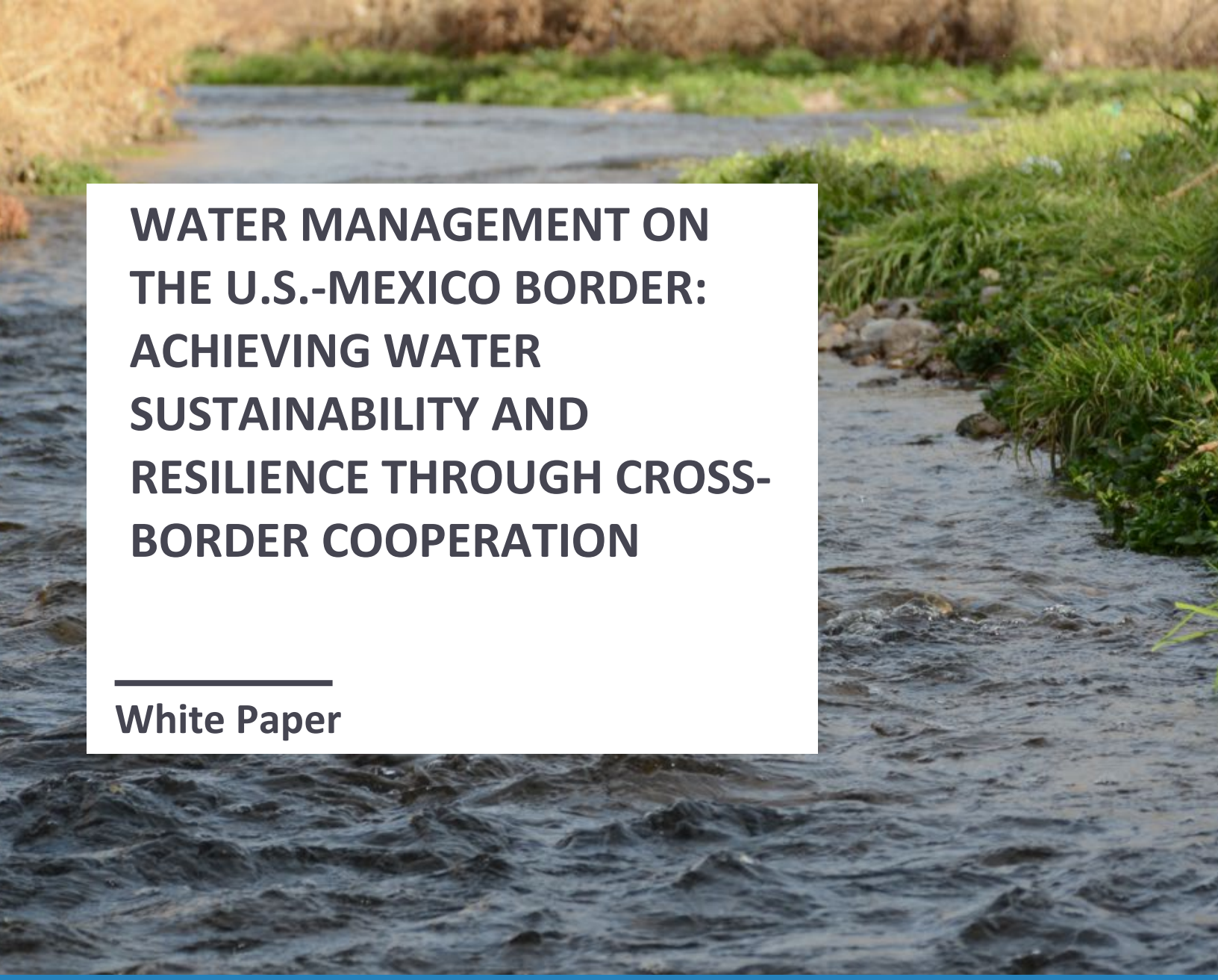

WATER MANAGEMENT ON THE U.S.-MEXICO BORDER: ACHIEVING WATER SUSTAINABILITY AND RESILIENCE THROUGH CROSS-BORDER COOPERATION

White Paper

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Leading Authors:

Irasema Coronado (Arizona State University), Francisco Lara-Valencia (Arizona State University),Stephen Mumme (Colorado State University)

Contributing Authors:

Christopher Brown (New Mexico State University), Paul Ganster (San Diego State University), Hilda García (El Colegio de la Frontera Norte), Donna Lybecker (Idaho State University), SharonMegdal (University of Arizona), Rosario Sanchez (Texas A&M University), Alan Sweedler (San Diego State University), Robert G. Varady (University of Arizona), Adriana Zuñiga (University ofArizona)

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School of Transborder Studies, Arizona State University
Tempe, Arizona

https://sts.asu.edu/
P.O. Box 876303, Tempe, AZ 85287-6303
(480) 965-5091

Purpose

This white paper outlines a set of proposals intended to strengthen the ability of the United States International Boundary and Water Commission (USIBWC) to respond to the challenges of U.S.-Mexico border water management in the 21st century. The paper is placed within the context of the USIBWC's long history of handling water management issues on the U.S.-Mexico border and its demonstrated capacity to respond and adapt to the changing social, political, and environmental conditions and needs of residents of the border region. The paper draws on the extensive individual and group experience of the authors. It is guided by our collective understanding that water sustainability, resilience and efficiency along the U.S.-Mexico border are better achieved through cross-border cooperation, local participation, and partnership with universities and research institutions.

The paper is divided into three main sections: (1) institutional context, (2) current and emerging water management challenges and opportunities, and (3) institutional and policy requirements needed to achieve water sustainability, resilience, and efficiency along the U.S.-Mexico border**.**

1. INSTITUTIONAL CONTEXT

The Boundary Convention signed in 1889 and the Water Treaty signed in 1944 are the two main sources of authority of the International Boundary and Water Commission (IBWC) over all water boundary and border water management issues between Mexico and the United States. According to the 1944 Water Treaty, the IBWC is responsible for three interrelated water management functions:

- Plan, construct, operate, and maintain joint boundary and waterworks, including international dams and reservoirs, hydroelectric power plants, and stream-gauging stations required to produce the hydrographical data required to determine treaty allocations of transboundary waters.
- Undertake measures to fulfill other rights and obligations, especially in regard to improving border sanitation and other water quality problems, flood control, and preserving the Rio Grande/Río Bravo (hereafter, Rio Grande) and the Colorado River as the international boundary; and
- Resolve disputes between the United States and Mexico regarding the interpretation or application of the 1944 Water Treaty.

Tasked with the responsibility of being the primary negotiator and arbiter of transboundary water resources disputes, the IBWC has proven its institutional effectiveness by addressing conflict between the two neighboring nations and by moving the binational water agenda forward. However, the 21st century sees the U.S.-Mexico borderlands facing an emerging array of water resource management challenges. These challenges range from the increasing demand of water due to urbanization, industrialization and agricultural expansion. This growing demand strains the capacity of limited water supplies to deal with a host of social, legal, and environmental issues threatening surface and underground water quality and security. Perhaps most salient among these issues are the palpable impacts of climate change on the hydrological cycle and on water security on both sides of the border. Droughts across the region, already decades-long, are likely to continue and to constrain even further the ability of the parties to meet water delivery obligations in the Colorado and Rio Grande rivers.

CLIMATE CHANGE AND VARIABILITY ARE NOW STRAINING EXISTING INSTITUTIONAL CAPACITY AND WATER SUPPLIES.

Continued drought conditions are generating internal and bilateral tensions as competing water users in Mexico and the United States struggle to meet their needs. Climate change also contributes to more frequent and severe flooding events, resulting in threats to critical border water infrastructure, heightened sanitation and public health issues, as well as greater contamination of transboundary water bodies. Tension over the use of shared groundwater is increasingly apparent as the lack of clear guidelines over its management collides with a greater demand for this resource.

However, arguably the biggest challenge for border water management originates from the social and economic transformations of the border region itself. As cities on both sides of the border keep growing and expanding, the regional balance between water demand and supply will be put increasingly at risk. Population and economic growth require a steady water supply, which border cities will likely struggle to secure. Agricultural production, the main water user in the border region, is still a strong sector of the border economy and is expanding in the irrigated areas of northern Mexico. Recent tension over the allocation of water resources is a harbinger of a future, where competition over unreliable water supplies will intensify. While engineering solutions are central to the USIBWC's work, the larger evolving social, economic, and political context of the borderlands is increasingly relevant. Therefore, meeting these challenges will require innovative and strategic thinking recognizing the complex and dynamic interaction between coupled environmental forces and socio-economic systems in the border region. The purpose of the following vignettes is to capture the central aspect of some of these

challenges and outline general lines of action to achieve water sustainability and resilience through enhanced binational cooperation.

2. U.S.-MEXICO BORDER WATER MANAGEMENT CHALLENGES AND OPPORTUNITIES IN THE 21st CENTURY

2.1. Coping with climate change

The past two decades have shown that a changing climate presents an existential threat to transboundary water management. Such a development has no real precedent since the USIBWC was established in 1945. Although the rate of change and precise effects remain difficult to predict, the science behind climate change in the U.S.-Mexican border region and all of North America is clearly established (Wilder et al. 2013). The science tells us that the border region must cope with:

- Rising average temperatures, including nighttime temperatures, presenting increased human health effects and disproportionately burdening low-income communities;
- Changing weather and precipitation patterns manifesting in more extreme weather risks, flooding, and erosion;
- Decreased water production expressed in shortages of available surface and groundwater;
- Chronic drought amplifying incidence of wildfires and altering ecosystems; and
- Rising sea levels threatening the border's coastal communities (GNEB 2016).

Responding to the impacts of climate change is within the USIBWC's overall mission—specifically, via the execution of the Commission's water distribution and flood control responsibilities, transboundary water distribution in the watersheds of the Rio Grande and Colorado rivers, operation and maintenance of water storage reservoirs and hydroelectric dams on the Rio Grande, and flood protection along the principal boundary rivers through levee and interior floodway projects. In addition, the Commission's border sanitation and water quality mission includes operating wastewater treatment plants in San Diego, California; Rio Rico, Arizona; and Nuevo Laredo, Tamaulipas. Addressing climate-related issues is a binational challenge for the USIBWC and its Mexican counterpart. The USIBWC is currently tasked with (1) reaching a new agreement on Mexico's Rio Grande treaty water deliveries by 2023; (2) reconsidering renewal of shortage sharing agreement on the Colorado River in 2026; and (3) developing different solutions to sanitation problems impacting the Tijuana River.

IBWC WILL NEED TO APPLY INNOVATIVE AND STRATEGIC THINKING TO CONTEND WITH SOCIAL AND ECONOMIC AS WELL AS CLIMATIC TRANSFORMATIONS OF THE BORDER ITSELF.

Climate considerations should be incorporated in future USIBWC Minutes addressing water availability on the treaty rivers and transboundary sanitation financing and management. Such efforts conform with the U.S. administration's recent Executive Order 14008, "Tackling Climate Change at Home and Abroad" (White House 2021), which urges U.S. federal agencies to (1) make climate change a consideration of all U.S. foreign policy (Section 101); (2) incorporate climate into

their rationale for program funding (Section 102); and (3) build climate change into their operational plans and strategies (Section 103).

Given the severity of climate change effects, the USIBWC needs to proactively consider climate change and its human impacts in managing its ongoing activities, responding to emergencies, and planning for discharging its responsibilities in the medium and long term. Thus, environmental justice, greenhouse gas effects of energy required for water and wastewater, reclamation and reuse, stormwater capture, and other climate-related matters should be incorporated into all the USIBWC's border water management activities.

2.2. Managing water shortage: augmentation/diversification

The specter of climate change and its corollary, persistent water shortage amidst rising water demand, now colors and imperils the long-term future of the border region's water supply. On the Colorado River, recent USIBWC shortage sharing agreements, Minutes 319 (IBWC 2012) and 323 (IBWC 2017), formally acknowledge the prospect of diminished future flows. In addition, diminished precipitation on the Rio Grande contributed to Mexico's missing treaty water delivery targets twice in the past 20-years; for example, Mexico's recent compliance in October 2020, acknowledged in Minute 325 (IBWC 2020), sparked social unrest in that nation's upstream irrigation districts (Varady, Mumme, and Gerlak 2021).

PRESENT IBWC STRATEGIES ARE NOT SUFFICIENT TO CONFRONT LOOMING WATER SHORTAGES. IBWC WILL BE AN IMPORTANT LEADER IN HELPING BORDER COMMUNITIES ADAPT TO NEW CONDITIONS.

Confronting these unprecedented constraints on the region's freshwater supply, the adaptive strategies of border communities in both countries, rural and urban, now include diversification of water sources, augmentation of existing water supplies, and conservation of existing water stocks by more efficient irrigation methods and various means of water reclamation and reuse. Irrigated agriculture on both sides of the boundary is pressed to use water more efficiently than ever before.

To date, adopting more efficient irrigation conservation technologies and wastewater reclamation have been the dominant strategies for augmenting and diversifying water sources along the boundary. Desalinization, despite its expense, is now increasingly turned to at various locations for purifying brackish groundwater, with seawater desalination now adopted or seriously considered in some border coastal communities and being considered in others.

Present strategies are not sufficient to meet the needs of border communities in the 21st century. Going forward, a "hydrological cycle" approach to water stewardship is needed, centered on conservation efficiencies and employing both direct (tap-to-toilet) technologies of water reuse and

indirect technologies aimed at aquifer recharge and recovery. Purifying wastewater to potable water standards as seen in San Diego will be needed in urban communities elsewhere in the border region. Land management strategies facilitating greater percolation of runoff water into local aquifers can boost local water supplies. Groundwater, which now supplements border region surface water availability to an unprecedented extent, must be fully integrated into water resource management strategies to amplify efficiencies across the water cycle.

The USIBWC has an important role to play as border communities adapt to these new hydrological conditions, particularly where transboundary rivers and aquifers are concerned. As its recent agreements affirm, it has already performed important service in advancing the monitoring and modeling of hydraulic flows and working with the North American Development Bank (NADBank) to support improved conservation practices in Mexico's Rio Grande tributary river watersheds. The Commission has signaled its interest in supporting national and binational efforts to tap additional groundwater and desalinate brackish groundwater and seawater in the lower Colorado River Zone and Tijuana-Rosarito, Baja California. It has also contributed to a better understanding of transboundary aquifer assets through its participation in the implementation of the Transboundary Aquifer Assessment Act (TAAP).

THE USIBWC SHOULD ADOPT A WATERSHED-MANAGEMENT AND HYDROLOGICAL-CYCLE APPROACH AND COMMIT TO AN AGREEMENT TO STRENGTHEN BINATIONAL CAPACITY FOR ADAPTING TO COMING WATER SHORTAGES.

But the USIBWC can do even more. First, it should sustain its technical advisory bodies on the treaty rivers in partnership with domestic water agencies to gain a dynamic and harmonized watershed level understanding of existing stocks, flows, and consumptive uses of water in the transboundary river basin. Second, it should monitor developments in groundwater management along the border, including the new and emerging efforts to desalinate brackish groundwater seen in Brownsville and El Paso, Texas, and develop aquifer storage and recharge programs. Third, it should work with the national governments to build a framework agreement on transboundary groundwater that supports aquifer-specific groundwater protection and conservation initiatives. And fourth, it should approach transboundary groundwater issues attentive to the conjunctive uses of aquifers and surface flows as it considers potential solutions for managing shared aquifers.

As it pursues its article 3 mandate under the 1944 Treaty regarding transboundary sanitation solutions, the USIBWC should work with stakeholders to build in state-of-the-art water reclamation and reuse facilities that advance the potential for fully utilizing these water resources for human and ecological needs. In the process, it should be attentive to the hydrological cycle and the different ownership regimes of these resources in the U.S. and Mexico, pursuing equitable compensatory

solutions as needed, making provision for the dynamic development of consumptive water needs in these communities.

Finally, the USIBWC should strengthen its informal commitment to watershed-management and hydrological- cycle approaches to the shared stewardship of binational rivers and aquifers and consider acknowledging this commitment in an agreement that strengthens binational capacity for meeting the challenge of climate change and greater surface water shortages in the coming years.

2.3. Managing water harms

Although afflicted by drought and water shortages, the border region will see increased hazards from flooding in the future due to the effects of increased urban development and climate change (GNEB 2008). In 2020, an estimated 8 million residents lived in U.S. counties along the border, and a somewhat smaller number lived in the Mexican border municipalities; the population in this binational border zone is growing faster than that in their respective states or nations (Ganster and Collins 2021). Poorly planned and haphazard urban and peri-urban sprawl accommodates the growing population and often extends to flood plains and unstable hillsides. Increased stormwater runoff related to urbanization and destruction of natural stream function and habitats will be compounded by more frequent and intense storm events associated with climate change. Higher temperatures and changes in rainfall patterns produce more frequent and more intense wildfires that strip vast areas of the border region of water retaining vegetation and increase stormwater runoff to exacerbate flooding, landslides, and mudflows. Sea level rise and more coastal flooding are also growing threats.

The IBWC is engaged in reducing risks related to flooding and devotes considerable effort to the construction and maintenance of flood-control levees, mainly in the Tijuana River and at many sites along the Rio Grande from El Paso to the Gulf of Mexico. The USIBWC also provides flood warnings and outreach materials on preparedness for a range of natural disasters along the border (www.IBWC.gov.2021). Due to the dynamic population growth in the border region and accelerating climate impacts, control of floods brings new challenges. These are especially significant in the lower Rio Grande Valley, an area that is hit frequently by hurricanes and tropical storms. These challenges also are present in other basins along the border, such as the Ambos Nogales watershed in the Arizona-Sonora border.

Flood maps issued by the Federal Emergency Management Agency (FEMA) are a basic tool to aid communities and agencies in planning and maintaining flood control strategies and infrastructure. These maps, which determine the size of the 100-year and 500-year floodplain, have enabled the USIBWC and other agencies to build adequate flood control structures, including the systems of levees the Commission maintains along the border. However, the hydrological models used to establish these flood risk maps may be inaccurate due to land-use changes in relevant watersheds, greater urban development in flood plains and other low-lying areas, and cumulative effects of

climate change (GAO 2021). These maps also do not extend into Mexico, and we propose future joint work by the U.S. and Mexican sections to address this data gap.

Utilizing rapidly evolving science, the Commission must develop more realistic and timely estimates of flooding risks to mitigate risks to border communities and USIBWC infrastructure. Taking a watershed approach to such an effort provides a very useful geographic frame for this work, consistent with the approach undertaken in the development of USIBWC Minute 320. The USIBWC can play an important role in updating models to support its efforts to build and maintain levees against increasingly severe flooding. Efforts to extend flood modeling upstream on both sides of the international boundary can assist in restoring natural stream function, increasing recharge, and reducing flooding through green infrastructure.

THE LIKELIHOOD OF MORE SEVERE FLOODING IN THE FUTURE PROVIDES THE USIBWC WITH AN IMPORTANT OPPORTUNITY TO MITIGATE RISK TO BORDER COMMUNITIES.

A central element of this broader approach to flood risk should include expanded community engagement to convey information about risks as well as adaptation options at the community level. The existing USIBWC Citizens Forums, especially if expanded to be truly binational in nature, could facilitate this process. As helpful as these Citizens Forums have been in exploring issues in urban areas, similar issues face unincorporated communities in both the U.S. and Mexico. We suggest that Commission staff work with select authors of this report to explore how best to engage in these less populous communities that face water insecurity and other challenges.

2.4. Groundwater management

The Colorado and Rio Grande rivers surface water systems are experiencing increasing stress due to growing demands and dwindling supplies. Water—to support (1) population expected to double by 2050; (2) irrigation, which accounts for around 80% of border groundwater use; (3) industry, mostly maquiladora; and (4) new uses, such as fracking in the Texas-Mexico border— will need to come from alternative sources. Climate variability and growing uncertainty of environmental threats have directed worldwide attention to groundwater. Groundwater can enhance the resiliency of water-resources systems and link strategic and integrative water management approaches. Its common omission from transboundary water conversations has limited the strategies for coping with drought and generalized water scarcity. Moreover, surface-groundwater conjunctive use, which is essential, requires specific—but often unavailable—knowledge of aquifer conditions and groundwater governance.

Recent research reports 28 known transboundary aquifers in the cross-border region (Sanchez and Rodriguez 2021). Additionally, about half of the shared land between Mexico and the U.S possesses good aquifer potential and good-to-moderate water quality. Yet, groundwater historically has

received limited attention binationally. Minute 242 from 1973 (Yuma aquifer extraction limits) identifies groundwater as a pending issue to address in the bilateral water agenda, thereby providing a foundation to engage binationally on the issue of transboundary groundwater resources (IBWC 1973). But neither of the current legal instruments (1906 Convention or 1944 Treaty) addresses the use or management of groundwater, per se (U.S. Department of State 1906, 1944).

The Transboundary Aquifer Assessment Program (TAAP) is the current binationally-agreed- upon framework for studying groundwater resources (IBWC 2009). To date, TAAP has assessed only four priority aquifers: Santa Cruz and San Pedro (shared by Arizona and Sonora), and Mesilla Bolson and Hueco Bolson (shared by New Mexico, Texas, and Chihuahua). A collaborative team has developed a binationally approved report for the transboundary San Pedro aquifer and is finalizing a similar report for the transboundary Santa Cruz aquifer (Callegary et al. 2018). However, work that is explicitly binational has experienced only limited success on the other two priority aquifers. There have been isolated modeling efforts on other aquifers (Mimbres, Bajo Rio Bravo, Allende-Piedras Negras, Tijuana Aquifer), but only Allende Piedras Negras has included the Mexico side of the aquifer. Limited trust, lack of data, and insufficient follow-up, funding, institutional commitment, regulatory framework, leadership, willingness, and interest all have been cited as key factors limiting cooperation on transboundary groundwater resources (Sanchez and Eckstein 2020). However, while some local, informal efforts reportedly have experienced short-term success (e.g., El Paso Water 1990s), long-term impacts have been limited due to inadequate institutional (i.e., formal) support and established mechanisms for collaboration.

CONSIDERING THE DIFFERENCES IN COMPLEXITY, NEEDS, CULTURE, PRIORITIES OF EVERY REGION/AQUIFER, A CASE-BY-CASE APPROACH IS LIKELY THE MOST FEASIBLE STRATEGY TO ADDRESS TRANSBOUNDARY GROUNDWATER RESOURCES.

In view of the rapidly rising necessity of groundwater use in the border region, the USIBWC has an important opportunity to make transboundary aquifer management an institutional priority. Fortunately, a legal source (Minute 242) exists to enable and promote transboundary groundwater cooperation through the IBWC. The TAAP cooperative framework is the immediate vehicle to build upon a more integrative scope of transboundary groundwater cooperation using a minute-scale regional process rather than a border-wide agreement. An extension of this framework, both in space and subject matter, should be considered. Local, informal approaches—as well as the involvement of stakeholders under a cooperative framework for integrated water resources management—are recommended as an initial step to lead a formal effort. In this process, the USIBWC would serve more as facilitator than as the leader or authority in moving the effort forward, similar to its role in advancing Minute 320. Groundwater needs to be included in any formulas for integrating water-

resources management, green-based solutions, climate adaptation and resilience, community-building and vulnerability analysis.

2.5. Public health

Public health concerns have been a long-term priority for border water management and the IBWC. Article 3 of the 1944 Water Treaty tasks the IBWC with finding solutions to water sanitation problems, a chronic environmental issue of the borderlands. Rural communities and many urban areas in the border region are still struggling to fulfill basic services needs such as water and wastewater treatment. This situation persists despite the significant improvements in water and wastewater services attributable largely to infrastructure projects funded through the BECC, NADB, and USEPA binational programs (Mumme 2021).

The U.S. and Mexico governments recognize that deficits in basic sanitation services will be exacerbated by sustained economic and demographic growth of the border region, posing a significant human health and environmental threat to communities on both sides of the border. The public health implications of the lack of potable water for border communities is widely acknowledged, as well as the exposure to open raw wastewater discharges affecting residential areas. This includes exposure to pathogens such as bacteria, protozoa, and viruses producing infectious diseases such as hepatitis A, dysentery, cholera, and other gastrointestinal diseases. Domestic sewage can also contribute to pharmaceutical compound interactions with bacteria, the latter then developing resistance to medical interventions. Lack of water and sewer infrastructure and its concomitant health effects disproportionally impact vulnerable and impoverished communities (i.e., colonias in Texas), as it has been well documented since the 1970s (Coronado 2003). Unfortunately, to date, the problem persists (Coronado 2019). Climate change and its impacts on flood-related risks and operation of sanitation systems, carries an additional threat through the spread of vector-borne diseases and access to safe water.

CROSSBORDER COOPERATION HAS PROVED TO BE THE MOST EFFECTIVE METHOD TO PRODUCE THE ACTIONS AND RESOURCES NEEDED BY BORDER COMMUNITIES TO ACQUIRE LEVELS OF BASIC SANITATION REQUIRED FOR A HEALTHY LIFE AND ENVIRONMENT.

Many border communities depend on shallow groundwater sources and often are located within floodplains, which compound health risks due to potential water contamination from untreated wastewater leakages and combined sewer overflows (CSOs) during storm events. Groundwater resources are also at risk from leaking septic tanks and leach fields, especially in rural areas that lack centralized wastewater collection, treatment, and disposal facilities. In addition, it has been evident since the late 1990s that spillage of chemical substances from supply vehicles, industrial facilities, and leaking underground storage tanks of fuel products can pose risks to human health across the border

as these chemicals are transmitted through groundwater aquifers and yield contaminated groundwater plumes (Varady, Lankao, and Hankins 2001).

As reported by the GNEB (2012), the combined effect of chronic infrastructural deficits, technical and administrative gaps, and the lack of financial resources undergird the persistent sanitation challenges facing border communities. Crossborder cooperation among U.S. and Mexican agencies has proved to be the most effective method to produce the actions and resources needed by border communities to acquire levels of basic sanitation required for a healthy life and environment (Giner et al. 2017). The identification of common environmental health priorities within a framework of collaboration with local communities in implementing them is imperative for the success of the IBWC in finding solutions to border water sanitation problems.

2.6. Green/gray infrastructure

The U.S.-Mexico border region is highly urbanized, with cities on both sides experiencing steady growth and urban sprawl. This expansion alters natural landscapes and impacts water security, urban resilience, and livability through:

- Expansion of impervious surfaces and shrinking recharge and infiltration areas—due to the construction of roofs, parking lots, streets, and other urban infrastructure.
- Modification of watercourses—caused by encroachment of floodplains by roadways and buildings; and
- Alteration of drainage and rainfall-runoff patterns—through leveling, cutting, and filling of natural areas to accommodate land demand.

As a result, urbanized areas—particularly those directly abutting the border—experience high-volume/high-velocity streamflows during seasonal storms, causing flooding, property destruction, infrastructure damage, social disruption, and even loss of life. Intensified stream flows also erode disturbed areas and transport sediment, debris, and garbage that enter the sewage conveyance network, producing combined sewer overflows (CSOs). CSOs contain untreated human and industrial waste, toxic materials, and debris, as well as stormwater that can overwhelm sewage and wastewater treatment systems. In addition, local water sources, especially groundwater, are impacted by low recharge rates and high concentrations of pollutants that threaten plants, animals, and human life.

Compounding the challenge of border water management, climate change will render border cities even more vulnerable to extreme weather and floods in the coming decades. Thus, without the appropriate vision and policy tools for sustainable water planning and management, cities and people on both sides of the border will continue to face the negative impacts of urbanization and climate change, compounded by the risk of reduced economic growth and lowered quality of life.

Green infrastructure (GI), defined by the U.S. Water Infrastructure Improvement Act as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters" (U.S. Congress 2019), is increasingly promoted in water planning. It is seen as a way for cities to curb the impact of urbanization, adapt to climate change, improve livability, and become more sustainable and resilient. In particular, GI is used to mitigate urban hydrological modification, thereby decreasing peak runoff rates, increasing groundwater recharge, mitigating the urban heat-island effect, and providing other ecosystem services. In addition to providing hydrological and ecosystem services, GI also can yield social and cultural benefits.

GREEN INFRASTRUCTURE, IN COMBINATION WITH CONVENTIONAL INFRASTRUCTURE, CAN HELP IMPROVE TRANSBOUNDARY WATER MANAGEMENT IN A DECENTRALIZED, BUT INTEGRATED MANNER WHILE IMPROVING THE SUSTAINABILITY AND RESILIENCE OF BORDER COMMUNITIES.

As evidenced by efforts in El Paso, Brownsville, and Nogales, planning departments and community organizations are recognizing the need to apply GI for long-term strategic planning to advance border sustainability and resilience (Giner et al. 2019). GI can be used in cities as a "front-of-the-pipe" or as an "end-of-the-pipe" solution. As a front-of-the-pipe solution, GI captures stormwater before entering the conveyance system, which helps on-site infiltration, decreases flooding, and replenishes local aquifers. At the end-of-the-pipe, GI can provide a second treatment to effluent before being discharged into water bodies. This GI approach is particularly relevant in border cities with unitary sewer systems prone to produce CSOs running through streets and reaching water bodies, posing a severe health risk to people (Lara-Valencia et al. 2021).

In combination with so-called “gray infrastructure”—piped drainage and conventional treatment systems—GI solutions are seen increasingly by border environmental institutions like the NADBank and the U.S.-Mexico Border Environmental Program as an effective and comprehensive approach to protect communities on both sides of the border from flooding, protect water quality, and provide green space to residents on both sides of the border (Giner et al. 2019).

Because border cities are interconnected through their hydrology and urban infrastructure, water managers are considering watershed boundaries as the most useful water planning unit. Hybrid systems combining green-gray infrastructure can help improve transboundary water management in a decentralized but integrated way while improving the sustainability and resilience of binational urbanized watersheds.

However, the adoption and long-term prospects of GI in the border region depend mainly on its institutionalization and the support provided by champions promoting its implementation at a cross-border scale. The IBWC has the capacity and experience to champion decentralized GI solutions for border water management by including local government officials, holding public forums on GI practices, and developing GI criteria for USIBWC construction projects. To facilitate this process, the USIBWC should launch a minute-scale process leading to the negotiation of GI minute with the IBWC Mexican section. This perspective is consistent with transboundary watershed management approach of Minute 320 for the Tijuana River Watershed.

2.7. Energy/water nexus

Distribution and treatment of water and wastewater in the border region are energy-intensive, and energy requirements for these activities will almost certainly increase along with climate change effects. Energy use and sewage treatment both produce greenhouse gases, contributing to global warming. The USIBWC now faces a significant hurdle in meeting the growing energy requirements for its activities while reducing its carbon footprint. Going forward, the USIBWC should proactively incorporate climate change projections as part of its operations and planning activities and should periodically conduct energy and greenhouse gas (GHG) audits to facilitate energy efficiency and GHG minimization.

Many of the water and wastewater treatment facilities that the USIBWC manages and operates were built when energy requirements for these facilities were not a major factor. Today, however, and in the future, energy requirements for existing and new facilities must be considered when upgrades are needed during operation, in the planning phase and during construction. For example, the energy requirements for the South Bay International Wastewater Treatment Plant in the San Diego-Tijuana region are considerable, as are the costs. The USIBWC might consider alternative energy sources for this and other facilities it operates, alternatives that were not available when the facilities were built. The cost of solar has come down dramatically in the past few years and operating a wastewater treatment plant on renewable energy would send a powerful message about using renewable energy to deal with an important environmental issue in the border region. In addition to the energy requirement of wastewater treatment, water reuse has become very important in recent years, especially in the water-poor regions of the border. Maintenance of water storage reservoirs and flood protection are also responsibilities of the USIBWC.

Water pumping and distribution depend heavily on electricity to move the water from place to place. New and more efficient motors and dedicated solar systems for water distribution are available and may save on the energy used for pumping water. Electricity is the main form of energy used by the USIBWC; taking advantage of significant cost reductions in on-site power generation and new and efficient pumping systems would be an area to investigate.

It is clear that energy and water are conjoined, and one cannot meet the water needs and responsibilities of USIBWC without thoroughly understanding the energy requirements needed for various facilities managed by the Commission. To this end, it is necessary to bring energy into every project developed by USIBWC immediately at the early planning stages. A working group or subcommittee dealing specifically with energy-related issues should be considered as a permanent part of the administrative apparatus of the USIBWC.

INCREASED ENERGY DEMAND WILL REQUIRE THE USIBWC TO ADAPT BY REDUCING ITS POWER REQUIREMENT, USING MORE ENERGY-EFFICIENT FACILITIES, AND TURNING TO ALTERNATIVE SOURCES.

Other specific areas that are relevant would be the future of desalination (seawater and brackish water) in the border region. Although tempting to exploit this technology, given the location of the border on the Gulf of Mexico and the Pacific Ocean, it is very expensive, and other alternatives are available. However, at some point, a thorough analysis of costs and benefits would be useful for future planning.

Climate change will be the overriding factor driving the water responsibilities of the USIBWC in the near and midterm future. However, it is clear that much of planetary warming is locked in, and the rate of temperature increase is yet to be determined. Therefore, it would seem prudent for USIBWC to begin to adapt to the inevitable warming and to closely examine the energy requirements, which will be affected by the warming, needed for maintaining current water infrastructure and planning for future projects.

3. INSTITUTIONAL AND POLICY NEEDS

3.1 Local involvement

Involving local stakeholders in dialogic processes about water management on the U.S.-Mexico border has been important and continues to be vital for the successes of the USIBWC in recent years. The importance of participatory policy-making is reflected in the growing capacity of the USIBWC to trigger collaborative efforts involving community, environmental, tribal, academic, and government actors that lay the groundwork for complex negotiations on critical issues for binational water management.

The USIBWC has set a precedent for involving local stakeholders, including governmental and non-governmental organizations, in meaningful policy-making processes. An example of this inclusive approach was the establishment of the Binational Core Group (BCG) and the four Binational Work Groups (BWG) to explore and evaluate opportunity areas for water conservation, storage, supply augmentation, and environmental protection in the context of the Colorado River Joint Cooperative Process (IBWC 2010). Likewise, a BCG comprising community leaders was also established to oversee

the work of three binational working groups to address transboundary issues in the Tijuana River Basin under Minute 320 (IBWC 2015). Membership of these groups included federal and state representatives, along with nongovernmental organizations, tribal nations, and universities from both sides of the border.

Within the USIBWC framework, these public-participation mechanisms were established "as an inclusive process to obtain recommendations from stakeholder groups on transboundary issues" and to "jointly identify measures that require cooperative action to benefit the residents on both sides of the border" (IBWC 2015). Overall, the binational groups were important for conducting studies to identify issues and suggest solutions. The USIBWC's inclusion of diverse stakeholders shows an understanding of the immediate and long-term benefits of this inclusive approach. In the short term, the Commission has been able to access local expertise and available information in support of its activities. In the long term, this strategy brings credibility and legitimacy to decisions made by the Commission to address the many conflicting water issues affecting the border.

The USIBWC needs to continue its efforts to find solutions to binational water management through an optimally diverse range of stakeholders and adequate levels of participation. The outreach capabilities of the Commission were expanded with the creation of the Citizen Forums that operate in five different sections of the border. This effort reflects an ongoing commitment of the USIBWC to operate in a more open and participatory way intended to enable a "two-way flow of information, concerns, values, and needs between the USIBWC and the general public, environmentalists, government agencies, municipalities, and other interested parties" (USIBWC 2022). A continued effort to include the voices of indigenous communities, water users, environmental groups, citizens, local governments**,** and the private sector will allow for a greater understanding of binational water problems and open the path for creative and sustainable solutions. In addition, by hearing the public voices, the USIBWC will gain social support, diminish misinformation, and reduce conflict and delays in implementing critical programs.

THE USIBWC'S COMMITMENT TO TRANSPARENCY AND COMMUNICATION SHOULD IMPROVE WATER MANAGEMENT THROUGHOUT THE BORDER REGION BY RESPECTING THE COMMUNITIES IN WHICH THEY WORK.

3.2. Integrated approach to water management

Integrated water resources management, broadly conceived, in the border region between Mexico and the United States can provide considerable utility in water policy development, planning, and implementation of resilient water resources systems. Such an approach should adopt a watershed based approach attentive to surface and groundwater interaction, the multi- sectoral demands on water resources, water-energy interactions, and the multi-governance administrative aspects of

water administration. However, the transboundary nature of water resources makes this task a rather complex challenge that needs to take into account important considerations on the border. First, effective management requires multiple and creative ways to assess water resources institutionally, operationally, and socially at the watershed scale. Second, water needs to be deployed through a strategy for cooperation requiring stakeholder involvement at the appropriate scale, with effective and resilient communication tools and with involvement and support of formal and informal institutions. The USIBWC's role should be to facilitate needed discourse and lead the development and implementation of strategies that promote integrative water management approaches.

The watershed-scale approach has been successfully launched in the border region in the Tijuana River Watershed (IBWC 2015). This experience provides a useful and well-grounded geographic frame for developing and implementing water resource management strategies in a binational context. The Minute 320 experience demonstrates the value of the input of stakeholders and university researchers at a watershed level that supported the elaboration of this Minute. The lessons from the Minute 320 experience can be applied in exploring larger watersheds, such as the Rio Grande basin. However, such an effort would require a parallel, multiscale approach due to the extent and scale of this larger watershed. Generally, funding efforts tend to compartmentalize regions within watersheds that respond to a project/based approach rather than to a watershed approach; therefore, the systemic impact has been limited. Connectivity and an integrative approach should be the guiding principles when exploring IWRM in other basins in the U.S.-Mexico border region.

3.3. Science/research-based policy

The USIBWC should maintain and further develop cross-border collaboration and synergistic partnerships with other water stakeholders in the academic, private and government sectors. Partnerships are an important vehicle for the production of science to support more effective solutions for binational water issues and amplify local ownership of water management decisions. Working with groups and individuals with experiential (i.e., users and practitioners) and specialized water knowledge (i.e., scientists and researchers) will strengthen the opportunities for the co-production of knowledge and data to support decisions on complex water issues resulting from urbanization, economic expansion, and climate change.

AN ADVISORY GROUP ROOTED IN THE ENVIRONMENTAL SCIENCE OF THE U.S.-MEXICO BORDER COULD PROVIDE LEGITIMACY AND CAPACITY TO THE USIBWC'S EFFECTIVENESS.

Championing initiatives that advance a long-term vision to climate change challenges is vital for the USIBWC water management decisions in the coming decades. As mentioned earlier, the problems created by climate change cut into the core of the mission of the USIBWC in addressing areas such as water supply, water quality, and management of binational water infrastructure. In addition, policies linked to mitigating water insecurity and

adapting to the impacts of climate change are intertwined with the broader governance and development issues complicating water management along the U.S.-Mexico border. However, governance systems to address these challenges effectively have yet to be designed and implemented, and the USIBWC could be a key player in their construction.

In recent years, the USIBWC has embarked on a trajectory of cooperation, inclusion and looking toward the future. Continuing to strive to achieve those management techniques will be important for the future of the U.S.-Mexico border region and the well-being of its residents.

Community engagement and effective communication through already established collaborative platforms, like the Permanent Forum on Binational Waters (PFBW), has proved to be an effective tool. The PFBW is a networking platform of scientists, experts, city, state, and federal officials, NGOs, and private citizens from both sides of the border. Members of the PFBW are interested in supporting collaborative and binational efforts to improve the resiliency of border communities through:

- effective communication,
- dissemination of scientific information,
- community building, and
- permanent discussion forums to inform the decision-making process at a border-wide scale.

The PFBW is comprised of over 150 binational members and 50 partnering institutions, 16 working groups (topic based), one task force, a binational archive of research, news, events, RPFs, conferences, calls for action, and initiatives (women in science, for example). It is considered an informal "safe space."

We propose establishing a science advisory group that would explore the two approaches discussed above to develop specific, actionable ideas into a framework that can be deployed in different binational watersheds along the U.S.-Mexico border. Such an advisory group would be informal in nature and "on-call" to advise the leadership of the USIBWC on specific challenges that surface in binational basins from an integrative perspective. This line of action would benefit USIBWC by providing updates on current issues and generating potential alternative ideas to meet emerging challenges to be shared with stakeholders. This will improve the coping capacity of shared water resources, and at the same time, will ratify the leadership of the USIBWC in the subject matter.

3.4. Financial capacity and long-range planning

Funding for USIBWC projects derives from multiple sources, including federal appropriations to the State Department and to the Environmental Protection Agency (EPA), as well as state and municipal contributions.

The USIBWC's 2020 budget request to Congress totaled $74.2 million, of which $48.2 million was directed to meeting salaries and expenses tied to staff and field office and ongoing operations of international sanitation facilities located on the U.S. side of the boundary. In addition, a total of $26.0 million was for construction costs related to Rio Grande flood control (U.S. Department of State 2021). There were no active sanitation development projects at this time. However, the USIBWC is initiating work to rehabilitate the trunk line and international outfall interceptor serving the NIWTP at Nogales/Rio Rico and will soon be tackling additional works and improvements to sanitation facilities at San Diego with funds authorized by the new United States-Mexico-Canada Free Trade Agreement (USMCA) approval process (USIBWC 2021).

THE USIBWC SHOULD PLACE LONG-TERM FINANCING ON THE AGENDA OF ITS PENDING BINATIONAL SUMMIT TO EVALUATE THE PLANNING AND EFFECTIVENESS OF SANITATION PROJECTS ALONG THE UNITED STATES AND MEXICO BORDER REGION.

In the 1980s and 1990s the EPA became involved in funding USIBWC projects directly and through its contributions to the binational North American Development Bank (NADB). The growing complexity of financing USIBWC projects is one of the reasons the USIBWC signed an official agreement, Minute 294, delineating its technical responsibilities related to NABD approved projects (IBWC 1995). As a result, each project stands unique in its financial mix and range of funding partners.

USIBWC has been successful in recent decades with many aspects of its mission. Among its successes are:

- Ongoing ability to work on both sides of the border with the Mexican Section and other federal, state, tribes, and local agencies from both countries;
- Colorado River waters reduction agreement;
- Minute 320 and binational management of Tijuana River Watershed;
- Minutes related to ecological restoration of the Colorado Delta;
- Management of three binational treatment plants and related infrastructure;
- Provision of water quantity and some water quality monitoring data; and
- Flood control infrastructures and levee systems

At the same time, the Commission has faced numerous challenges, some ongoing and some likely to become more problematic in the future. These include:

- Asymmetric national financial capacity and varying priorities in addressing identified needs;

- Complex and evolving partnership with the Mexican Section as well as with U.S. federal agencies, Mexican federal agencies, and NADBank; and
- Reactive mode, due to partnerships, budget process and constraints, and funding methods for major border water and wastewater infrastructure that have not included long-term Operations and Maintenance (O&M) support.

The USIBWC has long financed its public works on a per-project, case-by-case, problem-reactive basis, a pattern that restricts its ability to satisfy the transboundary sanitation needs of border municipalities. There is a growing need for long-range planning for financial support due to dynamic socio-economic conditions that include environmental justice concerns and greater effects of climate change in the border region (USIBWC 2021).

4. CLOSING REMARKS

Today, with fresh leadership, the USIBWC faces transboundary water-management challenges of an unprecedented nature and scale as the twin forces of rapid urbanization and climate change alter the demand-scape and the expected availability of waters shared by the two countries. Binational diplomacy and the USIBWC have dealt with and found solutions to vexing disputes in the past that, in their resolution, both strengthened the Commission as an institution and reinforced the 1944 Water Treaty as a resilient instrument for cooperatively managing national water resource endowments and transboundary water-related hazards arising from their shared border. In this, the 1944 Treaty has stood the test of time. It remains a vital mechanism supporting technical analysis and engaged diplomacy aimed at realizing cooperative solutions across a dynamic panorama of riparian and place-specific water and sanitation problems in the border region.

EXPANDING THE USIBWC'S CURRENT SCOPE TO GET IN FRONT OF, VERSUS ONLY REACTING TO BORDER WATER CHALLENGES, COULD ADDRESS ISSUES PRIOR TO THEM REACHING CRISIS PROPORTIONS, THUS SAVING TIME, MONEY, AND NEGATIVE ENVIRONMENTAL IMPACTS.

The present moment, however, requires more of the IBWC and its U.S. Section. Within the scope and limits of its formal jurisdiction, the USIBWC, working with binational and domestic agencies of the two governments, is especially well placed to offer a science-based diagnostic assessment of stresses on the treaty system and scenarios for addressing these stresses that the two governments should consider. It should move beyond its historic reactive posture in addressing treaty based challenges to scoping out transboundary watershed problems, convening technical expertise and stakeholder perspectives on actual and emerging challenges, and identifying responsibilities and action items warranting study and preemptory action by the Commission.

In the short run, the USIBWC confronts pending commitments on the Rio Grande and the Colorado River. The solutions to these issues are vital to sustained cooperative engagement by the governments in meeting the coming challenges. Beyond these immediate and near-term commitments, this paper has identified concerns and opportunities related to the Commission's treaty-based mandate that both sections should consider related to climate change, water conservation and augmentation, energy conservation and efficiency, groundwater management, sanitation and public health, flooding, environmental restoration on the treaty rivers, and financing solutions to pressing and emerging needs along the boundary.

With a new Commissioner at the helm of the U.S. Section, it is our hope that the preceding perspectives will provide needed context and direction that facilitates the Commission's vital work on transboundary water management in U.S.-Mexican relations.

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