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A Qualitative Approach to Understand Transitions toward One Water in Urban Areas across North America

Donya Dezfooli [1,*], Jessica Bolson [2], Mazdak Arabi [1], Michael C. Sukop [2], Inge Wiersema [3] and Sarah Millonig [1]

[1] Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, CO 80523, USA; mazdak.arabi@colostate.edu (M.A.); sarah.millonig@colostate.edu (S.M.)
[2] Department of Earth and Environment, Florida International University, Miami, FL 33199, USA; jbolson@fiu.edu (J.B.); sukopm@fiu.edu (M.C.S.)
[3] Carollo Engineers Inc., Los Angeles, CA 94598, USA; iwiersema@carollo.com
* Correspondence: donya.dezfooli@colostate.edu

Abstract: Urban water systems across the world are grappled with growing social and environmental pressures. To address these pressures, a transition from traditional water management systems towards a more integrated and sustainable approach known as "One Water" is vital. Although cities are enthusiastic about a One Water paradigm, there is a limited scholarly understanding of how to enable this transition. This study, therefore, aimed to improve intellectual comprehension of the factors that influence One Water transitions based on a series of expert interviews that were conducted with a number of utilities across North America. It was found that achieving social–environmental justice is among the most prominent drivers for utilities to start their transition, followed by concerns about climate change, water quality impairments, groundwater depletion and subsidence, and population growth. Our findings revealed that several critical barriers including a lack of regulatory frameworks and existing institutional siloes impede the transition toward One Water. Additionally, our thematic framework revealed that technological, cultural, and institutional actions are required to enable One Water transitions. However, the frequency of actions in the thematic framework sheds light on the point that cultural, institutional, and regulatory solutions are needed more than technological innovations to support the paradigm shift. Finally, our efforts identified nine key elements of a "One Water City" that could be used to characterize progress towards implementation of One Water approaches. Insights from this paper not only provide water managers with an understanding of the perspectives and actions required for enabling the One Water paradigm shift, but also can be used to develop a framework for self-assessment.

Keywords: urban water; One Water; sustainability; transition; integration; collaboration

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1. Introduction

Urban water management across the world has been plagued by various challenges including a growing population, more frequent extreme events occurring with climate change, aging and inadequate infrastructure, sea-level rise, combined sewer overflows (CSOs), water supply limitations, and reliance on imported water. Due to the existing complexities, the previously known best practice, the linear "take–make–waste" approach, has been found to be unsustainable because of its dependence on an unlimited availability of energy and resources. This approach is not subject to robust regulation and enforcement and overlooks the negative effects of greenhouse emissions and waste [1–13].

In this context, it is therefore necessary to change the current linear approach dominant in most cities around the world to one that utilizes a high degree of reuse and recycling. The new paradigm is known by many names: water-sensitive urban design [14], Integrated water resource management [15], and Soft Path water management [16]. Here, we use the name adopted by a growing number of water organizations, "One Water". The suggested

approach in current research is being strategically probed and implemented around the planet. Unlike the linear approach, this multifaceted approach not only considers energy efficiency, material cycling, waste management, and infrastructure in urban systems, but also improves equity, affordability, ecosystem and human health [1,4,5,17–19]. In 2017, the Water Research Foundation (WRF) published the Blueprint for One Water which identifies critical phases of progress toward implementation of One Water approaches and defines One Water as an integrated planning and implementation approach to managing finite water resources for long-term resilience and reliability, meeting both community and ecosystem needs [20].

Many scholars acknowledge that transition to the One Water paradigm is required [6,13,21–25]. Despite high aspirations for integrated water management, cities are dealing with several challenges in the transition from traditional siloed management schemes to a more integrated planning and management paradigm [26–32].

In cases where successful transitions have started, several studies provide insights into this shift. The One Water Cities (OWC) comprehensive literature review [12] revealed that many cities in Australia, Singapore, Denmark, China, and the Netherlands successfully implemented several strategies to achieve this holistic approach. These cities have adopted One Water principles and made efforts to take the whole water cycle into account [6–8,26,28,33–39]. Furthermore, many scholars identified several barriers that can impede the transition and pathways to foster this transition. For example, Ferguson et al. (2013) provided a list of pathways and barriers developed during participatory workshops with water practitioners in Melbourne for the transition to a Water Sensitive City [28]. In light of these studies, there is limited empirical research on paradigm shift across North America. This raises key questions: How can cities across North America improve and facilitate their understanding of the mechanism(s) influencing the long-term transition to One Water? How can this transition be effectively directed? Lastly, what insights can be gained from experiences in North America regarding the transformation of urban water systems?

In this regard, at least two issues have not been comprehensively addressed in previous studies: (1) deep evaluation of socio-cultural and institutional dimensions of this paradigm shift in different cities across North America, and (2) understanding the factors that facilitate a transition towards urban water sustainability in various regions (including both water-rich and water-scarce regions) rather than focusing on a single city or river basin.

This paper aims to address these gaps by analyzing empirical insights into several utilities across North America and identifying key elements influencing the One Water transition. Specifically, the objectives are to (1) characterize the most important drivers to implement One Water principles across several regions in North America, (2) characterize barriers inhibiting One Water transitions in North America, (3) characterize the most important actions taken by cities to foster the transition.

This study contributes to the research gap by providing in-depth insights into experiences, perspectives, and context-specific factors that influence the successful implementation of One Water initiatives in North American urban areas. The findings will be valuable for urban planners, policymakers, and water managers to aid in identifying the enabling and inhibiting factors in the paradigm shift, providing a more comprehensive understanding of the impact of those factors, and drawing key lessons from the data.

2. Materials and Methods

2.1. Data Collection and Case Studies

The research took a qualitative multiple-case study approach, including a comprehensive literature review [12] and interviews with key informants from utilities across the US and Canada. A series of 17 semi-structured expert interviews with utilities were conducted by three members of the research team via on-line meeting (Zoom) between July 2020 and May 2021. The ultimate goal of the interviews was to collect data and insights on different aspects of the paradigm shift including One Water drivers, leadership and organizational culture, institutional collaboration, funding strategies, technological solu-

tions, and stakeholder and community engagement activities. Before the interviews, each participant received a list of questions and was asked for consent to participate. Interviews lasted from 1 to 2 h. All interviews were recorded with participants' permission and then transcribed. High-level summaries were also produced for each interview. Participants were subsequently given the opportunity to verify the accuracy of these transcriptions and summaries.

Table 1 provides the list of cities that participated in the research effort, which represent various organizational stages on the journey towards implementing the One Water approach (see Figure 1). These participants were identified through the professional networks of the research team and through affiliation with professional One Water associations. It is worth noting that the participants were selected from water supply, wastewater, stormwater, and other related departments to explore water challenges and the need for One Water as well as barriers and pathways from diverse perspectives. These regions vary by climate, governance, and water issues; hence, they revealed important differences relevant for building and implementing One Water projects, programs, and policies under different circumstances.

Table 1. List of participating cities included in the interview process.

Location	Organization
Ashburn, VA, USA	Loudon Water
Denver, CO, USA	Denver Public Works
Fort Collins, CO, USA	City of Fort Collins Utilities
Honolulu, HI, USA	Honolulu Board of Water Supply
Houston, TX, USA	Houston Water
Los Angeles, CA, USA	LA Sanitation & Environment
Miami, FL, USA	Miami Dade Water & Sewer Department
New York, NY, USA	New York City Dept. of Environmental Protection
Oklahoma City, OK, USA	Oklahoma Water Resources Board
Philadelphia, PA, USA	Philadelphia Water Department
San Francisco, CA, USA	San Francisco Public Utilities Commission
Seattle, WA, USA	Seattle Public Utilities
Tucson, AZ, USA	Tucson Water
Vancouver, WA, USA	City of Vancouver
Vancouver, BC, Canada	City of Vancouver, British Columbia
Virginia Beach, VA, USA	Hampton Roads Sanitation District
York, ON, Canada	Regional Municipality of York

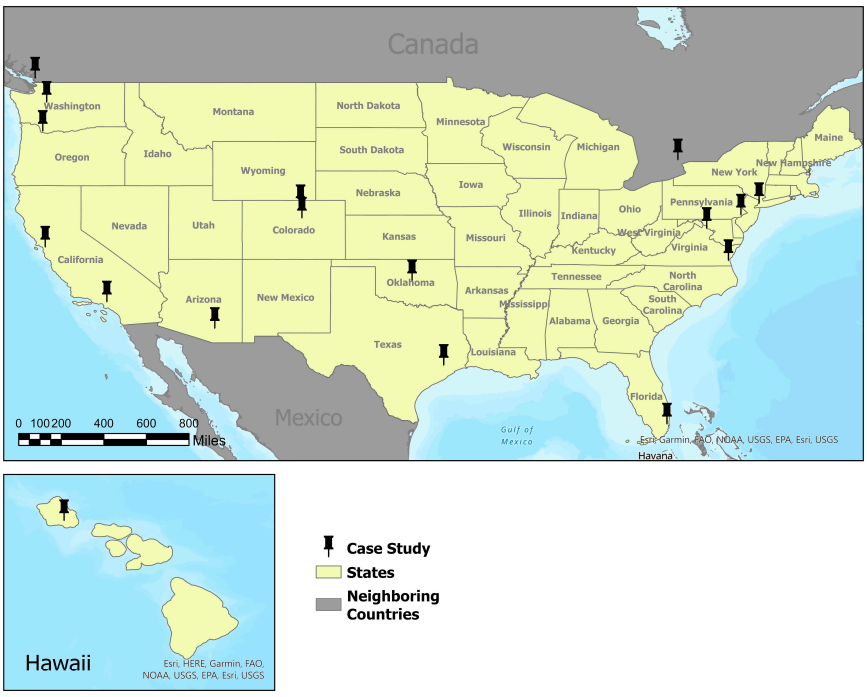

Figure 1. Expert interview geographic locations.

2.2. Data Analysis

Thematic analysis was employed in this study to evaluate the collected data and identify key themes and recurring patterns [40,41]. This method is commonly used for analysis of qualitative interviews [31,40,42–47].

The NVivo software was used to identify key themes and recurring patterns throughout the interviews. The coding process was conducted in two iterative stages, employing both inductive and deductive approaches. After transcribing the interviews, the initial phase incorporated inductive coding to recognize a broad range of themes from participant responses. The subsequent phase involved a more deductive approach, informed by a comprehensive literature review [12] and collaborative discussions within the research group. This process condensed the initially identified themes into a smaller set of primary themes, thereby facilitating the identification of patterns across these themes. It is worth mentioning that the lead author was responsible for the initial coding, and then the codes and themes were validated by the research team members who facilitated the interviews. This process not only improves the accuracy and transparency of the coding, but also helps to identify potential subjectivity.

3. Results

3.1. Thematic Framework

Table 2 summarizes the thematic framework employed to organize the data collected during interviews. The collected data are classified into four thematic categories including drivers, actions, barriers, and co-benefits (Table 2). The frequency of each theme and sub-theme in the interviews is provided in the table as well. In the following section, each main theme and sub-theme are discussed to address the research questions.

Table 2. Thematic framework.

Main Themes	Sub-Themes
Drivers (152)	• Climatic (23) • Economic (11) • Environmental (23) • Water resources (16) • Social (49) • Regulatory (17) • Urban (13)
Actions (699)	• One Water Governance (462): Asset management and data governance (10), Collaboration (189), Funding mechanism (113), Integration (34), One Water vision (17), Regulatory environment (21), Stakeholder and community engagement (78); • Socio-cultural (200): Connection with water (6), Organizational culture (194); • Regenerative systems /Technological (37): Resource recovery (19), Stormwater management (10), Water conservation (8).
Barriers (88)	• Financial barriers (28) • Institutional barriers (20) • Regulatory barriers (37) • Technical barriers (3)
Co-benefits (81)	• Water resource benefits (44) • Economic benefits (21) • Social benefits (11) • Environmental benefits (5)

3.2. Drivers

There are several factors driving cities toward the implementation of One Water approaches. These drivers fall into seven primary categories: urban, climatic, economic, environmental, regulatory, social, and water resources. Figure 2 indicates the percentages of participants mentioned for each category.

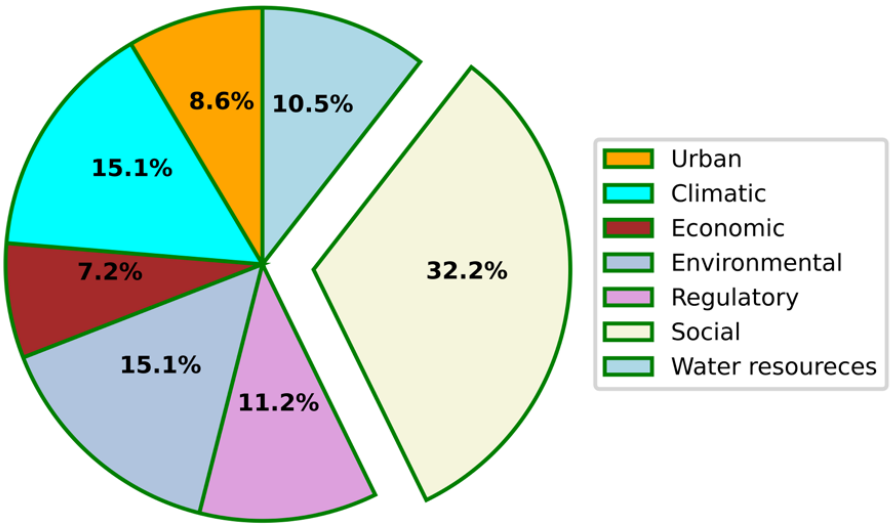

Figure 2. Main drivers for cities across North America to implement a One Water approach.

Social equity and environmental justice are among the most critical social drivers for the utilities to initiate their One Water transition (Figure 2). Social equity may be one of the most important One Water outcomes and triggers many utilities to transition to the One Water paradigm. The OWC interviews revealed that North American utilities seek to implement environmental justice in different aspects of water management, not solely restricted to delivering safe water services equitably and cost effectively. For example, several utilities are reaching out to underrepresented communities to understand their water-related concerns to build more inclusive programs. Some utilities implement financial assistance programs to provide affordability for low-income-level communities. In some regions (such as the Colorado Front Range and the Pacific Northwest), these communities are also prioritized for water quality and flood protection. Moreover, more progressive cities, such as Los Angeles, are looking to modify project scoring criteria to incorporate environmental justice evaluation factors.

Environmental and climatic drivers are responsible for 30% of the total references to drivers. Table 3 shows that surface water quality covered 54.2% of the environmental drivers. Most utility drivers regarding surface water quality are related to meeting total maximum daily load regulations (TMDL), reducing CSOs, and protecting aquatic life. Groundwater depletion and subsidence are other critical environmental drivers, especially for coastal cities. Therefore, replenishing the groundwater supply and looking for aquifer storage and recovery opportunities are strong drivers for cities facing groundwater depletion. Beyond that, climate change and its consequences were among the most frequently described challenges. Most cities in different regions of North America are dealing with climate concerns, including sea-level rise, flooding, extreme droughts, and saltwater intrusion. For example, cities along the Pacific Ocean focus on mitigating droughts and sea-level rise. For many cities on the mid- and south-Atlantic coast, climate change concerns include salinity intrusion, flooding, and infiltration and inflow into wastewater and stormwater systems.

Regulatory and water resource challenges are among other critical drivers moving cities towards implementing a One Water approach in many regions. Regulatory measures and compliance, including meeting water quality standards for receiving waters, indirect potable reuse and reducing pollutant loadings were most frequently mentioned. In addition, consent decrees for upgrading aging water infrastructure and curtailing groundwater withdrawal in Miami and Virginia Beach, respectively, are among the regulatory drivers specified by the participants. Water resource challenges, the fourth most frequent driver mentioned, consist of several subcategories, namely water supply accessibility, resiliency, and redundancy, and the need for alternative water resources (Table 3).

Table 3. Frequency of main drivers and their subcategories for cities across North America to implement One Water approach.

Social (49)	Climatic (23)
• Social Equity (49)	• Climate Change (23)
Environmental (23)	
• Surface Water Quality (13)	
• Subsidence (9)	
• Environmental Health (1)	Urban (13)
Regulatory (17)	• Population Growth (9)
• Regulatory Measures and Compliance (13)	• Infrastructure Needs (3)
• Consent Decree (3)	• Urban Heat Island Effect (1)
• Nutrient Credits Trading (1)	Economic (11)
Water Resources (16)	• Cost-effective Solutions (3)
• Water resources Accessibility (9)	• Financial Capacity (8)
• Resiliency and Redundancy (5)	
• Need for Alternative Waters (2)	

Economic and urban drivers comprise the smallest proportion of the total drivers encouraging cities to implement the One Water approach (Figure 2). The most frequently mentioned urban subcategory is population growth which was specified most in the Colorado Front Range, Gulf Coast, South Atlantic, and Pacific Northwest regions. In addition to population growth, infrastructure needs and the urban heat island effect were also mentioned by participants. Economic drivers including financial capacity and providing cost-effective solutions occurred the least. Regarding resource constraints and finite financial resources, many utilities are encouraged to implement the One Water approach to leverage resources. This not only increases affordability but also provides additional cost savings.

3.3. Actions

As described by water experts interviewed, the actions taken by cities fall into three main nodes: (1) One Water governance, (2) socio-cultural, and (3) regenerative systems/technological solutions. Each of those is classified into several subcategories (Table 2). Each primary category and its related subcategories are elaborated on below to characterize enabling factors to achieve the One Water paradigm shift.

3.3.1. One Water Governance

The Global Water Partnership defined water governance as "the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society." [48]. Our thematic analysis revealed seven sub-themes for water governance that we categorized as (1) asset management and data governance, (2) collaboration, (3) finance strategies, (4) integration, (5) One Water vision, (6) regulatory environment, and (7) stakeholder and community engagement (Figure 3).

Asset Management and Data Governance

Dharshan and Gnanakumar (1999) described asset management as a systematic approach to the governance and realization of value from the things that a group or entity is responsible for over their life cycles [49]. The OWC interviews revealed that some utilities have strategic asset management practices to manage infrastructure and maintain customer service levels. For example, the utility in the Pacific Northwest has conducted considerable planning around asset management in terms of longevity for equipment and upgrading infrastructure. In addition, participants shed light on the importance of data governance models in their One Water journey. This indicated that developing a data

governance model is critical not only to achieving integrated urban water management but also to understanding how to convert and translate data into meaningful information for communication with stakeholders and local communities. For example, the OWC literature review [12] indicated that Denmark has successfully developed a range of new tools including databases, data collection systems, and modeling software to provide public access to high-quality data [12,50].

Figure 3. One Water governance.

Collaboration

Table 2 shows that collaboration is one of the most frequently mentioned nodes in water governance. This indicates that promoting collaboration within and across organizations is the key to removing institutional siloes and achieving the One Water paradigm shift. Our interviews showed that utilities across North America are looking for multi-benefit projects and collaboration with other agencies to develop strategic multi-disciplinary water plans. Cities that are progressive in adapting One Water strategies, such as Los Angeles (LA), have prioritized collaboration internally as well as with other external agencies.

The OWC interviews show utilities have implemented several methods, policies, or vehicles to facilitate collaboration within and across organizations. A common method for enhancing outside agency collaboration is a memorandum of understanding or a memorandum of agreement (MOU/MOA), which are legal documents between the parties that describe their cooperative work together. For example, MOAs were used frequently throughout the development of the One Water plan in LA. In addition, other utilities along the Pacific and Atlantic coasts, the Gulf Coast, and the Great Plains region have developed agreements with neighboring communities, regulators, and other city departments to collaborate in water planning.

Furthermore, building relationships, communicating with communities and stakeholders, establishing partnerships with other departments and agencies, and developing visioning documents are among other themes mentioned by participants to enhance institutional collaboration. Cities located along the Pacific coast build relationships with external agencies, regulators, and communities through a water cabinet in LA and publication of annual One Water report brochures in San Francisco. Also, building relationships with indigenous communities leads to understanding indigenous water values and interests in water system planning in different regions such as the Great Plains and Southern Ontario. In

addition, the OWC interviews indicated that developing several visioning documents such as the One Water LA 2040 Plan (2018), Denver One Water Plan (2021), and a range of master plans can help utilities facilitate collaboration with other departments or agencies [51,52].

Finance Strategies

Providing a favorable economic environment for private investment may be essential to support the One Water transition. The OWC interviews indicated several financial strategies to support this paradigm shift and overcome financial barriers. As Figure 4 indicates, providing financial incentives for customers is a common financing vehicle to support the One Water transition. These incentives, which vary in water-rich and water-scarce regions, are shown in Table 4. For example, in water-rich areas, financial incentives primarily rely on onsite water reuse and stormwater management, whereas incentives for water conservation, rainwater harvesting, and water-efficient appliance rebates are more prominent in water-scarce regions.

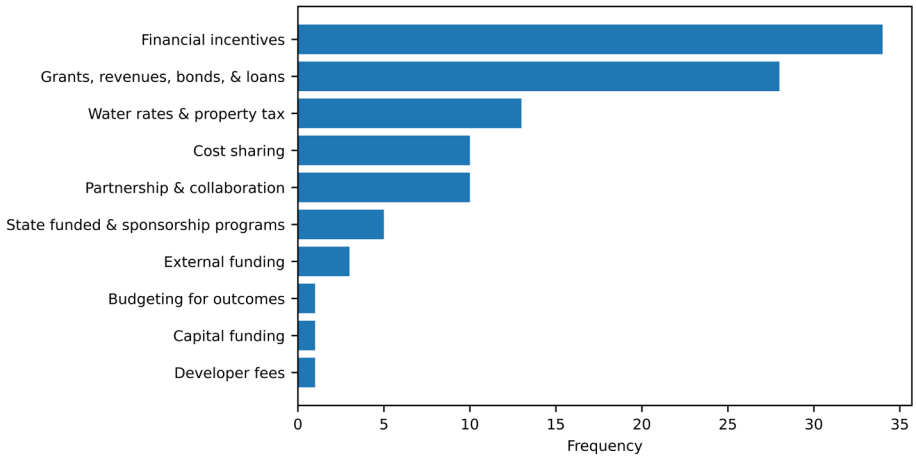

Figure 4. Frequency of each financial strategy taken by utilities across North America.

Several other funding mechanisms were applied across North America (Figure 4). Many utilities have used grants, revenue, bonds, and loans for the co-funding of multi-benefit projects. They have pursued grants such as those from the Federal Emergency Management Agency, the Water Infrastructure Finance and Innovation Act, the Texas Water Development Board, and the Rural Economic Action Plan. In addition, most organizations relied on ratepayers and water bills as their main funding resources. Another frequent strategy was cost-sharing, which increased funding opportunities. Cost-sharing is a process in which two or more agencies or departments work collaboratively to attain savings that one alone would be unable to achieve. To illustrate, cities progressively adopting One Water, such as LA and San Francisco, commingle funds between these different enterprises, and many projects have been co-funded by water and wastewater departments. Conducting several public–private partnerships (P3) with school districts, academic and non-profit organizations is advantageous because more sectors are engaged in funding mechanisms rather than relying only on public revenues.

Integration

The OWC literature review [12] described successful case studies such as that of Singapore exerting control over the entire water cycle and applying an Integrated Water Resources Management (IWRM) strategy; Singapore's Public Utilities Agency was reformed as a single water authority in 2001. Therefore, unlike many places in the world where water departments are separate from sewerage and drainage departments, Singapore's integrated water cycle is an ingenious invention to manage the entire water system as a whole [12,35,53].

Table 4. Customer incentives across the regions in North America.

Region	Incentives
Pacific	• Incentives for rainwater harvesting • High-efficiency toilet rebates • Incentives for onsite water reuse • Incentives for green infrastructure (GI) • Financial incentives on water, wastewater and power
Pacific Northwest	• Stormwater credit program • Low-income customer incentives
Mid-Atlantic	• Incentives for developers • Incentives for onsite water reuse • Incentives for building GI on properties • Stormwater management incentives • Incentives for retrofitting private properties
South-Atlantic	• Incentives for reclaimed wastewater system • Incentives for GI development • Stopped disconnecting water services during the pandemic
Gulf Coast	• Incentives for GI • Incentives for water conservation
Sun Corridor	• Rainwater harvesting rebates • High-efficiency toilet rebates • Conservation fund • Green stormwater infrastructure fee and fund • Customer assistance programs • Low-income assistance program
Southern Ontario	• Developer incentives • Incentives for water conservation
Colorado Front Range	• Water-efficient fixtures • Incentives for water conservation

Furthermore, the OWC interview analysis revealed that not only did the participants emphasize the consolidation of departments (water, wastewater, power, etc.), but they also highlighted the role of integrated planning in achieving this holistic approach. In fact, they justified the necessity of developing a cohesive and integrated One Water plan to meet all water-related obligations rather than developing several individual plans for these obligations. This requires synergies across different silos and integrated thinking in the organization.

One Water Vision

A One Water journey begins by developing an understanding of existing conditions and establishing direction through a shared vision and objectives. Our efforts revealed that progressive cities in the One Water journey, such as LA and San Francisco, developed their One Water vision from the top-down, which helps the cities provide guidance and achieve their goals. On the other hand, cities at the beginning of the One Water journey that lack top-down guidance struggled to develop their One Water visions and guiding principles. It is worth noting that a One Water champion or team plays an influential role in developing a shared One Water vision because the city's champion(s) communicate a commitment to the One Water vision and objectives throughout the organization to build a common understanding of the benefits of the One Water approach and collaborative mindset.

Regulatory Environment

The WRF Blueprint for One Water [20] shows that a conducive regulatory and legislative environment for encouraging public and private participation is essential. In addition, the OWC interviews shed light on the importance of the regulatory environment in embracing the One Water culture. In addition to endeavoring to stay compliant with regulatory changes, cities also need to build trust with regulators early in the process; otherwise, different regulatory barriers can inhibit progress toward the One Water paradigm shift.

Furthermore, some interviews emphasized the importance of passing an ordinance to institutionalize collaboration and make a law that cannot be changed over time. A successful example is the Honolulu ordinance [54] that established the framework and procedures to tackle climate change concerns by implementing a One Water approach. Having a supportive regulatory environment is crucial to enable the shift towards the One Water approach.

Stakeholder and Community Engagement

Organizations must share their vision for a One Water transition with the community and related stakeholders. Since water often transitions between multiple institutional boundaries, One Water can only be successful when all stakeholders are engaged in planning, prioritization, and implementation. The OWC interviews revealed several methods of stakeholder and community engagement currently being implemented by the study participants (Figure 5).

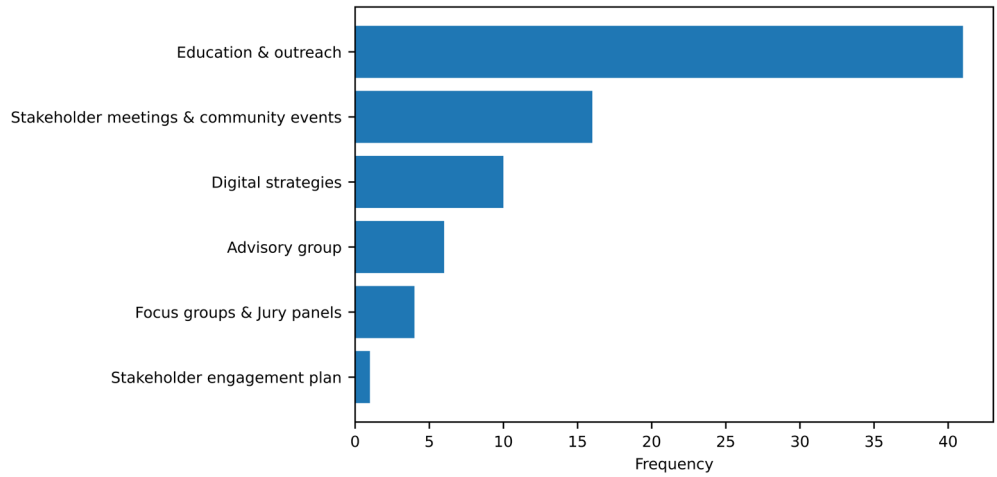

Figure 5. Frequency of different methods of stakeholder and community engagement.

Our analysis indicated that education and outreach about One Water with the general public, stakeholders, and indigenous people are the most common methods of stakeholder and community engagement in North America.

These strategies improve water literacy and awareness in the community and help educate youth, school children, and the indigenous community. Other utilities relied on stakeholder and community meetings, workshops, and digital strategies (such as mass email mailings, digital surveys, websites, social media, etc.) to involve all stakeholders in the planning, prioritization, and implementation of the One Water approach.

3.3.2. Socio-Cultural

The themes identified in the OWC interviews all demonstrate the importance of cultural change to break down silos. Socio-cultural actions are related to social and cultural practices that help change common traditions, norms, and beliefs among communities and organizations. The OWC interviews indicated that cities progressive in One Water, such as Los Angeles and San Francisco, are trying to facilitate a thriving One Water culture by building relationships with several departments, agencies, and communities. Our

thematic framework shows two important sub-themes related to this category, including (1) connection with water and (2) organizational culture.

Connection with Water

Interviewee responses revealed that a successful transition to the One Water approach requires fostering the connectedness of people with water by appreciating water's role in landscapes and learning to live with water. Our participants' responses revealed that people in cities located either in water-scarce or water-rich regions recognize the interrelationship between land and water. For instance, people in coastal cities, such as Houston, are learning to live with water in a way that is healthy for both the community and the environment; in the Sun Corridor region, people feel a connection with water-related assets and support more green solutions to achieve broader livability and resilience.

Furthermore, several codes indicated the role of cultural issues around water. Unlike traditional water approaches in which cultural and spiritual values associated with water are often neglected [55], our participants emphasized the role of recognizing indigenous water values and interests in water system planning and management, as well as involving indigenous people in water system governance. This issue was discussed by participants and varied from the lens of social equity and water rights of indigenous communities to include their voices and perspectives in One Water projects.

Organizational Culture

OWC interviews revealed several key characteristics of an organization that advances a One Water culture. As Figure 6 shows, among several attributes mentioned by participants, fostering a One Water mindset/culture among staff, community, and regulators is the most frequent key characteristic mentioned by the practitioners, followed by supportive leadership, collaboration and building relationships, and availability of dedicated resources (staff, funding resources, etc.).

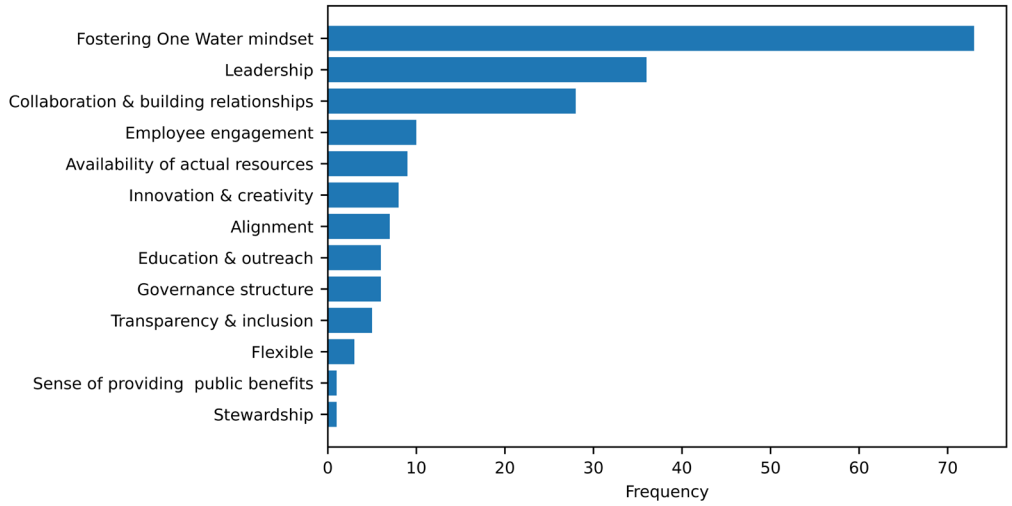

Figure 6. Frequency of key characteristics of an organization that advances a One Water culture.

Our participants' responses indicated the importance of mindset change to break down silos and support various technological solutions. In this context, the review of published literature also revealed that the biggest challenge to providing a significant shift is the issue of path dependence and cognitive lock-in. The term "cognitive lock-in" stems from the field of social psychology, where it has been used to investigate consumer habits and choices with respect to a product or service. To illustrate, historical investments into legacy infrastructure have yielded consistently high returns compared to those associated with alternative infrastructure. This phenomenon might discourage future adoption of alternative technology and management practices [56–58].

3.3.3. Regenerative Systems/Technological Solutions

This action is related to the implementation of new types of regenerative systems and technological solutions to provide a portfolio of systems from centralized to decentralized that increase the recovery of water, energy, heat, and nutrients. Our analysis indicated that this theme consists of three sub-themes: (1) resource recovery, (2) stormwater management, and (3) water conservation.

Resource recovery is considered the most critical element of regenerative systems, followed by stormwater management and water conservation practices. More than 50% of the respondents emphasized the need to achieve high levels of resource recovery across water, heat, and nutrient sources by a circular design of water systems. In addition, cities located in both water-rich and water-scarce regions revealed that stormwater was considered an asset rather than a nuisance. For example, while coastal cities were managing stormwater to abate CSO by using nature-based types of infrastructure, cities located in water-scarce regions, such as the Sun Corridor, were harvesting rainwater to irrigate trees and make the city more livable. Finally, water conservation practices, such as implementing water-saving technologies, which constituted almost 20% of the total responses in this node, are common actions in cities located in water-scarce areas.

3.4. Co-Benefits

The OWC comprehensive literature review [12] revealed that co-benefits are crucial components in assessing progress toward the One Water approach. Darrel Jenerette et al. (2011) identify several co-benefits that natural and built water systems provide to energy sustainability as well as human health and comfort by buffering extreme heatwaves, mitigating urban heat effects, enhancing urban biodiversity, and ultimately improving urban livability [59]. Therefore, water managers and city planners should take into consideration co-benefits associated with the pursuit of the One Water paradigm.

Our analysis indicates several co-benefits in the participant's responses classified into scopes ranging from water resources benefits to economic, social, environmental, and climate-related benefits. As illustrated in Figure 7, water resource benefits are the most frequent co-benefits. For instance, implementing distributed green infrastructure and stormwater programs provide additional co-benefits in terms of flood mitigation, water quality improvement, and water supply benefits. Moreover, it is worth noting that this approach not only offers a resilient and reliable water supply in the context of shocks and stresses, but it also provides water infrastructure resiliency for many utilities. For example, many coastal cities interviewed focused on implementing One Water to improve the resiliency of their water systems.

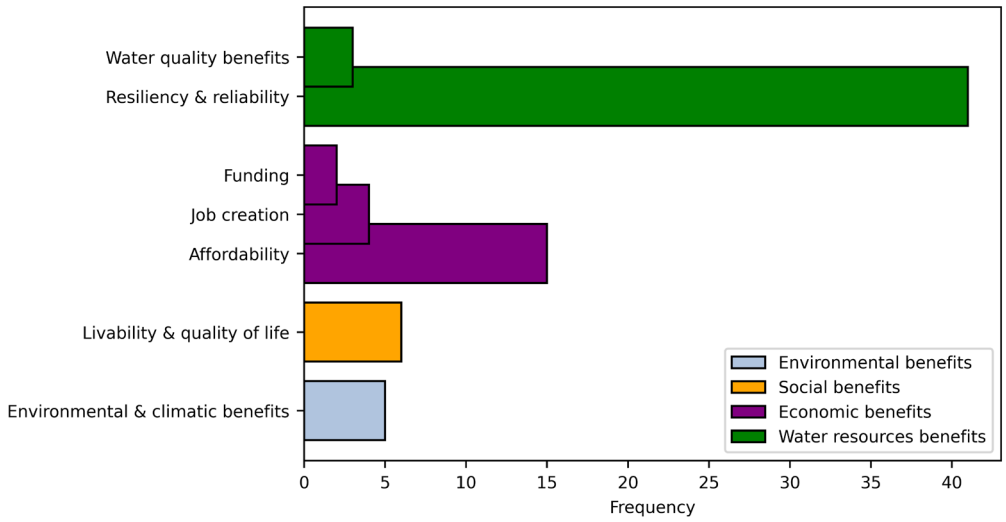

Figure 7. Scopes of co-benefits in seven dimensions.

Economic co-benefits ranked as the second most frequent co-benefit. The OWC interviews revealed that the One Water approach provides several economic benefits for cities regarding affordability, funding, and job creation. Many utilities indicated that providing an affordable and cost-effective water supply is the most critical aspect of the One Water approach for their organization. The concept of affordability is not limited to delivering affordability for customers, but also includes providing affordable housing in water-rich areas affected by flooding and sewer backups.

Furthermore, utilities across North America mentioned various social, environmental, and climate-related co-benefits. For example, livability and quality of life are among the social co-benefits associated with pursuing the One Water paradigm discussed frequently by utilities facing water shortages. However, the literature indicated that traditional water management regimes ignored the pursuit of livability [6]. Implementing this approach also leads to several environmental co-benefits such as aquifer recharge, heat stress reduction, and increased biodiversity for many cities.

3.5. Barriers

Several barriers to implementing One Water solutions were identified during the interviews (Figure 8). As previously discussed, the review of published literature revealed that the issue of path dependence and lock-in and institutional barriers are the most significant impediments. Institutional challenges, including strategic, tactical, and operational segments among public and private sectors, cause impediments for organizations transitioning along the One Water journey. These institutional challenges prevent organizations from cooperating, integrating activities, and progressing towards new systems that would optimize hybridization of distributed and centralized infrastructure approaches to resource recovery. Therefore, the absence of consolidated cultures leads to dependency on current institutional silos and subsequent stasis in the water industry [12,19,56,58,60,61]. Furthermore, our analysis revealed that institutional barriers could impede the ability of utilities to take the whole water cycle into account. For example, obstacles due to lack of coordination and cooperation between departments were described by the participants when trying to expand water reuse programs.

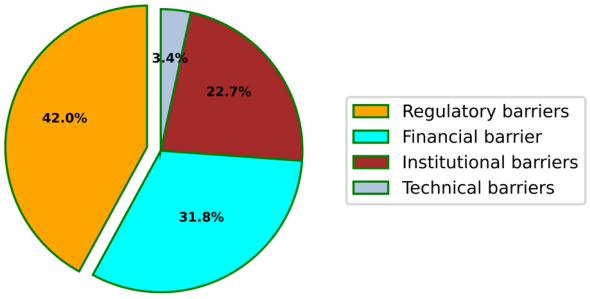

Figure 8. Frequency of barriers to implementing One Water.

In addition to institutional hurdles, the OWC interviews indicated that financial and regulatory challenges are among other significant barriers inhibiting transitions towards the One Water approach in North America. Figure 8 depicts that regulatory barriers were the most frequently discussed during the interviews. The analysis also revealed that water rights, in terms of harvesting rainwater and interbasin transfer, are a considerable barrier for many utilities located in the Colorado Front Range and Gulf Coast regions. On the mid- and south-Atlantic coasts, many local, state, and federal regulators have limited will to support the implementation of the One Water paradigm shift, and do not intend to incorporate the One Water approach into long-term control plans, which instead emphasizes reduction in CSOs and improvement in water quality. Meeting pollution control regulations is another barrier mentioned by the participant in these regions. Along the Pacific coast, including the Pacific Northwest and Southwest, participants shed light on

several regulatory impediments in the realm of combined multi-benefit project funding, lack of water quality and stormwater regulations, and lack of federal oversight in evaluating long-term plans and accuracy of implementation schedules. In addition, two more barriers were mentioned that impede utilities in this area from progressing towards the One Water approach. The first one is inflexibility around current requirements, which do not consider future changes, especially climate change. The second one is lack of clarity in water reuse systems, ranging from permitting to inspection, which needs to be addressed in order to meet future demands.

Financial limitations ranked as the second most frequent barrier mentioned by participants. Not only did many utilities face economic recession and resource constraints, but also budgets were significantly impacted during the global COVID-19 pandemic. In addition, several financial barriers were reported regarding the cost-sharing of projects and splitting of funds across various initiatives. This stems from the fact that there is no uniform approach to quantifying benefits so that combing funds cannot be justified.

Technical barriers seem to be the least significant impediment for utilities in their One Water journey. In terms of technical obstacles, lack of training and shortage of the workforce in water utilities were mentioned by participants. Collaboration between governments and academic institutions would provide a fundamental step for students and children to become future stewards and potential workforce candidates.

4. Discussion

The results from key informant interviews indicate several pressures on urban water management regimes across North America. In many cases, these pressures are serving as drivers to initiate a transition toward One Water approaches. Although the pressures and drivers described by participants varied by geographic conditions, it appears that climate change pressures, declining surface water quality, population growth, groundwater depletion and subsidence are among the most critical pressures across North America. In addition, regulatory and social drivers (e.g., environmental justice) are catalysts for utilities to initiate their One Water journey. To illustrate, some participants pointed to the utility's consent decree to upgrade aging infrastructures and improve wastewater systems. These findings aligned with previous studies regarding the challenges to urban water systems [62–66].

Our findings also revealed several barriers to transitioning toward the One Water paradigm, supporting prior studies [11,18,24,27,63,67–71]. Although the OWC literature review revealed that institutional barriers and the issue of path dependence and lock-in are the greatest impediments (Arabi et al., 2021), the OWC interviews indicated that in addition to institutional barriers, regulatory and financial challenges are among the most frequent and problematic barriers. Financial challenges were exacerbated by losses in revenues associated with the COVID-19 pandemic, as well as siloed regulatory regimes such as water right issues. Regulatory and institutional barriers appear to be significant impediments to the adoption of One Water strategies and create crucial barriers to the implementation of many One Water solutions, such as expansion of green infrastructure and harvesting rainwater, especially in the mid-Atlantic and the Front Range regions. In this context, several studies have indicated that the barriers to achieve the paradigm shift do not always stem from the inaccessibility of technological solutions and scientific knowledge, but instead often originate from the social and institutional change process necessary to support directional shifts [6,19,26,57,63,72].

Therefore, characterization of pathways to facilitate transitions toward implementation of One Water approaches are necessary. The interviews identified several funding mechanisms to overcome financial barriers such as co-funding strategies, ratepayer funds, and partnerships with academia and non-profits. Diversifying funding sources leads to an expanding resource pool to support the paradigm shift. For governments, transferring the risk to private firms and using their technical knowledge and managerial potential while the private sector enjoys considerable profit returns could be considered a primary bene-

fit. Furthermore, our responses revealed that cities with semiautonomous/autonomous governance structures were able to achieve financial capacity and consequently did not experience significant financial barriers. This stems from the fact that a semiautonomous organization is administered by an appointed board of stakeholders with a duty to set rates and policies. This provides organizations with an ability to manage their own budget and focus on sustainability goals and also facilitates the decision-making process and helps autonomy to be passed down to staff so that they do not rely on an elected body, such as a city council, for budget approval.

Our results illustrate that actions which enable significant change in urban water management can be driven by technological achievements, dominant cultural beliefs in the organization and community, and governance. These enabling factors were identified through our interviews in different ways. For example, the implementation of resource recovery and regenerative systems are considered technological pathways. Improved coordination in One Water governance is required to support the changing functional characteristics of urban water systems. Among several attributes that were discussed for empowered One Water governance, enhancing collaboration between multiple departments and/or agencies is crucial. Furthermore, our analysis suggests that cultural change and fostering a One Water mindset throughout the organization and community is essential to support directional shifts. For example, in terms of expanding the use of water recycling, a review of the literature revealed that public acceptance or the so-called "yuck factor" is one of the main barriers to treated wastewater reuse by households. Successful case studies such as that of Singapore show that the stigma related to wastewater reuse was removed by implementing several communication tactics such as changing the terminology from "wastewater" to "NEWater" to avoid invoking the yuck factor, attractive NEWater bottled packaging, strong support from media, and public education campaigns through the NEWater Visitor Centre [73]. This indicated that acceptance of any particular new technology or approach is based on the governing norms at a particular time [6,13,19,26,57,72,74–76].

Furthermore, our investigations revealed nine key elements of a One Water City. These elements represent the information gleaned from a broad review of One Water literature and targeted expert interviews with progressive utilities. The key elements that leverage previous efforts conducted in the One Water sphere [20,30,77] include (1) Institutional Collaboration, Governance, and Organizational Culture, (2) Stakeholder and Community Support, (3) Social, Environmental and Economic Equity, (4) Livability, Quality of Life and Affordability, (5) Water Supply Reliability and Resilience, (6) Watershed and Ecosystem Health, (7) Flood and Stormwater Resilience, (8) Climate Change Resilience, (9) Water Recycling and Resource Recovery (Figure 9). These key elements could be used to measure progress towards the implementation of the One Water approach.

Figure 9. Key elements of One Water Cities.

Finally, our thematic framework and feedback from our interview efforts helped us refine the One Water definition provided in the WRF Blueprint [20]. The recommended revised version is as follows:

> *"One Water is a collaborative planning and implementation approach that fosters integrated and equitable management of water resources for long-term resilience and reliability, meeting both community and ecosystem needs."*

Providing a more comprehensive and inclusive definition of One Water has an essential role in engaging organizations and communities to start their One Water journey. This is consistent with prior studies regarding the importance of developing a definition of integrated water resources management. Measurable criteria can be achieved if problems of definitional nature can be successfully solved in an operational manner. These criteria can then be used to show how the integration concept is applied and how relevant and useful it might be in a given area [18,31].

5. Conclusions

This paper presented a thematic framework and empirical evidence of essential elements to understand enabling factors toward sustainable urban water management in North America. This allowed us to document increasing drivers and pressures for organizations to implement the One Water approach. Furthermore, our findings revealed several barriers hindering the transition to the One Water paradigm. These barriers are not merely limited to financial barriers; instead, they stem from a lack of regulatory frameworks and community support, as well as institutional obstacles to expanding One Water strategies. Our findings emphasized the importance of cultural change and the necessity of fostering a One Water mindset among departments/utilities, regional entities, regulators, elected officials, academia, non-governmental associations, and community. This indicates the critical role of communication and outreach and calls for more research and pilot projects focused on effective information dissemination.

In addition, the frequency of enabling actions in our thematic framework indicated the importance of regulatory, institutional, and cultural actions. This highlighted the fact that a significant shift in urban water management cannot be driven only by reliance on technological solutions; rather, institutional and cultural contexts are required to support the One Water transition. Finally, there would be value in developing a framework that not only supports the transition to sustainable, resilient, and equitable urban water systems, but also provides solutions and pathways to address the existing barriers.

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