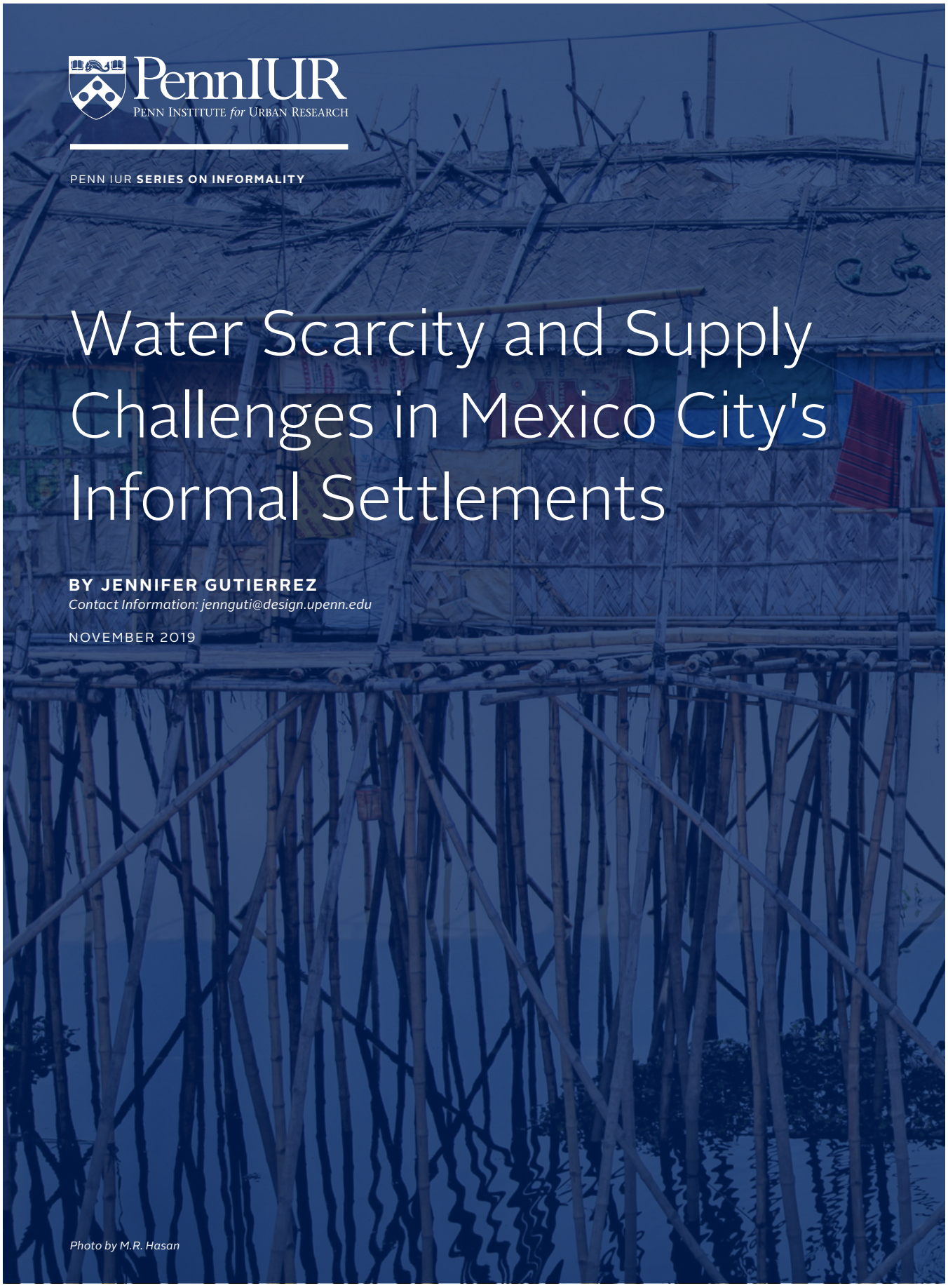

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Water Scarcity and Supply Challenges in Mexico City's Informal Settlements

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Photo by M.R. Hasan

INTRODUCTION

FIGURE 1:

Mexico City's boroughs, informal settlements, and conservation land. Source: Lerner et al. 2018.

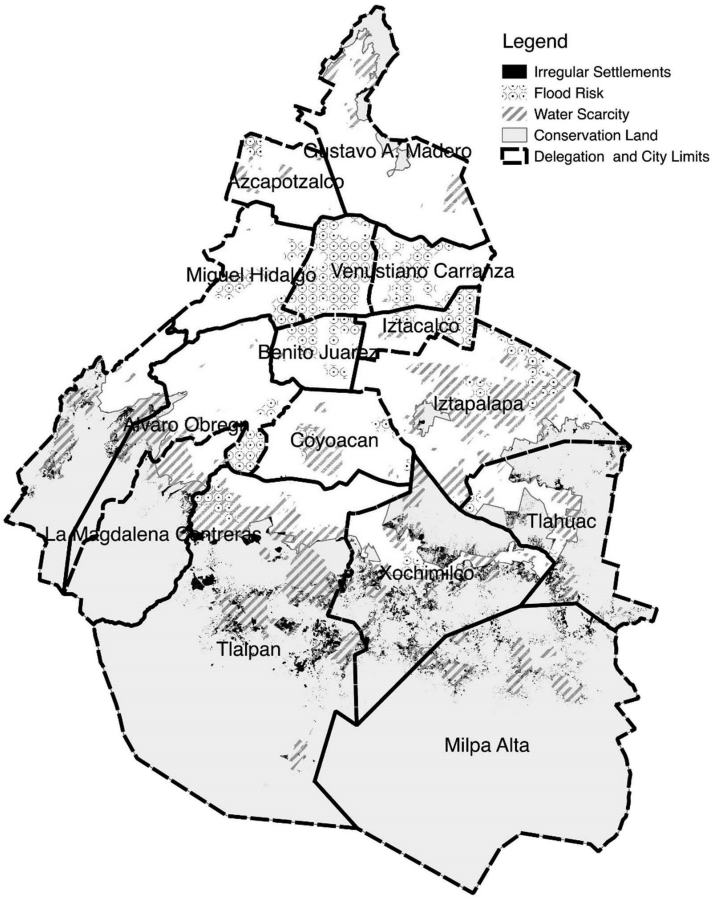


Fig. 1. Informal urban settlement areas, water scarcity, and primary flood zones in Mexico City. Author: Elizabeth Tellman. Sources: PAOT (Conservation Land Zoning), SEDEMA (2016 Mapping of Informal Settlements), CESOP (Digitization of Neighborhoods on the Tandeo System, all included in areas labeled water scarcity), SACMEX (Unidad de Tormenta).

Table 2
Formal water management agencies.

Agency	Scale	Function
DELEGACION DOH (Dirección de Operación Hidráulica Delegacional/ Department of Hydraulic Operation for city boroughs)	City borough	Local management of water services in city boroughs. Operator of local water and sewage systems.
SECRETARIA DE PROTECCIÓN CIVIL Ciudad de México (Secretariat of Civil Protection, Mexico City)	Mexico City	Attends to damage and impacts of hazard and risk in the city through prevention, assistance, rehabilitation, and reconstruction
SACMEX (Sistema de Aguas de la Ciudad de México/Water Commission of Mexico City)	Mexico City	Water operator of Mexico City. Responsible for the operation of water and sewage system
OCAVM (Organismo Cuenca Aguas del Valle de México/Organization of watershed management for the Valley of Mexico)	Regional	Maintains and administers national water in the watershed of the Valley of Mexico (where Mexico City is located)
CENAPRED (Centro Nacional de Prevención de Desastres/National Center for Disaster Prevention)	National	Provides planning and monitoring for natural disaster prevention at the national level
CONAGUA (Comisión Nacional del Agua/National Ministry of Water)	National	Preserves national water resources for its sustainable management and guarantees water security

Mexico City is a centuries-old metropolis located over 2,000 meters above sea level, surrounded by mountains within a valley that was once a network of lakes. The city's long history with water dates back to the Aztec capital Tenochtitlán, the lush, thriving metropolis built on an island in the lakes that had a sophisticated dike and canal system and floating gardens called chinampas. The Aztecs lived in harmony with nature. The conquering Spaniards "waged war against water, determined to subdue it. […] They replaced the dikes and canals with streets and squares. They drained the lakes and cleared the forestland" (Kimmelman 2017). The Spanish disposition for domination and urbanization was a key misstep in shaping the challenges with water that Mexico City faces today.

Mexico City is in the midst of a water crisis that is expected to be magnified by climate change in the coming decades, but its scarcity challenges are much more complicated than they appear. The United Nations recommends that every human have sufficient access to 50 to 100 liters of water per person per day (United Nations, "Water"). The average water use in Mexico City is 320 liters/person/day, more than triple the UN recommendation (SEDEMA n.d.), but that amount varies widely among neighborhoods and is as low as 10 liters/person/day in some (Oswald Spring 2014). Water supply management is especially challenging for Mexico City because 22% of its population lives in informal settlements (Chelleri et al. 2015, 124). The city's informal settlements are characterized as "groupings of unplanned, residential structures built on cheap, peripheral land with insecure tenure, often lacking basic services on land not designed for urban settlement" (Lerner et al. 2018, 62). Two-thirds of Mexico City's water supply comes from aquifers and the rest is imported from surface water 70 to 124 km away in other states (Rodríguez-Tapia et al. 2017), but eventually it is distributed to residents through a vast though quickly aging network of pipes that do not easily reach informal settlements.

RAPID URBANIZATION

Urbanization in Mexico City "is characterized by uneven development, wherein low-income residents, often in irregular settlements, face the greatest socio-hydrological risk, including water scarcity and flooding, and ecosystems protecting water resources are threatened" (Lerner et al. 2018, 62). Economic centralization and a development boom in the 1950s led to rapid metropolitan population growth over the following decades. By the 1980s, "demand for low-income housing led to the illegal occupation of thousands of hectares of […] ecologically valuable lands at the city's periphery" (Lerner et al. 2018, 62), but "new formal and informal settlements lacked connections to the formal public infrastructure" (de Alba 2017, 183). The overall rate of urbanization declined in the 1990s but continued in the southern boroughs of the city, further encroaching on the Conservation Zone that was established in 1992 to protect the city's watershed. Today Mexico City is home to about nine million people in sixteen boroughs, and with a population of nearly twenty million across three states, the Mexico City Metropolitan Area constitutes about 25% of the country's population (SEDEMA n.d.).

Regarding the provision of resources and the quality of infrastructure, there is tension between the central city and its peripheries. The central city has a formal water provision that is fully covered by the public infrastructure, while the peripheries are only partially covered by the formal water network, which does not function efficiently and cannot provide regular service (de Alba 2017, 184). Even if the formal infrastructure could be extended to the peripheral informal settlements, Mexico City's growth has outpaced the sustainability of its water resources. What has happened in Mexico City is indicative of the national trend in which there is an imbalance between water availability, population settlements, and production needs: 77% of people live in those areas that produce 87% of the country's GDP but where only 31% of the water is available (Oswald Spring 2014).

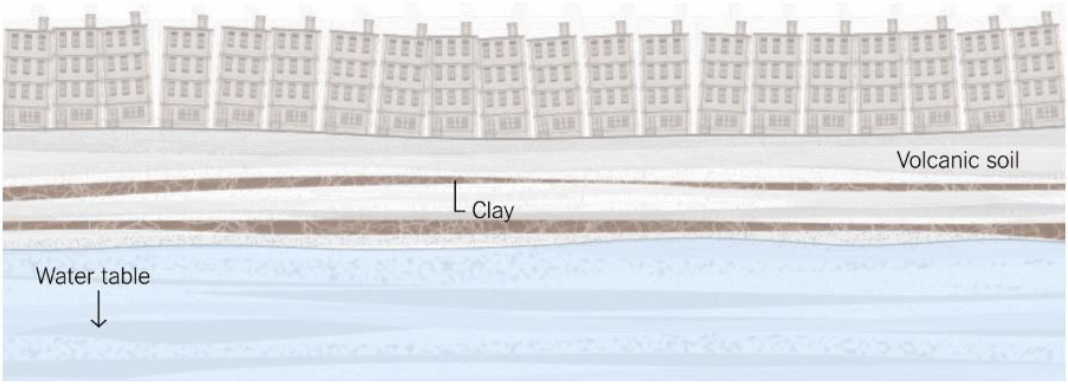
The proliferation of sprawling urbanization—both formal and informal—is a symptom of Mexico City's inability to match land-use planning with water resource management. Mexico City occupies what was once a series of lakes that has over time been drained, subdued, and built upon. The city's growth over that last 60 years "has produced a vibrant but chaotic metropolis of largely unplanned and sprawling development [that] has wiped

out nearly every remaining trace of the original lakes, taxing the underground aquifers and forcing what was once a water-rich valley to import billions of gallons from far way" (Kimmelman 2017). About 59% of the total land area of Mexico City today is a protected Conservation Zone but is threatened by urban sprawl, both formal and informal (Chelleri et al. 2015, 124). Urbanizing the Conservation Zone threatens the city's water supply because it impedes the infiltration process that replenishes the city's aquifer. Protecting the Conservation Zone is challenging, however, because of the segregation of managerial responsibilities between land-use and water sectors, in which "neither sector claims direct responsibility for managing hydrological risk" (Lerner et al. 2018, 62). As Mexico City continues to grow over the coming decades, it will be increasingly vital that it protect its water resources to secure its sustainability.

CITY-WIDE WATER CRISIS

FIGURE 2:

How aquifer depletion and soil type are causing Mexico City's subsidence. Source: Kimmelman 2017s



Mexico City is in a state of apparent water scarcity because the aquifer it depends on for most of its supply has been substantially depleted. The aquifer beneath the Conservation Zone provides 60 to 70% of the water consumed in Mexico City, but urban water demand exceeds natural availability (SEDEMA n.d.). The rate of extraction is greater than the recharge rate; the aquifer has a negative hydraulic balance because the urban water demand is 173% of the locally available renewable freshwater resources (Chelleri et al. 2015, 124). The aquifer does not recharge at the appropriate rate not only because of increasing demand, but because much of the porous land in the Conservation Zone has been "buried beneath concrete and asphalt, stopping rain from filtering down to the aquifers" through the naturally absorbent volcanic soil (Kimmelman 2017). As aquifer levels decline, deeper extraction pipes are installed, but deeper groundwater is of poorer quality, costs more, and destabilizes the city's volatile mix of clay lakebeds and volcanic soil.

In addition to the physical scarcity caused by overexploiting groundwater, Mexico City's water supply is further threatened by subsidence. As groundwater is extracted and the water table lowers, the mix of clay and volcanic soil sinks unevenly. This subsidence is particularly evident in the city's historic center where the National Palace "now tilts over the sidewalk like a sea captain leaning into a strong headwind"; buildings look like "Cubist drawings with slanting windows [and] wavy cornices," and the cathedral in the central Zócalo square "is a kind of fun house, with a leaning chapel and a bell tower into which stone wedges were inserted during construction

to act more or less like matchbooks under the leg of a wobbly coffee table" (Kimmelman 2017). The unstable sinking land is also damaging already poor infrastructure. SEDEMA, the city's environmental ministry, reports that the city is subsiding at rates of 6 cm/year to more than 30 cm/year and the undulating topography is damaging both waste and supply infrastructure.

The quality of the supply infrastructure is particularly challenging for informal settlements because of their geography. They are mostly located on hard volcanic rock or on the steep hillsides on the city's periphery, which makes installing conventional pipe infrastructure more difficult and more expensive. Access to water was included in the Mexican Constitution in 2011 (Oswald Spring 2014), and the Water Law of Mexico City recognizes that all residents have the right to water. SEDEMA states that 97% of the city has household water connections (SEDEMA n.d.), but while most of the population has access, that does not mean that there are no problems in terms of water or service quality (Tortajada 2006, 12). Even if water is considered a right, formal agencies are not always inclined to provide services because informal settlements are "perceived as illegitimate, environmentally damaging and as forcing the city's hand in water provision"; the controversy of servicing informal areas pushes formal agencies to provide minimal water so as not to encourage further informal urban expansion (Lerner et al. 2018, 66). Informal settlements are often geographically inaccessible, making the installation of formal infrastructure infeasible, but more importantly their water supply is limited by an unwillingness to provide services.

INFORMAL PRACTICES

Because the formal water supply is either lacking or too expensive, many informal settlements depend on alternatives. Mexico City's rapid growth pushed the infrastructure to its limits, so "the *tandeo* (suspension of service for long periods of time) and the *pipas* (trucks transporting potable water on-demand to precarious zones, highly marginalized areas with no service at all and to geographically inaccessible locations, a systemknown as *pipeo*) began to replace and complement formal state-provided water" (de Alba 2017, 184). While older settlements have infrastructure that has been installed and upgraded over time, in general the informal water supply is characterized by illegal pipe connections and *pipas*. The *pipas* are most prominent but can cost 500 times more than the regular piped water (Tortajada 2006, 15).

Initially most *pipas* were provided by the government, but today there is a large network of pipa routes that include those organized by informal intermediaries. SACMEX, the water commission of Mexico City, is responsible for providing the main water and drainage lines of the formal water system, while the boroughs manage secondary lines that are "often harder to maintain with regularity. The borough governments also act on behalf of the residents in informal settlements, organizing water delivery in trucks from SACMEX" (Lerner et al. 2018, 67). The government does not publicly recognize the informal *pipas,* but it began to allow and even encourage them "once it was no longer the sole and exclusive interlocutor of citizens. [It] became only one of many other agents" (de Alba 2017, 184).

The *pipa* system gets around the geographic inaccessibility problem that limits water supply in informal settlements, but it does not totally make up where formal infrastructure is lacking. Through fees SACMEX provides water consumption subsidies for low-income households throughout Mexico City, but only households connected to the formal water network are eligible. SACMEX estimates that 48,000 households (about 2%) are still not connected to public services, and "these are the households with the lowest economic incomes and with the greatest needs and they are supplied by mobile water tanks, bottled water and/or pipes, which are generally sold at much higher prices [and] of lower quality" (Morales-Novelo et al. 2018). The formal supply network does not reach them, and the informal water network is too expensive and not of acceptable quality, so informal settlements need a better alternative.

FIGURE 3:

Residents wait to fill their water drums from a pipa truck. Source: Patel 2015

GOVERNANCE AND TYPES OF SCARCITY

The government of Mexico City recognizes that it has a water scarcity problem, and in recent years it has put together numerous plans to address the issue. Both the 2014 Climate Action Program and the 2011 *Plan Verde* (Green Plan) emphasize the need to protect the aquifers. SEDEMA, the city's environmental ministry, put together an informational pamphlet called *Cuidar el Agua es Cosa de Todos y Todas* (Caring for Water is Everybody's Thing) that illustrates where the city's water comes from, why the supply is insufficient, and how people can reduce their consumption. None of these government publications, however, distinguish how informal settlements are impacted by the city's water crisis or how they are part of the solution.

SEDEMA provides several reasons for the city's water scarcity including growing demand, leaks, and wasteful use. In their 2003 article about water poverty indicators, water scholars Molle and Mollinga identified five types of water scarcity: physical, economic, managerial, institutional, and political. Mexico City's water scarcity can be characterized as physical, managerial, or institutional and each type warrants different strategies. Physical scarcity is an absolute type of scarcity, where water sources are limited by nature. Managerial scarcity occurs when water systems are not properly maintained or managed. Institutional scarcity signifies society's failure to deal with rising supply/demand imbalances and to preserve the environment (Molle and Mollinga 2003, 531). Water scarcity in Mexico City's informal settlements is particularly shaped by the managerial and institutional types of scarcity.

TABLE 1:

Reasons SEDEMA provides for water scarcity, categorized according to Molle and Mollinga's scarcity typology. Sources: SEDEMA n.d.; Molle and Mollinga 2003, 531

Physical	Managerial	Institutional
• Lower aquifer levels • Changing rain patterns	• 30-45% potable water lost to leaks • Extraction surpasses natural aquifer recharge • Not taking advantage of rainwater • Pollution	• Growing population = growing demand • For every hectare urbanized, recharge reduces about 2.5 million liters per year • Irresponsible, wasteful use

More than a physical water scarcity problem, Mexico City has a water distribution problem. There are parts of the city where people live with less than 20 liters per day, and parts where people use 500 to 700 liters per day (SEDEMA n.d.). This imbalance corresponds with the differences between wealthy, formal areas and poor, informal areas. For example, poor neighborhoods in the Iztapalapa borough receive less than 10 liters per person per day, often only once a week, while the wealthy Lomas neighborhood in the Miguel Hidalgo borough has unlimited access to water (Oswald Spring 2014). Mexico City's water challenges are multi-dimensional and include the availability and security of the water itself dependent on aquifer health; the quality of its aging distribution infrastructure that is further stressed by subsidence; and the inability of formal systems to account for and properly serve informal settlements. The Sustainable Development Goals set by the United Nations General Assembly as part of the 2030 Agenda include the goal to "achieve universal and equitable access to safe and affordable drinking water for all" and to measure progress toward that goal with the "proportion of the population using safely managed drinking water services" (United Nations n.d.). By that measure Mexico City still has work to do to resolve its water crisis in an equitable way, but without accurate data about the proportion of its population actually served by its water system, the city's path toward a solution is not straightforward.

POLICY RECOMMENDATIONS

FIX LEAKING INFRASTRUCTURE

A major factor limiting the amount of water reaching peripheral communities, including informal settlements, is that 35 to 40% of the water supplied is lost to leaks (SEDEMA n.d.). The leaking is caused by both deteriorating pipes and illegal connections. SEDEMA recommends that Mexico City increase funds for repairs by charging residents—especially in the formal city—more to reflect the true cost of operation and conveyance. Residents of Mexico City pay much less for water compared to other Mexican cities: 2.38 pesos/m^3 in Mexico City versus about 15 pesos/m^3 in Tijuana and Aguascalientes (SEDEMA n.d.). Without subsidies and with the true cost of operation and conveyance factored in, SEDEMA estimates that Mexico City residents should pay 20 pesos/m^3. This additional revenue could then be allocated for infrastructure maintenance and upgrades. However, depending on increasing fees to fix leaks is not an easily implementable way to guarantee that water reaches communities not currently served. SEDEMA estimates that 45% of registered users do not pay for their water use, and that figure does not account for the thousands of unregistered informal connections that illegally tap into the same supply that are not even part of the fee system. Fixing leaking infrastructure is and should be a priority for Mexico City, but funding it cannot depend only on increasing water fees.

MANAGE URBANIZATION

Mexico City must coordinate better between land-use management agencies and water management agencies so that urban demand does not further exceed availability of water resources. The city's long-term sustainability is in jeopardy if there is not a reliable source of water to serve all its people. Mexico City's development pattern has disrupted the natural water cycle by building over pervious surfaces and thus inhibiting aquifer recharge, pushing water agencies to install deeper extraction pipes that lower the water table further, contributing to subsidence that makes distribution more challenging. The city is stuck in a sort of land use-water mismanagement loop in which land decisions affect water and water decisions affect land, but the agencies involved continue to operate in silos. Mexico City needs an integrated management approach that recognizes how land-use impacts water availability and how water-use impacts the land. This approach would require a joint authority that brings together the relevant local, regional, and national land and water agencies. The challenge with this approach is that informal settlements develop despite formal plans. So in addition to an integrated management plan, Mexico City would need to establish stronger protections for its Conservation Zone as well as adaptive strategies to retrofit existing informal settlements to expand perviousness to increase the aquifer's recharge rate.

CULTIVATE A NEW SUPPLY

To reduce stress on the aquifer and discourage further reliance on expensive imported water, Mexico City should invest in an alternative water supply: rainwater harvesting. Both SEDEMA and non-profits like Isla Urbana are already installing household rainwater harvesting systems in hydrologically vulnerable communities. SEDEMA estimates that its rainwater harvesting (RWH) systems have the capacity to capture 25,000 liters of water per year (SEDEMA 2019b), which would satisfy about 70% of the UN's recommended minimum of 100 L/person/day. Each RWH system is valued at 18,000 pesos but would be free for residents of Mexico City. To qualify for a RWH system households must be inhabitants of the Xochimilco or Iztapalapa boroughs, and must meet several requirements including participating in educational sessions introducing RWH basics (SEDEMA 2019c). Those boroughs were chosen as the initial installation sites because they have historically suffered from water shortages in which water is available only every week, every 10 days, or even every 15 days (SEDEMA 2019a). SEDEMA began installation in the Iztapalapa borough in April 2019, and it aims to install 100,000 RWH systems in various parts of the city in the next six years to demonstrate the feasibility of using decentralized and sustainable water management models to improve the living conditions of the neediest populations (SEDEMA 2019c).

A decentralized water system that includes RWH will enable informal communities to build resiliency by taking control and management of water resources from the formal institutions that have either neglected them or failed to serve them sufficiently. Isla Urbana has been installing RWH systems since it was founded in 2009 and its work in the Valle de Chalco neighborhood has demonstrated how "decentralized rainwater harvesting utilization and management in urban settlements can potentially reduce the use of drinking water in an average household by up to 70%" (Chelleri et al. 2015). The primary concerns with RWH are the possibility of pollution if the systems are not installed and maintained properly, and that its dependence on rainfall patterns makes it capable of facilitating access to water in homes only five to eight months per year (SEDEMA 2019c). This means that while RWH will be an important factor in increasing water supplies in informal settlements and helping the city as a whole reduce its dependence on the stressed aquifer, Mexico City must still address its ongoing infrastructural and management challenges.

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