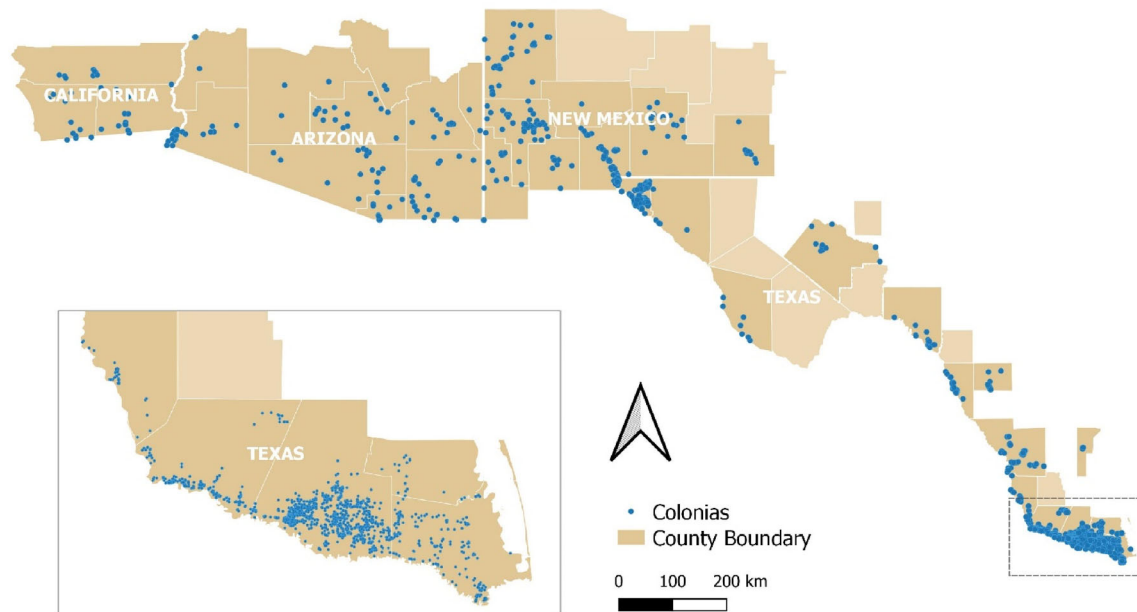


FIGURE 1 Map of colonias in four states (Texas, New Mexico, Arizona, California) on the U.S.-Mexico border. This map reflects only colonias in the 4 U.S.-Mexico border states, but not other border-state communities with similar infrastructure conditions

a migrant labor program that encouraged Mexicans to enter the U.S. legally as low-paid farmworkers (Donelson, 2004; Korc & Ford, 2013; Montejano, 1987; Velez-Ibanez et al., 2003), many of whom were ultimately repatriated. The colonias helped farmers secure access to low-income farm labor without paying the costs of basic sanitation, safe housing, and infrastructure provision—all of which are particularly challenging in the arid U.S.-Mexico border region.

U.S. colonias development continued through the 1960s–1980s, when the Border Industrialization Program attracted workers to work in the supply chain associated with maquiladoras (factories) on the Mexican side of the U.S.-Mexican border (Korc & Ford, 2013; McDonald & Grineski, 2012; Vélez-Ibañez & Heyman, 2017). Ward (2010) demonstrated how broader shifts in the regional political economy produced U.S. colonias as cheap housing for people for exploited labor market. As agricultural labor decreased (Anderson & Gerber, 2008, p. 134) and friction in cross-border mobility increased due to a new era of immigration controls (Massey et al., 2002), the demand for cheap housing within the 100-mile border region also increased; and thus, colonias continued to expand without public services and resulting in what some colonia scholars have called “poor people’s suburbs” (Campbell & Heyman, 2007, p. 17).

In the late 1980s, a public outcry arose over living conditions in Texas colonias (Mukhija & Monkkonen, 2006; Mukhija & Monkkonen, 2007). This outcry focused particularly on the lack of water and sanitation infrastructure in colonias (Hill, 2003; Jepson, 2012). Media attention and policy support coalesced to advance colonias residents’ long-standing fight for improvements (Esquincia & Jaramillo, 2017; Mukhija & Monkkonen, 2007).

Each U.S. border state has a unique history and legacy of colonia formation. Texas has more colonias than the other three border states combined. Until 1995, Texas permitted property sales via “contract for deed,” an exploitative arrangement in which the sellers owned land until buyers’ payments were complete (Mukhija & Monkkonen, 2006; Ward et al., 2004). Contract for deed agreements could be verbal, informal, or unrecorded (Durst, 2014b). After a single default, buyers could lose their land and all prior payments (Davies & Holz, 1992). These arrangements created housing insecurity for buyers in U.S. colonias, and increased poverty for those who defaulted. Often segregated to flood-prone subdivided agricultural land, farmers, and developers were not legally required to provide services like water and sanitation until 1989 (Mroz Jr et al., 1996). Fraudulent seller promises of water and waste water infrastructure to come were common (Davies & Holz, 1992; Esquincia & Jaramillo, 2017).

New Mexico, Arizona, and California have far fewer colonias than Texas, and the limited research on colonias in these states reflects that difference. In New Mexico and Arizona, the emergence of colonias has similarly been facilitated, similar to Texas, by laws that allow for property subdivision without requiring water and wastewater utilities. New Mexico, like Texas, had contract for deed arrangements. While New Mexico has taken steps to close these

loopholes, Arizona has not. In Arizona and California, some colonias are on sovereign tribal land (Esparza & Donelson, 2008; Mukhija & Monkkonen, 2006; Norman et al., 2012), where water insecurity results from longstanding U.S. policies of dispossession, enclosure, regulatory politics, and intentional underdevelopment that are discussed at greater length elsewhere (Curley, 2019, 2021; Wilson et al., 2021). California, with the shortest and most urbanized border, hosts the fewest communities designated as colonias, though many nonborder communities also fit the core definition of colonias (Huntoon & Becker, 2001; Mukhija & Monkkonen, 2006). Instead, colonias are found in California's agricultural heartland, the Central Valley, where they offer cheap housing for low-income, and in many cases, migrant workers similar to the situation in south Texas.

3 | DEFINING U.S. COLONIAS: FEDERAL AND STATE LEGISLATION

U.S. colonias are legally defined, at the federal level, by the Cranston-Gonzalez Act National Affordable Housing Act, which funded water infrastructure and other services for colonias. In 1990, the U.S. Department of Housing and Urban Development (HUD) took the lead in defining colonias. The U.S. EPA and USDA Rural Development (USDA-RA), in their funding programs for colonias, loosely adopted the definition established by HUD, applying variant criteria, as shown in Table 1. Broadly, U.S. government criteria to define colonias typically include: lacking water and sanitation, housing, and paved roads; location in the four US-Mexico border states; and a legal or historical classification.

The four border states—California, Arizona, New Mexico, and Texas—have each applied statutory criterion differently at times (GAO, 2009a, 2009b). The variations in definitions arise from objectives of designated fund programs, and power dynamics between state and local agencies providing infrastructure and planning land development.

Once designated as a “colonia,” there is no process for un-designation; as a result, some colonias no longer meet these criteria but retain the federal designation (Rural Community Assistance Partnership et al., 2015). The number of colonias that might qualify for undesignation is not known, but a preliminary estimation might be attained by

TABLE 1 Comparison of Colonia definitions across three major federal funding agencies and four border states

	HUD ^a	USDA ^b	EPA ^c	TX ^d	NM ^e	AZ ^f	CA ^g
Lacks water supply and sewage	x	x	x	x	x	x	x
Lacks decent, safe, and sanitary housing	x	x	x	x ^h	x	x	x
Lacks paved roads		x	x	x			
Within 150 miles along the United States and Mexico border	x	x	x ⁱ	x	x	x	x
Outside of a Metropolitan Statistical Area with a population exceeding 1 million	x					x	x
A rural community with a population <25,000					x		
Existed as a colonia before the date of the enactment of the Cranston-Gonzalez National Affordable Housing Act (November 28, 1990)	x	x			x	x	x
Existed as a colonia before October 1, 1989		x					
Must provide documentation of existence before 1989 to support the designation of a colonia by the municipality or county.					x		

^aSchusheim and Milgram (1991).

^bThis definition is set forth by Individual Water & Wastewater Grants provided through USDA rural development, Appendix 6 Section 306C WWD Grants To Individuals, <https://www.rd.usda.gov/files/3550-1appendix06.pdf>.

^cMukhija and Monkkonen (2006).

^dDifferent state agencies in Texas adopt various definitions for colonias depending on the type of agency, government code or issue being addressed at any given time (Lewis, 2015). The definition shown here is set by Colonias Prevention Laws, <https://www.texasattorneygeneral.gov/divisions/colonias-prevention/colonias-terms>.

^eThis definition is set forth by New Mexico Colonias Infrastructure Act, NM Stat § 6-30-3 (2018), <https://law.justia.com/codes/new-mexico/2018/chapter-6/article-30/section-6-30-3/>.

^fThe Arizona Department of Housing adopts this definition for Colonia Certification and Designation, <https://housing.az.gov/sites/default/files/documents/files/Colonias%2520Certification%2520Packet.pdf>.

^gThe California Department of Housing and Community Development adopts the definition for Colonia set forth by the National Affordable Housing Act of 1990, <https://www.hcd.ca.gov/grants-funding/active-funding/cdbg.shtml>.

^hThe language about housing conditions is implicit.

ⁱNAFTA provision (Mukhija & Monkkonen, 2006).

TABLE 2 Percentage of colonias residents in the four U.S.-Mexico border states that have attained some level of water and wastewater service (data from RCAP et al., 2015)

U.S.-Mexico border state	# of colonias	Total colonias population	% population with water service	% population with wastewater service
Arizona	104	278,209	72%	84%
California	35	46,269	79%	36%
New Mexico	154	157,408	8%	22%
Texas	1884	358,024	93%	70%

Note: “Water service” is defined as adequate water quantity and quality from a public water system, private well, or combination of these; “wastewater service” is defined as a public or private sewer, onsite septic, or any combination of these (RCAP et al., 2015, p. 12). RCAP noted this level of service may not be adequate to provide fully for residents’ needs, including for economic development.

looking at the percentage of residents that have attained some level of water and wastewater service, as shown in Table 2.

4 | THEORIZING U.S. COLONIAS IN GLOBAL CONTEXT

Studying U.S. colonias can illuminate the structural and social conditions that produce water insecurity in high-income countries (Jepson, Budds, et al., 2017; Meehan, Jepson, et al., 2020). However, there remains significant debate among scholars of U.S. colonias about the experiences of residents and how these communities should be understood analytically (Campbell & Heyman, 2007; Martínez et al., 2019; Ranganathan & Balazs, 2015; Vélez-Ibáñez, 2004; Vélez-Ibáñez & Heyman, 2017). These debates have important implications for how U.S. colonias are brought into broader comparative scholarship about global patterns of water insecurity. Here we summarize debates about how to understand and represent U.S. colonias; we reflect on implications for theorizing water insecurity in U.S. colonias in global context.

4.1 | “Colonias” as a stigmatizing and racist label

Informal settlements have long existed in the western U.S., but the term “colonias” was only widely adopted to describe informality on the U.S.-Mexico border during the 1980s (El Paso Herald Post, 1987a, 1987b, 1987c; Hill, 2003; U.S. House, 1990). The term “colonia” in Spanish simply means “neighborhood.” In U.S. English, however, scholars find “colonia” to have pejorative connotations—denoting racialized poverty, social stigma, disease and illegality (Barracough, 2018; Davies & Holz, 1992; Hill, 2003; Kerwin, 2001; Longazel, 2013; McDonald & Grineski, 2012; Mukhija & Monkkenon, 2006). Some scholars argue that the borrowed Spanish term underscores the racialization of colonias residents and foments moral panic over immigration; some believe “colonias” should be discarded for new terminology—such as “Disadvantaged Unincorporated Communities” (DUC)—that recognizes many U.S. communities share similar infrastructure conditions (Flores-Yeffal et al., 2019; Hill, 2003; London et al., 2021; Mukhija & Monkkenon, 2006, 2007; Ward, 2015; Ward & Peters, 2007). Because community-level racialization and stigmatization are hypothesized to drive processes that produce water insecurity in the Global North and South, the analytic decision to group colonias with DUCs may have important implications for theorizing water insecurity.

4.2 | “Third World in the First World”

U.S. colonias have been characterized as having “Third World” living conditions, disease rates, poverty levels, or development trajectories, by scholars (Davies & Holz, 1992; Holz & Davies, 1993; Meyer et al., 2013), by government officials (U.S. Congress, 1990; Hill, 2003), and in popular media (Mukhija & Monkkenon, 2006, 2007; U.S. News & World Report, 2018). Water insecurity, in particular, is often viewed as a “Third World problem” (Ranganathan & Balazs, 2015, p. 417; Vandewalle & Jepson, 2015). Scholars argue that the Third World discourse—now widely

understood as derogatory (Shakow & Irwin, 2000)—is used to discredit or marginalize residents of U.S. colonias (Mukhija & Monkkonen, 2007; Vandewalle & Jepson, 2015). Complexly, however, the Third World frame has proven a politically-powerful discourse that helped advance communities' own efforts to secure policy support and funding to address water infrastructure needs (Anzaldúa, 1987; Davies & Holz, 1992; Donelson, 2004; Hill, 2003; Jepson, 2012; Lopez & Reich, 1997; Vandewalle & Jepson, 2015). Following these analyses of U.S. colonias, scholars examining the discourse, rhetoric, and politics of water insecurity might explore the extent to which “Third World” framings are or are not rhetorically powerful for other water-insecure communities in the Global North.

4.3 | Global processes of water inequality

Water scholars view U.S. colonias as illustrative of global processes of water inequality (Dolhinow, 2010; Esparza & Donelson, 2008; Giusti & Estevez, 2011, p. 307; Jepson & Brown, 2014; Olmstead, 2003; Ranganathan & Balazs, 2015; Vandewalle & Jepson 2015; Ward & Peters, 2007, p. 206). Jepson and Brown (2014), for example, note that disconnection and decentralization are important for understanding water insecurity patterns in U.S. colonias, much like in the Global South. Following this insight, recent scholarship has decisively debunked the myth of water security in the Global North and argued for a relational approach—that encompasses social positions and processes—to understand the drivers of global water insecurity (Jepson, Budds, et al., 2017; Meehan, Jepson, et al., 2020; Meehan, Jurjevich, et al., 2020). Such insights build on the work of scholars of U.S. colonias, who have long understood that these communities are connected to transnational patterns of migration, labor exploitation, and income inequality (Donelson & Esparza, 2010; Núñez & Klamlinger, 2010; Núñez-Mchiri, 2009; Vélez-Ibáñez, 2004; Velez-Ibanez et al., 2003; Vélez-Ibáñez & Heyman, 2017). This suggests analysis of transnational processes of inequality in migration, labor, and wealth may have important implications for theorizing the emerging field of water insecurity.

Here, our focused review aligns with the view that water insecurity in U.S. colonias is indicative of broader global patterns of marginality and dispossession. Research on dynamics that “transcend North-South binaries,” such as informal water provision, can advance our understanding of global water insecurity (Meehan, Jepson, et al., 2020, p. 4). Such research can go well beyond the application of so-called Third World solutions in the First World, to leveraging theories from the Global South countries to understand water insecurity in the Global North (Furlong & Kooy, 2017; Pacheco-Vega, 2019; Sultana, 2018; Vandewalle & Jepson 2015). In this article, then, we engage the literature on U.S. colonias with the goal of advancing theorization of broader patterning in global water insecurity.

5 | WATER INSECURITY TODAY IN U.S. COLONIAS

Water insecurity is more than just the absence of a piped water connection to homes (Jepson, Budds, et al., 2017). Water insecurity also encompasses the relations that produce unsafe or inaccessible water; high economic, social, and psychological costs; and experiences of poverty, illness, uncertainty, and distress associated with water insecurity (Deitz & Meehan, 2019; Jepson, Wutich, et al., 2017), as shown in Table 3. Yet, even a simple measure of “plumbing poverty”—the presence of complete household plumbing—suggests that residents of U.S. colonias are disproportionately at risk for water insecurity (Deitz & Meehan, 2019). The most water-insecure U.S. colonias tend to have mainly Hispanic (90%–100%) residents, low household incomes (between \$10,000 and \$20,000/year), locations far from cities, and small

TABLE 3 Water insecurity conditions and their known health impacts in colonias

Water insecurity conditions	Health impacts
Water scarcity	Restriction of water for household purposes Psychosocial distress Unsanitary living conditions Increased susceptibility to common diarrheal pathogens
Poor water quality	Gastrointestinal disease Disruption to liver and kidney function Increased prevalence of methemoglobinemia Increased risk of carcinogenic exposure

populations (<250 residents) (Hargrove et al., 2018, 2020). Nuanced measures show that water insecurity in U.S. colonias has three key dimensions—water access, water quality, and water distress (Jepson, 2014).

5.1 | Inadequate water access in U.S. colonias

Water access is defined by the capacity to obtain water for household use, including physical accessibility, affordability, and reliability (Jepson, 2014, p. 113). Between 5% and 28% of the colonias in Texas, New Mexico, Arizona, and California are not served by community water systems, and as-such require residents to arrange alternative water sources (Rural Communities Assistance Partnership, 2015). Water insecurity problems in colonias generally result from precarious reliance on a combination of private water truck vendors, self-hauled water, or bottled water; shutoffs or inability to afford piped water connections; reliance on a private well with unregulated groundwater; or connection to a piped water system with unsafe water (Hargrove et al., 2020; Jepson, 2014; London et al., 2021). As of 2015, an estimated 30% of 840,000 colonias residents lacked access to safe drinking water (Rural Community and Assistance Partnership et al., 2015). There are an estimated 374 colonias that lack sufficient water service, with 6000 people who are entirely unserved and 263,000 people who are underserved (Hargrove et al., 2020; Rural Communities Assistance Project et al., 2015). Across the border region, public water systems are inaccessible to over 134,000 residents in 604 colonias, resulting in severe water scarcity and heavy reliance on bottled water for consumption. (Hargrove et al., 2018).

While there are different ways to measure water affordability (Pierce et al., 2021; Teodoro, 2018; Wutich et al., 2020), the first quantitative study of household water insecurity in U.S. colonias (Jepson, 2014) reported that 84% of households sampled in south Texas communities reported water expenditures (including utility bill, bottle water, and vended water) above 2% monthly income, a benchmark for affordability. Among these colonias residents, 71% adapted water usage to save money on their water expenditures; 37% experienced difficulties paying water utility bill; and 18% experienced water-service shutoff due to late utility payment. Tippin (2021) also reported that the average household in one Texas study community paid almost nine times more for monthly water than a similar water user would pay in the nearby utility district. While these studies are not representative of all water affordability challenges across all U.S. colonias, the findings indicate the complexity and diversity of water access experiences and affordability challenges for residents.

5.2 | Poor water quality in U.S. colonias

Early research suggested U.S. colonias residents historically have been at risk for hepatitis, cholera, tuberculosis, dysentery and other waterborne disease due to poor water and sanitation (Hilfinger Messias et al., 2017). A 2000 study reported 89% prevalence of infection with the intestinal parasite *Cryptosporidium parvum*, the etiologic agent of cryptosporidiosis and *Giardia lamblia*, among children in seven Texas colonias (Leach et al., 2000). Since then, colonias residents have benefitted from connections to community water systems, but significant water quality problems remain a barrier to human health in colonias (Hargrove et al., 2015; VanDerslice, 2011). Each water pathway—from source to storage to tap—presents water quality challenges for thousands of colonias residents. While no published study exists reporting the prevalence of water quality issues for all colonias in the United States, the literature highlights that source pathways for contamination present continued water quality concerns (Amrose et al., 2015; VanDerslice, 2011; Wright et al., 2004).

Connections to community water systems, especially in south Texas where the largest concentration of colonias are found, provide the most protection from water contamination; but these colonias still face water quality challenges. Source water remains a concern. Water contamination by heavy metals and disinfection by-products presents is a major public health threat for colonias (Adams et al., 2016; Cheng et al., 2017; Noman et al., 2015; Saint-Jacques et al., 2018; Sanders et al., 2019). Southwest states are particularly susceptible to water contamination by disinfection by-products (DBPs) due to high temperatures and high levels of organic carbon in source water (Krasner et al., 2012; Richardson & Kimura, 2019). At the household level, there are no studies that measure water quality problems at the tap, but research shows colonias residents themselves perceive water quality problems from community water systems (Jepson, 2014). In fact, the market for drinking water vending machines is driven by colonia residents' concern that community water systems are contaminated in south Texas (Jepson & Brown, 2014).

Colonias residents who depend on their own well for drinking water face similar problems as other private well owners, in that there is little regulation or monitoring. Beyond this, colonias residents are more vulnerable to

contaminant exposure due to the compounding impacts of social and geographic marginalization. A study analyzing urine samples from colonia residents in Doña Ana County of New Mexico, for example, suggests elevated levels of uranium in drinking water from their wells potentially caused kidney damage (Adams et al., 2016). In Nueces County, Texas, north of the Mexico border, a study found that seasonal water quality deterioration exacerbated location in flood-prone lands, where heavy rainfall events and lack of infrastructure increased the susceptibility of groundwater and thus well contamination throughout the year (Rowles et al., 2020). Communities in San Joaquin Valley, which face similar challenges as colonias, depend almost entirely on well water, which has been characterized by some of the highest nitrate water levels in the country (Balazs et al., 2011).

Colonias dependent on water from tanker trucks face the most significant drinking water quality problems because there are more opportunities for contaminant exposure (Korc & Ford, 2013). Standpipes where trucks fill their tanks can seriously compromise water safety. One study in El Paso colonias reported that water quality generally worsened from the standpipe and delivery to the storage tanks, with documented negative impacts on turbidity, total coliforms and chlorine. The study noted that chlorine residual declines over time in the tank, allowing the persistence or regrowth of bacteria from biofilms in the tank (Graham & VanDerslice, 2007). These studies are confirmed by research that documents concerns over hauled water as unacceptable due to the smell and taste, feared contamination, and health concerns related to family intestinal illness (Garcia et al., 2016).

Water storage, which is necessary for households that rely on delivered water and common for many others who depend on vended drinking water stored in 20-liter containers, also poses health risks to colonias residents. Storage containers vary in terms of material, volume and safety, all of which influence water quality (Clasen & Bastable, 2003). It is common for colonias residents to store water in open 55-gallon drums. One study of colonias in the El Paso area determined that water hauled and stored in large tank (2500 gallons) was generally of poorer quality than other sources (Graham & VanDerslice, 2007).

5.3 | Water distress in U.S. colonias

There is a strong and consistent link between experiences of water insecurity and anxiety, depression, and emotional or psychosocial distress (Wutich et al., 2020). In U.S. colonias, the uncertainty, costs, and health impacts of water insecurity appear to be associated with significant psychosocial and emotional distress, as the literature predicts. Jepson's (2014) in-depth study in Texas colonias showed that distress is borne of feelings of worry, disgust, uneasiness, fear, and dissatisfaction over water as well as conflicts with others about water. In a survey completed by 64 residents of Las Pampas, a Texas colonia, the most prevalent health impact was stress related to the fear of running out of water (Hargrove et al., 2018). A number of scholars point out that water-related distress is also linked to broader fears and anxieties associated with the draconian U.S. immigration regime (Hilfinger Messias et al., 2017; Vélez-Ibañez & Heyman, 2017). For example, Jepson and Vandewalle (2016) reported that households with all undocumented members are 1.2 times more likely to be water insecure than households with members who are all documented, suggesting that "behaviors in response to precarious immigration status might 'spill over' into ... household water insecurity" (Jepson & Vandewalle, 2016, p. 79).

6 | CAUSES OF U.S. COLONIAS' WATER INSECURITY

Much of the literature has described the dynamics of water insecurity—such as reliance on water vendors or high water costs—in U.S. colonias. Here, we delve more deeply into the literature to understand three underlying root causes: political exclusion, municipal underbounding, and failures in water quality monitoring. These factors are multifaceted and interconnected; political exclusion, for example, is a broad process that contributes to municipal underbounding. Here, we give but a brief overview of key issues.

6.1 | Political exclusion of U.S. colonias residents

While the water situation in U.S. colonias might be characterized as a market failure, a problem of economies of scale, or "benign neglect," scholarly research finds that intentional political exclusions drove the trajectory of this water insecurity (Cavanagh, 2001; Jepson, 2012). In South Texas, for example, where colonias are located within, or near,

irrigation districts, residents of colonias were intentionally excluded as voters and stakeholders (Jepson, 2012). As this example shows, local politics often limit colonias' access to local resources, such as grants and loans, to address infrastructure needs (Henkel Jr, 2010; Núñez & Klamlinger, 2010). This, in turn, leaves residents dependent on regional or federal assistance, where colonias lack an active role in decision-making (Henkel Jr, 2010). Where local governments manage federal funds for colonias, as in some Arizona colonias, decision-making in funding has not prioritized communities' needs (Alvarez-Smith, 2009). Existing funds often come with burdensome requirements—such as technical expertise, collaborations with multiple government agencies, or applying for supplements to existing funds—that may put unreasonable demands on colonias residents due to language, trust, or political barriers (Henkel Jr, 2010).

In addition to exclusion from participation in democratic water management, colonias residents are also excluded from other water governance mechanisms. For example, colonias residents may receive water from water hauling—that is, trucking bulk water into the community. Elected officials, such as water boards or city/town councilmembers, typically set rates charged for water provision by municipal providers, including hauled water. Such officials are unlikely to consider residents of colonias as part of their constituencies, when colonias are located outside of the incorporated municipality. State agencies may set private water providers' rates, including for hauled water, with limited voice for residents of colonias as interested stakeholders. Water provision may also depend upon irrigation districts; these are quasi-municipal entities that manage water storage and infrastructure for farmers under state law.

The exclusion of colonias residents from water governance can be understood as a part of a wider project to disenfranchise, marginalize, and silence poor and racialized U.S. Hispanic residents and citizens (Braier, 2020; Hennenburger, 2000; Jepson, 2012; Marquez-Velarde et al., 2015; Mukhija & Monkkonen, 2007). Undaunted, many colonias have organized themselves or worked with nongovernmental agencies to counteract these political exclusions. In Texas, for example, colonia organizing can be traced to the United Farmworkers (UFW) in the 1960s and the Chicano political movement led by Cesar Chavéz (Bowman, 2005; Rivera, 2017; Rivera, 2020). As part of their efforts to organize civic engagement for social change, including colonias' needs, in 1989 Chavéz and Dolores Huerta founded La Unión del Pueblo Entero (LUPE; The Union for All the Struggles of the Community) (Rivera, 2020). The creation of LUPE led to other projects to support colonia residents such as the Land Use Colonia Housing Action (LUCHA) program in 2012 (Rivera, 2020). This program aimed to mobilize colonias residents' political engagement with government and media to address border region challenges (Rivera, 2020). In other colonias, such as in New Mexico, colonias may be organized through a nonprofit classification, allowing them to apply for funding from federal and private foundations (Núñez-Mchiri, 2009). Some colonias have also adopted informal modes of organizing, such as community councils or selecting a spoke person to be resident's liaison with local, state, or federal institutions (Núñez-Mchiri, 2009).

6.2 | Municipal underbounding in U.S. colonias

For more than a century, the expansion of cities and water system boundaries by annexation—whether the water system is an arm of municipal government or a separate entity—has been a major method of growth for American cities. For an annexing entity, the two major benefits are: access to increased tax revenue (including property taxes and sales taxes) and the ability to recover the cost of existing utility services from a larger service population (thus lowering the cost per household for the existing customer base). For an entity that is annexed, benefits can include access to a wider range of municipal functions and amenities, and being able to share in the economies of scale associated with a larger and growing utility network. A number of scholars suggest that U.S. colonias have been intentionally isolated by predominately-white decision-makers in order to facilitate the economic exploitation and political disempowerment of Mexican-Americans (Donelson, 2004; Durst, 2014a, 2014b, 2014c; Hennenburger, 2000).

While some U.S. colonias have been annexed, cities have used selective municipal underbounding—or the intentional avoidance of annexing low-income minority communities—to exclude colonias (Durst, 2014a, 2014b; Jepson, 2012; Mukhija & Mason, 2013). This has been accomplished through “conspicuous gerrymandering,” or even selectively excluding colonias that are entirely surrounded by municipalities (Durst, 2014a, 2014b, p. 1703). Cities may avoid annexing certain areas because people living in those areas are poor, they wish to exclude minority residents, the prospect of a tax bonanza is small, or infrastructure provisioning is seen as too costly. Since the costs of improved water infrastructure would often be greater than the tax revenues from colonias, municipalities that already have services may oppose annexation of underserved colonias (Gardner, 1984; Olmstead, 2003; Wilson & Menzies, 1997).

Where annexation does not occur, it is common in the United States to find impoverished minority communities adjacent to, but excluded from, neighboring municipalities and utility systems unwilling to assume the cost of serving them (Romero, 2011). Initially, colonias residents may have settled in unannexed areas precisely because they have low incomes and housing is inexpensive. Yet, because of the lack of economies of scale in water provision, the cost of remaining unannexed is very high for colonias, ranging from several million dollars for a colonias with 100 residents, and \$20 million for a colonia with thousands of residents (Hargrove et al., 2020).

6.3 | Failures in water quality monitoring in U.S. colonias

In the United States, the quality of drinking water provided by public water systems is supposed to be regulated under the Safe Drinking Water Act (SDWA). The SDWA applies to all public water systems, meaning systems with at least 15 service connections are serving at least 25 people per day for 60 days/year (40 U.S.C. § 300f et seq.). The SDWA requires public water systems to conduct periodic water quality monitoring and reporting to either State agencies, when they have primacy, or Federal USEPA or Tribal health agencies, although smaller systems (serving fewer than 3300 people) have more lax regulatory requirements than larger systems (40 C.F.R. § 141.2). Many systems serving colonias would be regulated as small systems under the SDWA. Classification of water systems impacts the frequency of water quality analysis, which can be as infrequent as one sample every few years.

Yet many colonias residents are among the U.S. households that use private drinking water systems not covered by the SDWA (Fedinick et al., 2019). They rely on small-scale water provision, including private wells (sometimes drilled illegally) which are governed by state policy (Bowen et al., 2019). States regulate such private wells differently, but generally have no water quality monitoring (except in some states at the time of home selling/purchasing). Because private wells are largely unregulated, often no samples are collected and analyzed for water quality. This is the case for many wells in colonias, and as such has led to poor of water quality.

The lack of a systematic assessment of colonias limits a comprehensive view of the range of water quality issues. Smaller-scale studies in colonias suggest that water quality violations and risks in U.S. colonias are significant (Hargrove et al., 2015; Leach et al., 2000; Romero, 2015; VanDerslice, 2011). Thus, failures in water quality monitoring systems are another major structural driver of water insecurity in U.S. colonias.

7 | FOUR WAYS TO ADDRESS WATER INSECURITY IN U.S. COLONIAS

The ingenuity, building skills and problem-solving abilities of U.S. colonias residents are widely remarked upon in the literature (e.g., Campbell & Heyman, 2007; Davies & Holz, 1992; Durst, 2014a; Durst, 2014b; Velez-Ibanez et al., 2003). In this section, we address four ways that U.S. colonias residents have sought to secure safe, sufficient water: soft paths and social infrastructure, decentralized water treatment, informality, and legal and policy activism and innovation. For each of these, we describe the approach, review key research findings in U.S. colonias, and—where possible—evaluate feasibility, efficacy, and ethical considerations.

7.1 | Water delivery: Soft paths and social infrastructure

Soft paths have been proposed as an alternative to expensive, larger-scale centralized water systems (Wolff & Gleick, 2002). Generally, soft paths are considered to include: conservation, wastewater reuse, and small-scale infrastructure. Recent research suggests soft paths can substantially improve water quantity, quality, and cost, in the continued absence of hard-engineered infrastructure in U.S. colonias (Hargrove et al., 2020).

Taking a practical approach, Hargrove et al. (2020) suggest a soft path strategy that includes: increasing supply with decentralized wastewater reuse and rainwater harvesting, improving water quality with point-of-use treatment, and conservation to reduce water demand (e.g., low volume toilets, drip irrigation) (Hargrove et al., 2020, p. 34A). Rainwater harvesting in U.S. colonias can reduce by half the amount of water households haul, and reduce trips from 1–3 times/week to 1 time/week (Hargrove et al., 2020, p. 36A; Prasek, 2004). Containerized community-level wastewater treatment systems can replace cesspools and aging septic tanks, improve sanitation, and provide treated wastewater for nonpotable outdoor reuse (Hargrove et al., 2020). Where soft paths have served colonias well, residents have proven

unwilling to fully join formalized water systems, preferring instead to keep control over self-built rainwater and wastewater systems for nonpotable reuse.

Soft paths require significant knowledge, support, and participation from community members (Jordaan et al., 2009; Pahl-Wostl et al., 2008; Wutich et al., 2014). To address this, social infrastructure—or, social networks, cultural norms, and informal rules—can support soft paths (Wutich & Jepson, 2021). In U.S. colonias, for example, *brigadas de limpia* (clean-up brigades) are a form of social infrastructure that helps remedy stormwater damage (Vélez-Ibáñez, 2004). Extension programs that may exist for other rural populations, like well-owners' associations, may be offered to colonias so that residents can benefit from well stewardship support (VanDerGeest et al., 2020). Like social capital (Roque et al., 2020), social infrastructure can amplify the impact of community efforts to build soft paths to water provision, treatment, and conservation (Wutich & Jepson, 2021). This is particularly important for wastewater reuse, as this challenging treatment alternative can result in high human risk if not done correctly. Yet the social, technical, and financial inputs required to establish soft paths can create a heavy labor burden, which some see as disproportionate and unfair to U.S. colonias residents (Vandewalle & Jepson, 2015).

7.2 | Decentralized water treatment: Point-of-use, point-of-entry, and fit-for-purpose systems

In U.S. colonias and elsewhere, the use of unregulated private well water, aging municipal infrastructure, failures in federal regulation for emerging pollutants, and household plumbing degradation has created a need for locally tailored modular and decentralized water treatment systems in the U.S (Stoler et al., in review). Point-of-use (POU) and point-of-entry (POE) treatment (within homes or at the tap) and fit-for-purpose treatment (in nonresidential settings like restaurants) are increasingly common (Clasen, 2009; Sharvelle et al., 2017; Stirling et al., 2020; Zodrow et al., 2017). Both point-of-use and fit-for-purpose water systems can provide high quality water for those able to afford to install and maintain the technology.

An in-depth study of POU systems to date was conducted in U.S. colonias in Doña Ana County (New Mexico) and El Paso County (Texas) (Campos Flores, 2015). While acknowledging that many colonias residents are reluctant to adopt POU systems, a study of five focus groups found that residents were concerned about unsafe water and expressed openness to adopting POU (e.g., under sink) or POE (e.g., whole house) water treatment systems (Campos Flores, 2015). Assessing the sustainability of a range of POU systems for colonias dependent on water vending trucks or groundwater, Campos Flores (2015) found important considerations to be: user preferences, economic cost, environmental impacts, and technical performance and reliability (e.g., removing bacterial pathogens and contaminants, reducing total dissolved solids, improving aesthetics). The findings emphasized colonias residents' need for support in choosing, monitoring, and maintaining POU systems. Hargrove et al. (2020) concluded that POU systems held promise in U.S. colonias—despite the cost (\$250–\$500) and maintenance needs (6–12 months)—given residents' preferences for sink-attachment POU systems with advanced filtration.

Despite these promising findings, there are some concerns that reliance on POU and other water systems may disadvantage lower-income families, put communities with aging infrastructure at greater risk of contaminant exposure, and pose unsustainable maintenance costs (Vandewalle & Jepson, 2015). Early research in U.S. colonias finds dependence on nongovernmental organizations (NGOs), universities, and other external actors for water infrastructure and water treatment technologies—typically with little investment in political organizing or building social infrastructure—suggests that such improvements may ultimately be unsustainable (Donelson, 2004; Lemos et al., 2002). More recent research questions the ethics of interventions that transform “temporary solutions” into “a legitimised technological fix,” that does more to benefit market and university actors than colonias residents (Vandewalle & Jepson, 2015).

7.3 | Informality: Infrastructural, economic, and socio-cultural innovations

The Global North is often wrongly assumed to lack informal water systems (Meehan, Jepson, et al., 2020). In U.S. colonias, scholars have documented informal arrangements for water delivery, economic needs, and social support that help address water insecurity. In such settings, informality can produce innovative solutions that are well-tailored to local cultural, economic, and political conditions.

Informal arrangements for water provision in U.S. colonias can provide water provision, sanitation, and financing. Water vendors with rates unregulated by municipalities and state agencies, for example, are more likely to serve U.S. colonias than municipal providers (Olmstead, 2003), using tanker-trucks and standpipes (Olmstead, 2010a, 2010b). The widespread perception that even piped water is unsafe in U.S. colonias led many to rely on water vending kiosks for drinking water (Dean et al., 2012; Jepson & Brown, 2014). U.S. colonias residents dig their own wells, using groundwater transported in buckets in their own self-built showers (Campbell & Heyman, 2007). In addition, households share and sell water among themselves (Coronado, 2018; Jepson & Vandewalle, 2016; Olmstead, 2010a, 2010b). Plumbing poverty led U.S. colonias residents to develop innovative sanitation practices (Dean et al., 2012), including wastewater reuse, evaporation fields, and septic tanks (Ward et al., 2004). To meet economic needs, U.S. colonias residents developed informal arrangements for renting, credit/savings, and lending. These include informal renting (e.g., without contracts or tenant protections) (Durst, 2014a, 2014b; Durst & Ward, 2014, 2016) and rotating credit associations to save money (Vélez-Ibáñez, 2004; Velez-Ibanez et al., 2003), which can be used for water infrastructure investments (Wutich & Jepson, 2021).

The literature suggests informality in U.S. colonias may be more inhibited than elsewhere globally. U.S. regulatory codes impede colonia residents' abilities to create innovative solutions to water insecurity (Ranganathan & Balazs, 2015; Ward & Rodriguez, 1999), such as communal bathing and laundromat facilities (Davies & Holz, 1992; Eichelberger, 2010). Informality does, however, carry a number of significant risks, including unsafe water storage (Davies & Holz, 1992, p. 127), safety violations (Donelson, 2004), piecemeal and partial solutions (Balazs & Ray, 2014), and unpredictable or unsafe water provision (Wutich et al., 2016); it also shifts costs, labor, responsibility, and risks onto individuals (Jepson & Brown, 2014). In the view of many scholars, then, informal solutions should be shunned as a sign of state negligence rather than being celebrated as bootstraps ingenuity (Durst & Ward, 2014; Jepson & Brown, 2014).

7.4 | Policy, law, and politics: Innovation and reform

There is a clear consensus, in much of the literature about water insecurity in U.S. colonias, that the best path forward would be laws and policies that extend municipal water systems to colonias. A number of policy reforms have improved water security in U.S. colonias (Durst, 2015, 2016). Such policy reforms include regularizing colonias, preventing further growth, and supporting residents' own innovations. However, environmental racism and the perception of U.S. colonias as "unlawful" persist (Davies & Holz, 1992; Hill, 2003; McDonald, 2012), curtailing broader efforts to attain water justice and equity.

Starting in the early 1990s in Texas, for example, reforms were enacted to protect property buyers from abusive contract for deed sales and to require that developers provide appropriate infrastructure. In addition, some Texas counties participated in land title regularization programs with hopes to foster residents' socio-economic mobility and increase household wealth (Ward, 2010, 2015; Ward et al., 2004). Older, legacy colonias also have attained critical potable water and wastewater services, such that they are classified as "green"—at low human health risk—in Texas' colonias program (Durst, 2016; Parcher & Humberson, 2009). Recent research suggests that colonias have become important rental markets for the most vulnerable (Durst, 2014a, 2015). These reforms and investments went some way in addressing socio-economic vulnerabilities in U.S. colonias.

Beyond this, current laws and regulations have impeded policy and legal innovations that might improve water conditions in U.S. colonias. In some cases, innovation, flexibility, and informality—such as off-the-books adjustments to application of stringent water regulations—have some benefits for residents (Ranganathan & Balazs, 2015; Ward & Rodriguez, 1999). Findings from other rural, disconnected U.S. communities, like those in rural Alaska, further suggest that novel in-home reuse water systems may be viable options to mitigate household water insecurity (Lucas et al., 2021), if regulatory agencies can get ahead of and support the implementation of such innovations (Sanchez-Flores et al., 2016). In California, for example, regulators avoided issuing water quality violations where efforts toward improvements were made, in order to spare these small water systems from financial penalties (Ranganathan & Balazs, 2015, p. 413). These kinds of regulatory innovations, however, may have resulted in undocumented violations of the Safe Water Drinking Act. Thus, the possible benefits of regulatory informality and innovation in the water policy realm remain an open empirical question for U.S. colonias residents.

Colonias residents themselves have long fought for such inclusion through legal activism, political self-organization, and policy self-advocacy (Davies & Holz, 1992; Donelson, 2004; Jepson, 2012; Vélez-Ibáñez, 2004; Velez-Ibanez et al., 2003). Since the mid-1980s, colonias have worked with nonprofit and faith-based organizations to improve water infrastructure (Donelson, 2004; Henkel Jr, 2010; Lemos et al., 2002; Núñez-Mchiri, 2009; Olmstead, 2003). Such

collaborations have advanced lobbying, funding, and public awareness (Donelson, 2004; Henkel Jr, 2010). For example, the Texas Industrial Areas Foundation (TIAF) supported water infrastructure funding for colonias in South Texas (Donelson, 2004). Groups like TIAF, Valley Interfaith, and El Paso Interreligious Sponsoring Organization (EPISO) helped improve water utility services in colonias through community organizing, political lobbying, and media outreach (Cavanagh, 2001; Donelson, 2004; Olmstead, 2003). Collaborations between colonias, nonprofits, and faith-based institutions have been complicated, however, by issues of trust, disagreements about the importance of political organizing versus service provision, and undelivered promises to provide water and other services to colonias (Donelson, 2004; Esparza & Donelson, 2008; Henkel Jr, 2010). Colonias' political exclusion has forced residents to develop alternative approaches to political mobilization and self-advocacy, which have incompletely addressed their urgent needs for water infrastructure.

8 | CONCLUSION

Colonias in the United States have, since the 1980s, been defined by their lack of water provision. In recent scholarship, colonias are a powerful example of the unjust and inequitable dynamics that produce water insecurity in the Global North (Jepson, 2012; Jepson & Brown, 2014; Jepson & Vandewalle, 2016; Meehan, Jepson, et al., 2020). In this article, we traced the history of water infrastructure development in U.S. colonias.

We reviewed arguments proposing U.S. colonias are an important example for theorizing water insecurity in the United States and beyond in the Global North. We discussed key factors that produce water insecurity in U.S. colonias: political exclusion, municipal underbounding, and failures in water quality monitoring. We showed that water insecurity in U.S. colonias has led to negative outcomes, including poor water access, risks to physical health, and mental ill-health. We examined four approaches suggested in the literature to advance water security in U.S. colonias: (1) soft paths and social infrastructure for water delivery, (2) decentralized water treatment approaches, such as point-of-use, point-of-entry and fit-for-purpose systems; (3) informality, including infrastructural, economic, and socio-cultural innovations; and (4) political, policy, and law innovations and reforms. Our review highlights the need for improved water conditions for U.S. colonias residents. Future scholarship must reflect seriously on how water security can be achieved in partnership and aligning with the visions of U.S. colonias residents themselves.

We have also argued that it is important to bring U.S. colonias and similar communities in the Global North into broader comparative scholarship on global processes of water insecurity. Cross-cultural research designs could explicitly compare the causes, consequences, and solutions to water insecurity in colonias and other water-insecure communities internationally. Additionally, newer theoretical frameworks for understanding water insecurity, such as relationality (Jepson, Budds, et al., 2017; Jepson, Wutich, et al., 2017), may help scholars clarify the extent which colonias and other water-insecure communities in the Global North can be understood using the same concepts and theories as better-documented water-insecure communities in the Global South.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Amber Wutich: Conceptualization (lead); funding acquisition (lead); methodology (lead); project administration (lead); writing – original draft (equal); writing – review and editing (equal). **Wendy Jepson:** Conceptualization (equal); project administration (equal); writing – original draft (equal); writing – review and editing (equal). **Carmen Velasco:** Conceptualization (equal); project administration (equal); writing – original draft (equal); writing – review and editing (equal). **Anais Roque:** Conceptualization (equal); project administration (equal); writing – original draft (equal); writing – review and editing (equal). **Zhining Gu:** Formal analysis (equal); visualization (equal); writing – review and editing (equal). **Michael Hanemann:** Writing – original draft (equal); writing – review and editing (equal). **Mohammed Jobayer Hossain:** Project administration (equal); writing – review and editing (equal). **Laura Landes:**

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in the text of our article.

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