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The Governance of Water Innovations: To Quench a Thirst

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The Governance of Water Innovations: To Quench a Thirst

Preface

The early 1960s were a time of fervent geo-political competition. Cold War rivalry between the Soviet Union and the United States took many forms: a spiraling arms race, debate over the comparative advantages of capitalism versus communism, and competing claims of scientific and technological superiority. President John Kennedy's May 1961 announced goal of sending men to the moon by 1970 was a profound manifestation of this skirmish. His bold gambit signaled that the U.S. would go to extraordinary lengths to vie for the loyalty of non-aligned nations by extolling the preeminence of American ingenuity.

Rarely recalled is that a month before his "moonshot" speech, JFK articulated another technological challenge: the provision of freshwater. He stated: "If we could ever competitively— at a cheap rate—get fresh water from salt water, that would be in the long-range interest of humanity and would really dwarf any other scientific accomplishment." Desalination, he later noted, "is a work that in many ways is more important than any other scientific enterprise in which this country is now engaged."¹

Kennedy believed desalination could help eradicate poverty and improve public health. Not far from his mind, however, was the conviction that efforts to promote this innovation might also give America an edge in its struggle against the appeals of communism. In fact, Kennedy initially conceived large-scale desalination as a means of winning the hearts and minds of people in developing countries. Only later was he persuaded that an ambitious space

¹ See: Michael E. Webber and Sheril R. Kirshenbaum. 2012. "Time for Another Giant Leap For Mankind," *Issues in Science and Technology* 28, no. 3 (Spring). <https://issues.org/realnumbers-30/> and Jacob Roberts and Kenton G. Jaehnig. 2018. "Nor Any Drop to Drink," *Distillations: Using Stories from Science's past to Understand our World*. November 12. <https://www.sciencehistory.org/distillations/nor-any-drop-to-drink>

program might serve the same purpose more effectively (Spudis, 2013).

Earlier, in February, 1961, in a message to Congress on natural resource policy, Kennedy gave a boost to funding for research on advanced wastewater treatment, devoting particular attention to reuse of wastewater:

“Pollution of our country’s rivers and streams has – as a result of our rapid population and industrial growth and change – reached alarming proportions. To meet all needs ... we shall have to *use and reuse the same water*, maintaining quality as well as quantity. In many areas we need new sources of supply – but in all areas we must protect the supplies we have (U.S. Division of Water Supply and Pollution Control, 1962: iv).

While JFK made no mention in this instance about global competition with the Soviets, or the Cold War, he clearly signaled a pre-occupation with national security. In essence, the President stated that continued industrial and agricultural progress in the service of national needs partly depended on our ability to reuse water.

These anecdotes are important for two major reasons that are relevant to this book. First, they underscore the little appreciated, yet long-term preoccupation with the connection between water and national security. Innovations such as desalination and wastewater reuse are not only means to augment water supply, they are also methods to ensure a polity’s access to freshwater immune to control by uncooperative neighbors, and as strategies to bolster economic development. Growing reliance on these and other innovations exemplify this quest for water security. While President Kennedy may not have foreseen this trend, he clearly signaled its desirability. Today, in places where water demands continue to escalate while natural supplies diminish from drought and climate change, these innovations have become especially attractive. Imbalance between demand and supply, which experts refer to as *water stress*, encompasses a

wide and expanding swath of our planet (Boretti and Rosa, 2019; Felter and Robinson, 2021).

Second, these anecdotes attest to the enduring importance of measures to obtain clean, safe, potable freshwater from any available source in order to lift people out of privation and disease and toward a path of improved health and well-being. What was seen as a growing need in the early 1960s has become an even more critical challenge today. The task of furnishing clean water has become urgent due to dramatic rates of population growth in developing nations and increasing demands for freshwater for food and energy production everywhere. Contrary to the optimism displayed by decision-makers six decades ago, however, the notion that technological innovations can provide abundant and *inexpensive* freshwater to serve growing needs has turned out to be wishful thinking or naïve conjecture. Desalination, wastewater reuse and rainwater harvesting – the major water innovations examined in this book – are neither “magic bullets” nor technological panaceas. They are, instead, complex, capital intensive options that become practical only when governments invest in their deployment.

In many cases, they are introduced by for-profit corporations that pursue innovations as business investments. This is attested to by the growing global competition among vendors eager to expand their market share in desalination (Williams and Swyngedouw, 2018). It is also exemplified by the growing market for various wastewater reuse technologies being developed by a growing list of entrepreneurs (Water Technology Futures, 2015; IDE technologies, 2018). In short, deployment of water innovations often comes with “strings” attached, making their control and oversight by beneficiaries a challenge. This is another theme explored in this book.

The Cold War ended over 30 years ago. We no longer worry about water innovations as tools of superpower rivalry. However, we now face a new challenge no less profound: environmental catastrophe as the result of climate alterations caused by the burning of fossil

fuels. These alterations will likely impact available water supplies by making precipitation patterns more erratic and less dependable, streamflow more variable, and temperature and other weather factors less predictable. Such changes will affect the water needs of agriculture, the availability of water for energy production, and the water demands of cities.

While various technological innovations have the potential to address these challenges, they also harbor problems of their own. Innovations may impose risks to human health, environmental quality, and the quality of life – risks as profound in their own way as the environmental problems they are intended to address. Desalination can adversely affect marine life along coastal areas where seawater intakes are located and concentrated brines from the desalting process are discharged. Wastewater reuse poses human health concerns if improperly managed, and almost always generates concern when proposed as a means to convert sewage into drinking water or, as more colorfully expressed in the media, from “toilet-to-tap.” And, decisions regarding where and how any innovation should be deployed, including rainwater harvesting, are often contentious, especially when land use, aesthetics, recreational impacts, user costs, and environmental quality are important public policy issues.

Growing skepticism toward technologically-complex resource-management innovations that directly impact people’s lives, and whose inner workings are little understood by a public increasingly pre-occupied with environmental justice, warrant a more prudential view of these innovations and their feasibility. Illuminating the importance of these challenges, and determining the most effective and equitable ways of meeting them, are the principal objectives of this book. Among the questions I pose are: will the public accept these innovations as safe, secure sources of freshwater? Can innovations be implemented with regard for the needs of inclusive governance and democratic accountability? While some assume that water innovations

will be viewed as publicly acceptable so long as they are viewed as effective remedies for water stress, this assumption remains open to investigation.

The thesis of this book is that the most profound challenges facing policy-makers seeking to adopt water innovations are engaging relevant stakeholders; ensuring that innovations are operated with due consideration for public concerns over health, safety, and community well-being; and, providing assurances that they can be managed in a publicly-accountable manner. While my primary attention is on the “big three” water supply innovations: desalination, wastewater reuse, and rainwater harvesting – alternatives generally characterized by large infrastructure and high cost – exceptions to these generalizations are duly noted. Low-energy, low impact rainwater infrastructure efforts are becoming popular in many population centers worldwide, for example, while efforts to make desalination more “distributed,” less centralized, and more reliant on renewable energy are occurring on several continents.

Water supply innovations are but one example of a growing set of complex, hybridized technologies that derive their development from fields as diverse as information technology, automation studies, artificial intelligence (AI), nanotechnology, and other disciplines. Like other complex technologies, their deployment is being driven by the aspiration to address important social needs. And, as is true with these other technologies, managing their implementation often exceeds the capacity of government to regulate, or of the public to have an effective voice in, their oversight. There is another connection between these hybridized technologies and water which we also explore: demand-side approaches that rely upon “smart” sensors, digitized data collection systems, and cyber-infrastructure. These technologies harbor challenges to personal freedom, user privacy, information security, and protection of our water supply from various forms of cyber-warfare.

My previous research on water and environmental policy has led me to two conclusions which have prompted me to pursue this project. First, while many environmental and resource problems have multiple solutions, some solutions have the potential to generate new and unanticipated problems. With respect to water, these problems are not merely technical, but societal: perceptions regarding an innovation's impact upon people's health, welfare and well-being, as well as its possibly adverse environmental impacts partly revolve around trust in institutions and confidence in the officials who manage them. Thus, adoption requires flexible methods of political engagement to ensure that the public has a role in their governance.

Second, prospects for resolving these problems are likely to become more daunting as freshwater demands grow and prospects of satisfying them conventionally (via continued reliance on off-stream and groundwater withdrawals) diminish as a result of climate change. In adopting any innovation, we should be prepared to introduce governance approaches that permit knowledge exchange between experts and laypersons, and that enable the amicable resolution of conflict. Such governance approaches might also be appropriate for other technologies as well. Thus, while the book is principally directed at those interested in water innovations, students of environmental policy, science and technology studies, and natural resource policy – as well as environmental governance practitioners – will hopefully find its lessons of value.

I owe a profound debt to many colleagues who, over the years, have encouraged this book; shared ideas about the issues it discusses; and, in some cases reviewed the manuscript and offered advice, correction, and clarity about these issues. At the University of California, Irvine, I want to especially thank Shannon Roback, Sunny Jiang, Amir Aghakouchak, Brian Tarroja, Doug Colby, and Genia Nizkorodov. Stanley Grant at Virginia Tech has been a steady and reliable source of inspiration and an incredibly knowledgeable colleague. Wing Cheung, a

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Last but certainly not least, I dedicate this book to Justin, Michelle, Hannah and Seth – their generation will be the greatest benefactors of the innovations discussed in this book. They are also the generation that will be most highly burdened by the necessity of ensuring that they are governed in appropriate ways that ensure they are more beneficial than burdensome. Most of all, I thank Jill for her constant encouragement of my writing, even at times when the goal of completing this work was most difficult, and finding the right words most elusive.

CHAPTER 1—THE GLOBAL NEED FOR WATER ALTERNATIVES

Two commonwealths, one challenge

California needs water – lots of it. With a population of forty million, bustling cities that include the nation’s second largest metropolitan area, a robust agricultural sector with an annual production value exceeding \$50 billion, and the world’s 5th largest economy, this need would be obvious even in normal times. These times are hardly normal, however. The impact of climate change on the state’s precarious rain and snowfall is one harbinger of looming peril. Contention among hundreds of water agencies and stakeholders over how to allocate available supplies is another.

Southern California faces reduced deliveries from the over-taxed, multi-state and bi-nationally-shared Colorado River. Northern California’s reliance on capture and storage of Sierra runoff faces both diminished snowmelt and future likelihood of a tunnel under the Sacramento-San Joaquin Delta to convey water to thirsty southern neighbors. And, recent groundwater policy reforms will regulate agricultural water withdrawals in an effort to ensure that continued pumping does not further deplete this precious resource (Walters, 2019; California Water Boards, 2020; Mount et al, 2018).

Given this worrisome context, it is somewhat surprising that plans by the California American Water Corporation (Cal Am) to build a desalination plant in the town of Marina, along Monterey Bay on the state’s central coast, were recently withdrawn by the company. Desalination plants are often contentious. They consume copious amounts of electricity, are expensive to construct, and often lead to water rate increases. In this case, however, many influential individuals and local conservation groups viewed the project as an environmentally-friendly alternative to satisfy the growing water needs of the isolated Monterey peninsula. The region lacks access to state and federal aqueducts and has limited

supply options. Cal Am, the region's main water purveyor, is under state order to stop over-pumping the Carmel River, a major regional water source, in part to protect steelhead trout.

Despite this, local residents and the mayors of Marina and neighboring Seaside, oppose the project. They contend it is unfair to burden their communities with a project that will not supply their residents with freshwater, and whose predominantly working class, minority communities will be partly responsible for the ratepayer burden of \$1.3 billion over 30 years it will generate. They and others have urged Cal Am to instead expand an existing wastewater recycling plant at a fraction of the cost.

A collateral benefit of *not* building the desalter, they insist, is that the proposed 30 acre site, an environmentally sensitive habitat featuring coastal sand dunes, would be protected, as would community access to its family-friendly beaches (Oglesby and Delgado, 2020). In announcing its decision to terminate the project, Cal Am stated that it “heard serious environmental justice concerns from residents of Marina, and cost concerns from our customers” (Xia, 2020: B3).

Regardless of the long term prospects for the project, two things stand out about this case. First, the state's Coastal Commission, empowered to license ocean desalination facilities, has authority to consider harm to underrepresented communities as a legitimate issue in disapproving a water agency's plans. Water needs by themselves are not sufficient justification for a desalination plant. This is one reason Cal Am – for now – has backed away from the project. Second, Marina and Seaside, communities long afflicted with unsightly industrial facilities, have made the issue of open coastal space a top environmental justice priority. One-third of local residents are low income and Spanish speaking. Cal Am's aggressive, expensive, and high profile lobbying effort on behalf of the desalination project also did not sit well with many local residents, a third of whom live below the poverty line.

Jordan is a country of 10 million whose population has doubled in the past 20 years, and where rainfall is predicted to decrease 30 percent by the end of the century due to climate change (Jordan, 2017). It is ranked among the world's most water-stressed nations. Currently, it plans to combine more efficient use, especially in agricultural irrigation with desalination and wastewater reuse to slake its growing thirst. According to Marwan Alraggad, head of the *Inter-Islamic Network on Water Resources Development and Management* the country has achieved "...a success story, considering the climatic, demographic, hydro-political and financial challenges we are facing" (Lindsey, 2020). Nevertheless, serious challenges remain.

Despite rationing, storage of pumped groundwater in tanks, and purchases of bottled water for household use during summers, the country's aquifers are being drawn down at twice the rate they can be replenished, in part by illegal, unregulated private wells. A proposed Israeli-Jordanian funded desalination venture, the *Red Sea–Dead Sea Water Conveyance Project*, was slated to build a plant at Aqaba to produce drinking water for Israel, Palestine, and Jordan, including the city of Amman. The project's output of concentrated brine, together with seawater, would be used to replenish the shrinking Dead Sea (Markel et al, 2013). This ambitious project is currently on hold pending resolution of diplomatic issues between Israel and Jordan (Chapter 3).

While Jordan may soon build its own, smaller desalter, wastewater reuse appears to be the one technological approach harboring immediate promise, especially for meeting the needs of agriculture. A demonstration project near Al-Balqa Applied University, funded by Germany's Ministry of Education and Research, is trying to validate the feasibility and cost-effectiveness of different wastewater treatment systems. The greatest impediment to adoption, however, is overcoming public concern that treated wastewater is unclean. Noama Shareef, a senior wastewater engineer from

Germany involved in the project notes that: “There are a lot of people in Jordan with good education in water management,” but there is a need for hands-on practice.

According to Shareef, a pilot project in the nearby city of Salt, started a decade ago, has yielded some positive results. “... At first families in Salt hesitated (to adopt reuse), they were afraid the wastewater was dirty; the culture refused the idea,” she recounts. But after a couple of years, when they witnessed their neighbors’ flourishing gardens, “families came to us asking to be part of the project; some of them paid to build [a wastewater treatment system] themselves (Lindsey, 2020).”

Regardless of the ultimate fate of wastewater reuse in Jordan, three lessons are clear. First, as in other developing countries, Jordan’s choices over management of water supply are inseparable from its geo-political setting. Its only surface water sources, the climate-stressed Yarmouk and Jordan Rivers, are shared with Israel and Syria. Moreover, Jordan currently hosts 750,000 registered refugees, most of whom are Syrian ex-patriots seeking refuge from that country’s civil war. These trans-boundary issues impose significant pressures on its limited water supply, as well as inflicting water security concerns on its government. How much control will Jordan have over its access to water, barring adoption of supply innovations, including controversial ones?

Second, because fully half of Jordan’s water is used for agriculture – and exported in the form of water-thirsty strawberries, tomatoes, and cucumbers– the country is effectively exporting much of its freshwater. Thus, economic globalization is another driver of water stress in Jordan, and yet another reason new supply sources are desperately needed given the country’s development aspirations.

Lastly, water innovations have costs as well as benefits. Public reluctance to embrace wastewater reuse in Jordan isn’t merely a matter of personal preference: it’s a product of deep-seated and widely-shared religious convictions regarding cleanliness, safety, and

wholesomeness. Water represents purity in Islam. Its purpose is not only bodily hygiene, as in other cultures, but spiritual purification by means of daily ablutions. In accordance with the great Sufi Ibn ‘Arabi of Murcia (b. 1165 – d. 1240), by performing ablutions believers get rid of vanity and appear themselves as servants of the Creator (Jah, 2020). Similar cultural constraints, fervently and deeply held, are important factors affecting the adoption of water innovations in other societies, as we will see.

Acceptable solutions to unacceptable problems

How do the experiences of these two regions exemplify the challenges in meeting the world’s growing freshwater needs? Given the increasing urgency of water scarcity across the globe, how widely should innovations such as desalination and wastewater reuse become adopted? And, can these and other alternatives be deployed in a timely and effective manner while also assuaging public concerns over their cost, safety, and equity?

Freshwater is our planet’s most precious resource – essential for life itself. While most of us learned this fact at an early age, those of us living in affluent societies often take water for granted. We sometimes overlook difficulties in safely and reliably supplying it to others less fortunate –in our own societies and in others. Yet, many face daily hardships finding potable water. More than 40% of the world’s population lives in regions where uncontaminated water is scarce, a figure likely to rise in the future. And every day, nearly 1,000 children die from preventable water-borne and sanitation-related diseases (UN Sustainable Development Goals, 2019).

Threats to public health are not the only major problem associated with freshwater scarcity. Students of international politics increasingly warn about water *security* – the assurance that one country’s freshwater will not be subject to undue control by another. As we saw in the case of Jordan, countries that share water sources

with neighbors often encounter this problem, especially when water demands and other security-related concerns become conflated. Jordan is not alone in facing such challenges. A U.S. government study contends that the world's growing freshwater demands may lead to violent conflict due to expanding needs for food and energy, climate change-induced stress, and apportionment of rivers among contiguous – and sometimes contentious – nation-states. More than 260 river basins, home to over three billion people, are shared by two or more countries (U.S. Department of State, 2012).

Growing water demands due to population growth and economic expansion may also lead to *destabilizing migrations*, particularly if disagreements over equitable access cannot be amicably resolved. Prolonged drought makes this eventuality more likely. Some view the case of Syria's civil war, alluded to earlier, as an example of this (Gleick et al, 2020). As we will see, countries that have aggressively pursued water innovations, such as Israel and Singapore (Chapter 3), have been partly encouraged to do so by concerns related to sharing water with neighbors as well as growing demands revolving around food security and economic development. A U.S. *Intelligence Community Assessment* succinctly forecast the potentially dire implications of global water insecurity a decade ago:

During the next 10 years, many countries important to the United States will experience water problems—shortages, poor water quality, or floods—that will risk instability and state failure, increase regional tensions, and distract them from working with the United States on important U.S. policy objectives. Between now and 2040, fresh water availability will not keep up with demand absent more effective management of water resources (Global Water Security, 2012).

This quote underscores a further challenge: the appalling condition of water infrastructure globally. The *World Bank* has determined that many developing nations face potential catastrophe from intensive irrigation, urbanization, and deteriorating water supply and treatment infrastructure, and they cannot afford needed improvements. In many places un-treated wastewater is directly released into the environment though dumping into lakes, streams, and estuaries: a practice that remains widespread in low-income countries, which on average treat less than 10% of their wastewater discharges.

The bank's *Water Global Practice* program seeks to expand developing country efforts to achieve universal access to clean water and proper sanitation through legal, institutional, and regulatory reform, as well as financing. It supports innovative approaches to alter behavior, promote new products, and obtain funding for desalination, wastewater reuse, and other innovative water supply schemes (World Bank 2019). The Bank contends there are viable, fundable water alternatives. While this confidence may be warranted from a purely technical perspective, social and political challenges must first be overcome to make their economical adoption practicable – we will see numerous examples of this in subsequent chapters.

Many students of water resources planning agree that effective solutions to these health, security, and economic problems are rooted in technology: *innovations* that can diversify and enhance water supplies safely, reliably, and affordably. Among the most important of these are *weather resilient* sources of *new* water, such as desalination of sea- and brackish water via thermal and membrane technologies to remove salts; wastewater or effluent reuse – treated sufficiently for both non-potable and potable use; and, rainwater capture and harvesting. Innovations may also comprise solutions that promote water savings. These include methods that measure and monitor where, when, and how we use water; enhance demand-management and conservation; and provide

leak-detection and other benefits to minimize waste and accidental water loss (Water Technology Futures, 2015).

World-wide, water innovations have been widely adopted. In general, what we have learned is that the speed and degree of penetration of their adoption depends less on overcoming engineering and technical constraints and more on assuring users that they are safe, secure, affordable, and managed responsibly. Concerns over the potential impact on public and environmental health and community well-being are raised wherever plans to introduce innovations are launched. Moreover, proponents are increasingly called upon to address end-user costs and energy consumption (issues of particular salience for desalination), as well as perceived social inequities in their siting. Assurances must also be given that those who manage these innovations are competent and trustworthy (Asano and Bahri, 2011; Dolnicar et al, 2011, Fielding et al, 2019).

The degree to which these concerns resonate among members of the public is determined by a constellation of psychological and demographic factors. Anxiety over recycled wastewater use, for example, varies by age, income, degree of environmental concern, views about water scarcity, and trust in the process by which decisions over its adoption are made and in the people making them (Fielding, et al, 2019; Ross et al. 2014; Ormerod and Scott, 2012). Given these wide-ranging factors, efforts to alleviate public concerns is a complex challenge for three major reasons.

First, freshwater's essential and non-substitutable character make concern over its safety a non-negotiable issue. We drink it and bathe in it. We give it to our children whose health and well-being we value above our own. And, we implicitly trust those who provide it because they insist their product is safe: public confidence is the coin of the realm for water agencies in modern societies. Some describe the trust reposed in water providers as based on a kind of "hydro-social contract," an informal, yet binding

agreement based on the widely-held assumption that law, sound engineering, and good management assures that our water supply is safe (Linton and Budds, 2014).

Because water is far too important to take for granted, we are understandably concerned when proposals to provide it by means unfamiliar to us are introduced. Moreover, whether the provision of water by innovative methods is safer than that provided by conventional approaches (an argument sometimes made by advocates) is beside the point. Technologically-complex approaches to providing an essential service, and whose inner workings are dimly understood by lay audiences, tend to generate trust and confidence concerns. As we shall see, in some polities, a technocratic elite – widely trusted and highly trained – serves to allay many concerns over possible risks from innovations such as wastewater reuse and desalination. In other places, however, skepticism toward water governance authority, as well as a lack of political consensus around innovations, have made the introduction of such alternatives more difficult.

Second, the attitudes we harbor toward innovations such as desalinated and recycled wastewater are generally determined by our degree of interaction with them. End uses entailing direct bodily contact (e.g., drinking, bathing) tend to generate varying degrees of anxiety, while low- or no-contact uses (e.g., fire-fighting, crop irrigation) engender less worry or concern (Dolnicar and Schafer, 2006; Hurlimann and Dolnicar, 2010). Freshwater entering our homes from a familiar source, such as a local groundwater basin or river, and that has been treated to commonly-accepted standards, will likely be trusted. By contrast, recycled sewage, freshwater refined from seawater, and rainwater running off streets and paved surfaces will likely generate greater *perceived* risks to human health, at least initially.

Such concerns *are* to a degree warranted. All three of these above sources are likely to contain contaminants of one sort or another that, untreated, can adversely affect

people and the environment. Thus, water innovations often prompt one fundamental question that the average person might not pose with regard to “normal” water supply sources: Can the risks associated with these novel technologies be safely alleviated?

A third major explanation for the difficulty in addressing public concerns is found in the domains of *risk communication* and *risk management*. The first of these refers to the interactive exchange of information intended to convince citizens that some potential natural or human-caused hazard is being safely managed. We employ the term *hazard* broadly here. As one venerable treatise on the subject puts it: “A hazard is (any) threat potential posed to humans or nature by events originating in or transmitted by the natural or built environment” (Kates, 1978).

Responding to, and addressing, a hazard entails more than good messaging or savvy public relations. In the case of water innovations, it requires that officials devote ample resources and personnel to fully communicating about, overseeing, and alleviating potential problems. It also requires that an involved, informed public be provided with opportunities to collaborate with decision-makers in a fair-minded, reasonable, solution-oriented approach to co-managing innovations (Hadden, 1989; Renn and Levine, 1991; Mileti et al. 1994; Ng and Hamby, 1997; Gross, 1994).

The importance of all three factors in securing public acceptance is, in fact, widely appreciated by innovation proponents. Many agencies are far-sighted enough to undertake proactive measures to address potential citizen-driven concerns at a project’s outset, before they become apparent. Timely and cost-effective implementation of water innovations is a widely-shared goal among officials in every country whose business entails supplying water. Nonetheless, as we will see, officials are also sensitive to the need to ensure public trust and to practice sound risk communication and management strategies (Water Technology Futures, 2015; Asano and Bahri, 2011).

An oft-cited example is that of Orange County, California's adoption, in the 1970s, of what eventually became North America's largest indirect potable wastewater re-use system. The aptly-named *Groundwater Replenishment System* recharges the region's groundwater basin with recycled effluent. During initial planning, the Orange County Water District, the agency charged with the project's development, actively targeted affected communities through sophisticated information and education campaigns. These measures elicited decision-maker and public comments, incorporated a citizens' advisory committee and numerous focus groups to improve the effectiveness of outreach and risk communication, and – most of all – actively sought to satisfy the concerns of users that the proposed system would not only provide a safe, secure water supply but one managed by a trustworthy, competent organization that would take every conceivable measure to ensure safety (Harris-Lovett et al, 2015; OCWD, 2014).

Four factors weighed heavily in the system's successful adoption: officials allowed full disclosure of its costs, which also ensured transparency; the nearly \$1 billion project was brought on-line on time and within budget; its operation converged closely with community aspirations for a dependable water supply to support continued growth; and, public outreach was not only built into the project, but took place over an entire decade before the facility was actually built (Kenney, 2019: 111).

While these factors affirm the importance of *public perceptions, especially regarding risks*, they also reveal the importance of *governance* in successful adoption. Decision-makers charged with managing the system were also regarded as expert and experienced, and their decisions were viewed as fair, reasonable, and carefully considered (Fielding et al., 2018).

As we shall see, the type of collaboration seen in Orange County is critically important for promoting acceptance of water innovations (Chapter 4). It is also difficult

– and even arduous – to bring about. Satisfying public concerns regarding issues such as cost, public and environmental health, operational safety, and equitable implementation requires *adaptive governance* – a policy-making approach that emphasizes collaborative engagement between state and non-state actors to integrate specialized and local knowledge regarding the adoption of novel or innovative technologies.

We discuss the history and role of governance in managing and implementing water alternatives in Chapter 3, and the critical role played by *adaptive* governance in places resistant to innovative alternatives in Chapter 4. At this juncture, we need to understand why governance is so critical to effectively managing water innovations. Governance encompasses the political, administrative, legal, and economic factors that determine how water and water services are provided. To be effective – within countries as well as when managing water resources between different countries – analysts concur that governance institutions must be inclusive of all relevant stakeholders, accountable to their concerns, forthright in providing relevant information about risks and related concerns, and transparent (Sadoff et al., 2008: 83; OECD, 2018: 17).

To achieve inclusivity and accountability, four factors are critical. First, management institutions overseeing innovations must be comprised of competent, trustworthy and apolitical managers. Technically skill is valued over personal connection or ideology. Critics of water alternatives – in particular desalination – contend that reliance on a technocratic elite harbors other risks: above all increasing privatization of freshwater sources and their control by a global corporate network of vendors and supportive governments (Williams and Swyngedouw, 2018), an issue we explore later.

Second, a supportive economic and technological base is required for effective innovation research, development and implementation, and to help ensure trust and

competence. The more sophisticated the base of support, the more likely citizens will have confidence in their introduction and management. Polities with high-levels of development are better able to achieve these objectives than those in less developed countries. Third, achieving high levels of political consensus requires careful, deliberate efforts by officials to ensure public confidence regarding the safety, reliability, and quality of innovations and their operation. Lastly, a preoccupation with *water security* – a polity’s capacity to control, manage, and ensure dependable access to its supply, without having to rely on neighboring polities, underlies many efforts at innovation implementation, particularly in countries sharing river and groundwater basins.

For many reasons, some polities subject to water insecurity lack political consensus, display low levels of trust and confidence, have less economic or technological prowess to introduce innovations, and may not possess what the public considers apolitical, technocratically-skilled managers. For these polities, deficient in one or more of these respects, something beyond *ordinary* governance may be needed.

Adaptive governance is designed to overcome distrust and lack of confidence in the institutions that manage technological innovations, and to render decisions that can be modified in the light of experience. Where adaptive governance has been instituted in conjunction with the introduction of water supply innovations, trust, confidence, and cooperation among stakeholders can better result. In places, suffering a deficit in the factors mentioned above – including a lack of effort in effectively instituting adaptive governance, conflict over innovations and their implementation remains acute, sometimes impeding their adoption.

At the risk of over-simplification, it may be suggested that adaptive governance is what Jordanians are seeking in order to implement wastewater reuse and ensure it is publicly acceptable. The emphasis on demonstration and public outreach, cultivation of

community-level trust, and acknowledgement of the legitimacy of cultural and religious concerns all illustrate a desired propensity for collaboration and respect for local knowledge. By contrast, the proposed Monterey Bay desalination project in California has, until now at least, relied on high-profile lobbying and the support of a few well-placed politically-savvy interests. The concerns of local, under-represented groups residing in the area, and who are directly impacted by the project's footprint, have not been strongly embraced, and their engagement in the project has unsurprisingly been low. Moreover, convincing arguments that desalination is the best and most sustainable and secure water supply option have not, in the opinion of some, been effectively made.

An overview of water innovations - desalination

Let's turn to a preliminary discussion of water innovations. We begin with an overview of desalination: in actuality, a family of technologies for removing salt from ocean- and brackish water via reverse osmosis or other means. Desalination has been widely adopted in many arid, semi-arid, and otherwise freshwater-limited nations throughout the Middle East, parts of Europe (e.g., Spain), Australia, and some small island states (e.g., Singapore). It is also increasingly attractive in the western U.S., especially California.

Desalination's popularity is attested to by the sheer number and diverse location of facilities transforming sea- and brackish water into freshwater. As of 2019, there were some 15,906 operational desalination plants worldwide, producing around 95 million m³/day of desalinated water for human use. Some 48% of this desalinated water is produced in the Middle East and North Africa (Jones et al, 2019). While widespread in its adoption, its use is by no means universal. Some 300 million people worldwide receive their water through desalination – a considerable number, but one with considerable room for growth (Robbins, 2019).

Among the potentially negative impacts of desalination are high energy consumption and energy costs, threats to marine life, brine disposal safety, aesthetic considerations (e.g., noise and industrial appearance, as well as the smell and even taste of desalinated water) (Palomar and Losada, 2011; Cooley et al, 2006; World Health Organization, 2011). While many of these issues can be addressed through provision of on-site electricity generation, use of near ocean “diffusers” to reduce brine concentrations released to the ocean, and measures to ensure that plants minimize entrainment of aquatic organisms, other issues are more politically, and even ethically, intractable. Locational (supplanting of recreational beaches) and ratepayer impacts – as briefly discussed earlier – have in some cases proven more difficult to address.

Brine disposal remains among the most serious of this technology’s environmental impacts. Desalination results in production of copious amounts of a “typically hypersaline concentrate” discharge that requires costly disposal. Brine production is estimated to be around 142 million m³/day, and four countries – Saudi Arabia, UAE, Kuwait and Qatar account for 55% of the total global brine production (Jones et al 2019). Improved brine management strategies are available to limit the negative environmental impacts and reduce the economic cost of disposal. Nevertheless, reducing these adverse impacts are important for making this innovation acceptable. One widely-cited study reported on these adverse impacts some 20 years ago. Its findings are worth quoting at length, as they remain relevant:

Heat, trace metals, brine, and other toxicants may result in acute mortality to organisms in the receiving waterbody. Subtle changes in distribution and abundance patterns and sublethal changes in the physiological, behavioral, and/or reproductive condition of resident organisms may occur. These effects are inherently more difficult to detect because marine environments are

reasonably resilient to disturbances thus the aforementioned effects may occur gradually over a long period of time (Brining et al. 1981: 256-7).

Less frequently discussed in popular media, but widely cited by experts, are potential public health impacts arising from addition of pre-treatment chemicals to forestall corrosion, as well as introduction of biological or chemical contaminants into product water (Cooley et al, 2006; World Health Organization, 2007). For instance, Boron and Bromide are often found in desalinated water at levels 10 times greater than those present in conventional water sources. Boron has a negative impact on the yield, size, and color of citrus fruit, while bromides produce unpleasant smell and taste in potable water.

Israel, Cyprus, Qatar, Bahrain, the United Arab emirates, and in the U.S. – the state of California – have established drinking water limits on boron levels. These are regions that also produce large citrus crops (Voutchkov, 2013: 96). As with most issues surrounding potentially unwanted concentrations of chemical substances, mitigation measures are available, especially for desalination facilities using reverse osmosis membranes. These measures do, however, add to the already considerable cost of desalinated water production – an issue we discuss in Chapter 2.

Those skeptical of desalination urge caution and restraint in its adoption and point to what they contend is a lack of sufficient regulation to ensure that human and ecological health are fully protected from pollutants associated with salt brine, and an overall lack of clarity and consistency between national, regional, and even local regulations concerning desalination facility siting, licensing, and operation. To ensure these issues are fully addressed, skeptics note, approval processes must embrace “public transparency,” and establish criteria for assuming the financial risks of a project should its owners declare bankruptcy (Cooley et al., 2006). Critics further contend that other,

less tractable issues, must also be addressed including whether the water is actually needed and, if so, if the need can be met by more environmentally-benign, less expensive, sources.

The previous desalination case centered on Monterey Bay illustrates some of these concerns, while a Southern California case further amplifies them. Poseidon Water, a multi-national desalination vendor, is currently seeking to build a \$1 billion, 50 million gallon per day desalter in the scenic coastal community of Huntington Beach. While a series of final environmental approvals regarding the plant's impacts to local marine life are pending, the Santa Ana Regional Water Quality Control Board is trying to determine if the additional water to be supplied is actually needed.

Critics contend that the vendor's demand estimates are inflated and based on outdated growth projections, while others insist that upgrades to an existing wastewater reuse facility can adequately satisfy future needs. At the crux of the debate is that the water to be produced would cost over \$2200 per acre-foot, twice as expensive as imported sources from Northern California and the Colorado River. For their part, project defenders insist that these alternative sources are subject to future limitations, making desalination a salient option (Boxall, 2020).

In some countries where desalination has been strongly embraced – Israel and Spain, for instance – the issue of cost has arisen chiefly with respect to its allocation. In Israel, strong government investment in desalination has contributed to a surplus of water production due to the large number of plants built since the early 2000s. However, the “sunk costs” of these plants continue to be levied on water users – a problem that might not exist if the country adopted an “optimal” desalination output 60% lower than current levels, according to one study (Reznik et al., 2016).

In Spain, a different variation on this issue has arisen. Following an ambitious plan by the Socialist government that came to power in 2004, some 17 new reverse-osmosis desalination plants were constructed on the Mediterranean coast. Demand forecasts turned out to be overly-ambitious and, for a time, a number of these plants were operated far below their rated capacity. However, the costs incurred by the government in building these plants still had to be paid by water users to make good on the bonds sold to investors (Arahuetes and Villar, 2017: 70). In short, such cases point to a question of equity: should the costs of desalination be borne by investors, direct beneficiaries of the water produced, or by all water users regardless? And, is allocation of these costs among various stakeholders viewed as fair? Countries that have invested heavily in desalination find that careful thought must be given to who pays for its use.

Wastewater reuse – an overview

As noted earlier, wastewater re-use or recycling – also called effluent re-use – is another approach which has been growing in popularity. One alleged advantage of this technology is that it can be used to slake demands for either potable or non-potable water. In both cases, unfamiliar risks are at the heart of public contention over its adoption. Re-use has been adopted on a growing scale: notably in Australia, Israel, Jordan, Namibia, Singapore, Southern California, and elsewhere. Experts generally deem this technology to be safe if properly managed. Nonetheless, debates over its adoption have been especially contentious, and in some instances concerns regarding its potential risks have been voiced, slowing – if not altogether preventing – its adoption for non-potable as well as potable uses.

Latin America, a region that suffers from many water availability challenges, affords a fitting illustration. A number of initiatives are taking place throughout the continent, spurred by international development agencies and national governments, to

adopt wastewater reuse as a means of lessening reliance on increasingly scarce freshwater supplies. A recent World Bank report states that a distinct advantage to the region from reuse approaches is that they can satisfy many needs. They can be treated to various qualities for industrial and agricultural uses; satisfy instream flow as well as drinking water needs; and, as one means of water supply diversification, “enhance security and resilience.” Meanwhile by-products of reuse can be used for energy generation and agriculture, “making wastewater treatment plants more environmentally and financially sustainable” (Rodriguez, et al., 2020: 11).

Despite these benefits, achieving public acceptance of reuse has not been easy – in Latin America or elsewhere (see sidebar). Some farmers fear that wastewater reuse processes may remove desired nutrients, leading to diminished crop yields. Moreover, regulations in some places (e.g., Chile) explicitly limit or even prohibit the use of reclaimed water. And, public information and outreach strategies in some cases are poorly developed (Rodriguez, et al., 2020).

As for the role of governance – adaptive and otherwise – the collaboration and engagement necessary for successfully introducing these approaches in most of Latin America have been noticeably absent. Observers contend that planning efforts that span river and groundwater basins are poorly developed, and oversight, coordination, and accountability structures needed for effectively utilizing these technologies are sorely lacking. Moreover, governing structures that “allow stakeholders’ participation in the planning process and clearly establishes their duties” is deficient across the region (Rodriguez, et al., 2020: 23).

SIDEBAR: *Can beer make the world safe for wastewater reuse?*

Manufacturing beer uses a lot of water – between irrigation of barley and hops and brewing and bottling the beverage, some seven gallons of water are needed to produce one gallon of beer. It’s become fashionable for brewers, especially smaller

craft-manufacturers, to find ways to make their product more sustainably. A few have experimented with using treated wastewater in their product.

Village Brewery in Calgary, Alberta has released a blonde ale made from treated municipal wastewater “to bring attention to the issue of water security.” According to Christine O’Grady, a researcher with the University of Calgary “It tastes exactly like their standard product. The only difference being instead of drawing from the tap, they took water from us.” The process employs a combination of methods widely used in wastewater reuse: biological removal of contaminants, ultrafiltration, and reverse osmosis among them.

This Canadian brewery is not alone. A consortium of Swedish brewers and wastewater technicians are responsible for the world’s first commercially sold beer using treated wastewater. A partnership of Nya Carnegie Brewery, IVL Swedish Environmental Research Institute and Carlsberg Sweden came together to produce a pilsner called PU:REST “in order to try to get over public aversion to drinking treated wastewater more broadly.”

These pioneers are serious about using their novel product to draw greater attention to the growing problem of freshwater scarcity. Will it also change public attitudes? Calgary’s Professor O’Grady admits that it’s still a hard sell due to “the yuck factor.”

“I think we’ve demonstrated very effectively that it’s clean and safe water, but people still have that mental hurdle to overcome,” she says.

One thing seems certain – if drinking a popular beverage made from recycled sewage catches on, it’s likely that recycled wastewater will become more acceptable. At least these brewers think so (Robinson, 2020).

By contrast, the city-sized nation of Singapore affords an example of successful, large-scale wastewater reuse. Singapore is a model of how to increase water supply through diversification of sources *and* how to successfully induce reductions in demand. With a population of nearly 5.7 million, a paucity of domestic freshwater, historic dependence on Malaysia for imported water, and memories of the World War II invasion by the Japanese (Lafforgue and Lanouvel, 2015), water reuse, along with rainwater harvesting and conservation, have become major water supply strategies.

While still importing about 40% of its freshwater from Malaysia's Johor province, reclaimed wastewater now meets a considerable proportion of its total annual *non-potable* water needs. The water authority is responsible for managing all major water sources. Since its independence Singapore has pursued a re-design of its water infrastructure to protect, store, and reuse rainwater; has consciously raised public awareness through a cooperative water rationing program that interrupts different cohorts of residents daily; employs an effective consumption-based rate system which has achieved significant reductions in water use; and has cultivated a general outreach program to the public to build public trust and confidence (Lafforgue and Lanouvel, 2015; Hering et al, 2013). However, for reasons we later discuss (Chapter 3), we would not characterize this outreach program as an example of either adaptive governance or fully inclusive of divergent views. It is closely bound to a top-down approach to risk communication and a reliance on technocratic management.

Finally, Australia affords a novel example of the use of recycled wastewater for environmental protection – in this case, instream flow enhancement. A recycled wastewater plant on Jackson Creek, a rural sub-catchment of the Maribyrnong River north of Melbourne, Australia, has introduced a pilot program that uses recycled wastewater as part of a water quality “offset” program to mitigate the impacts of point source discharges, nonpoint source pollution, and sewerage overflows.

Given the controversy in this application of recycled wastewater, the local water agency employed a form of adaptive governance—collaboration with civil society groups, social learning through public participation within affected watershed communities, and policy experimentation which has been enabled through national regulatory agency adjustment on water quality guidelines. This effort was also part-and-parcel of larger regional efforts to achieve inclusive and bottom-up approaches to water

innovation implementation (see Chapter 4). All of this has contributed to more flexible policy outcomes, as well as enabling application of unusual end-uses for recycled effluent (Feldman et al, 2015).

Concern that contaminants potentially present in reclaimed wastewater have not yet been sufficiently studied have led to resistance to direct potable reuse in some U.S. states. Moreover, even in communities where effluent reuse has been adopted for potable uses (e.g., Australia), the public has often displayed a preference for indirect, rather than direct reuse (i.e., aquifer recharge through adding recycled wastewater into groundwater basins), or limiting use of reclaimed wastewater to agricultural and landscape applications (e.g., Israel). While adoption of these innovations is not usually driven by a need, say, to alleviate contaminants of emerging concern, existing public apprehensions regarding such issues often acts as a “brake” on the adoption of new water innovations in the public’s mind. In short, if water management agencies cannot adequately protect public health and safety by reducing such threats when posed by *existing* water provision approaches, how can the public be expected to have confidence in the adoption of new and untested approaches?

Unlike desalination, which generally relies upon large-scale, centrally-managed facilities, wastewater re-use can be more tailored to various scales-of-use. Treated effluent can be *graded* for non-potable as well as potable uses, and its energy use is lower than for desalination (OECD, 2008). Nonetheless, as we shall see, concerns include safety and equity (exemplified by insistence that reuse not be confined to communities with large under-represented populations). Among the questions that must be satisfactorily answered include: will consumers buy produce irrigated with re-used effluent? And, is the use of re-cycled effluent an incentive for unwanted growth – an action likely to arouse public opposition, as has occurred in Los Angeles, for example?

As previously noted, end-uses resulting in direct human contact (e.g., drinking, bathing, swimming), will likely arouse high levels of concern (Hurlimann and Dolnicar, 2010).

Rainwater harvesting – an overview

Rainwater harvesting is a venerable practice that, in various forms, harkens back to antiquity. While its time-honored use almost precludes calling it an innovation, we consider it such because the basic principle behind its use is that – even in the most arid climes – it occasionally rains. If this rain can be captured and stored for later use, high-priority water needs can be locally satisfied.

Archeologists and historians have chronicled the sophisticated methods of rainwater collection practiced in the Dead Sea region of present day Israel, as well as in the vicinity of Petra in modern day Jordan. Residents of ancient Qumran, among whom were the scribes responsible for producing what the world now knows as the *Dead Sea Scrolls*, were astute practitioners of rainwater harvesting. An aqueduct fed by seasonal floods in Wadi Qumran, a seasonal-flowing stream in the region, directed waters to a set of pools hewn directly into bedrock. In addition to providing a bank of potable supply for domestic use, some pools served as ritual baths (miqva ‘ot) for Qumranites who obeyed Hebrew purity laws practiced in the Hasmonean Kingdom 2000 years ago (Gal, 2010).

Directly south of the Dead Sea, the ancient Nabateans built subterranean cisterns in what is today southern Jordan. While Petra is the best known of this culture’s architecturally-impressive settlements, throughout their region of settlement, the Nabateans introduced innovative stormwater harvesting techniques that contributed to their commercial dominance throughout the region. These innovations included terraced hillsides constructed of stone walls, small dams to impound pools of water, and wide

use of rock cut, plaster-lined cisterns: “the mainstay of water storage throughout the Nabatean period” (Mithen, 2013: 112).

Contemporary rainwater capture and harvesting approaches are distinct from ancient practice in that they fuse several water management objectives into a single strategy – and they often do so through what are termed “low-impact” development: relying on wetlands, parks, rain gardens, and similar techniques for collecting and utilizing captured rainfall. The objectives of rainwater capture and harvesting include flood control, non-point runoff management, and urban water supply.

A basic principle guiding modern day rainwater harvesting is capturing runoff for the purpose of either recharging drinking water aquifers, or reusing it for non-potable irrigation needs (e.g., urban parks) (Hering et al, 2013). Rainwater harvesting has become a major source of non-potable water in cities across the globe. Two notable metropolitan examples are Los Angeles County, California and Melbourne, Australia.

The former operates over two dozen “spreading basins” that recharge groundwater sources in the San Fernando valley. Most of the runoff channeled to these basins is wet-weather flow during winter months. Parts of Los Angeles have been pursuing an effort to further enhance the recharge of stormwater as part of a strategy for coping with decreased imported water and to reduce runoff pollution, a serious problem in the Los Angeles basin as in many other densely-populated and heavily paved-over urban regions (Hering et al, 2013). In 2018, county residents voted an additional property tax increment of 2.5 cents per square foot of impermeable surface to be used to capture and clean-up stormwater to alleviate runoff of contaminants into streams and estuaries and procure additional supply for various end uses (Agrawal, 2018).

Under the jurisdiction of the Los Angeles County Flood Control district, Measure W – the voter initiative which produced the tax increment – aims to help

communities comply with federal *Clean Water Act* standards with respect to discharges of runoff into receiving waters. Several regional projects are currently underway to enhance available water supplies for outdoor uses, wetland improvement, and irrigation of recreational parks and playing fields, many adjacent to local schools. Prior to its passage, some advocates claimed an additional benefit would eventually be “hands-on learning opportunities (that) could improve our County’s environmental science curriculum” – a not uncommon claim made for such programs (Barragan, 2018; Central LA County and Measure W, 2018).

Like metropolitan Los Angeles, Melbourne aggressively adopted enhanced rainwater harvesting methods in response to a water-related crisis: the Millennium Drought which lasted from 1997 until 2009. The city’s goal was to develop a series of distributed harvesting and use approaches to enhance resilience to drought and reduce its long-term vulnerability to climate change. While total rainwater harvesting accounts for around 3% of total annual water use, its deployment is critical because it serves as a substitute for expensive potable supply. Treated runoff is used to flush toilets and irrigate ornamental landscaping.

A regulatory innovation adopted in Victoria is of special note: a legal distinction between rainwater – defined as the capture and use of water falling onto roofs (and stored for household use in the ubiquitous rainwater tanks seen in residential neighborhoods in and around Melbourne) as opposed to stormwater. The latter consists of diverted runoff from land surfaces such as streets and parking lots, and which is subsequently treated for non-potable distribution throughout the city by local water purveyors. These systems have many co-benefits for human and ecosystem health and have even found their way into local uses such as irrigating gardens, sport fields, and golf courses (State Government of Victoria, 2014; Low et al, 2015).

The most significant issues arising from rainwater capture and use revolve around the fact that rainwater is both a potential resource and a pollutant source. Thus, important issues in regulating its safety include whether it can be used for groundwater re-charge without special pre-treatment; if risks of pathogens and microbes from, for instance, roof runoff can be effectively mitigated (e.g., National Research Council, 2012); and, whether different public health standards for treatment and end use in adjoining communities can be reconciled to permit the “same” rainwater to be cooperatively managed by two or more jurisdictions. These are difficult issues to resolve, as we will see.

While the importance of providing maximum protection of public health is widely acknowledged, varying regulatory requirements can pose barriers for capture and use. Regional health agencies may have differing guidance and requirements for treatment and direct use of captured storm-water. There may also be other environmental impacts that have not been fully evaluated. For instance, excessive capture of rainwater that routes it away from the original source of precipitation may disrupt local watershed processes and negatively impact the well-being of local ecosystems. In addition, unknown and difficult to detect pathogen and microbe risks from household (roof) runoff may be present. Moreover, in the case of the U.S., there are no national treatment standards for direct, non-potable water use, although efforts to establish such standards have been underway for some time (Hamel et al 2013; California Water Resources Control Board, 2017).

Demand-side innovations – overview

Innovations that promote water savings such as tools to measure and monitor water use, encourage demand management, and detect leaks are generally far less controversial than water supply alternatives. This is probably because they are less visible to the public and tend to raise fewer issues with regards to public health and

safety. Nevertheless, these innovations can prompt concerns over privacy, data access and security, and intrusiveness.

These concerns are most apparent in the advent of so-called smart water systems: the growing digitalization of water flows, water meter data, sound detection tools, and virtual cyber-platforms that can analyze, model, and even automate certain water distribution and management functions at the city or even district level (de Vitry et al, 2019). These systems can detect leaks, attenuate water pressure to reduce subsequent losses, and facilitate the implementation of distributed, highly-localized water and wastewater treatment networks to ensure more efficient potable reuse. Recent work in the application of Artificial Intelligence (AI) to the detection and treatment of contaminants of emerging concern in urban wastewater streams, and for more efficient energy recovery, are also proving to have wide application (Argonne National Laboratory, 2021; University of Chicago, 2020).

As with any advanced technology that relies on Internet-based platforms, a number of potential risks may arise, ranging from data breaches, cyber-attacks, and threats of sabotage to the security of water distribution and treatment systems. Moreover, a smart system capable of closely monitoring residential wastewater, for instance, can also – at least in principle – provide knowledge of drug-use patterns and other personal information that is difficult to totally anonymize and may be subject to flawed interpretation. Such concerns may deter public support for the collection of this information, and it may also impede efforts to share such data with others (de Vitry et al, 2019; Sussha et al, 2019).

To the extent that the public believes such smart systems provide greater water savings and expedient water loss detection, they may view these benefits as more important than potential losses of privacy. There is anecdotal evidence from Israel, for example, which

suggests that introduction of innovative technologies such as Distant Meter Reading, a tool that permits users and water agencies to intermittently monitor water use, are popular precisely because they lead to lower water bills as well as provide early warning of leaks. A culture that deeply values water savings given the climatological and security challenges Israel faces may partly explain such high levels of support (Siegel, 2017: 49-51).

It is likely that public confidence issues with regards to cybersecurity and water management will increase over time. One of the most thorough studies yet undertaken of cyber-threats to water utilities in the U.S., for instance, underscores a number of challenges facing these agencies. These include “ransomware attacks, tampering with Industrial Control Systems, manipulating valve and flow operations and chemical treatment formulations, and other efforts to disrupt and potentially destroy operations” (Germano, 2019:6).

Especially sobering are reports from both the U.S. Department of Homeland Security and Federal Bureau of Investigation which warn of targeting water and other critical infrastructure for financial, political or other aims with frighteningly potential impacts to public health and safety, operations, and service outages (U.S. DHS, 2018a, b). Such reports remind us of a factor which innovations that rely on so-called smart systems for ensuring water quality, enhancing the security of water supply, and monitoring water and energy use share with other, “hard infrastructure” innovations – the possibility of breakdowns in public confidence due to failures in these systems, as well as perceived incompetence in their management.

Water stress and water justice

As we have discussed, Freshwater availability is becoming severely strained due to increasing demands for food, fiber, energy, and potable water and disparities in natural freshwater availability across the globe. By 2025, half the world’s population will reside in areas defined as water-stressed (WHO 2017), with low-income countries

facing the greatest risk of severe, chronic freshwater shortages (Vorosmarty et al 2010). Climate change and infrastructure deficiencies exacerbate the severity of these stressors. Increased temperatures, changing precipitation patterns, greater concentrations of pollutants, and shifts in disease vectors are impacting water quality and quantity, especially where water demands agriculture and energy production are high (IPCC 2014). Moreover, these stresses vary considerably at basin-level scales, with some places subject to limited adaptive capacity due to population growth, path-dependent water policies, land-use practices that inhibit changes to agriculture, and microclimatic effects of such factors as runoff (Dolan et al., 2021).

Many countries are responding to these challenges by upgrading their water infrastructure and thus, improving access to freshwater. However, they are doing so through privatizing supplies, which enriches global engineering firms that build infrastructure, but may make the benefactors of the improvements less able to hold the purveyors of the water accountable. Aside from the many questions raised by privatization with respect to who ultimately controls innovative alternatives (a subject we later explore), privatization by itself does not fully address the challenges of clean water access, which remains inadequate. Nearly 800 million people worldwide lack updated sanitation. In many instances primitive latrines release human wastes directly to the environment because local as well as national governments simply cannot afford provision of centralized wastewater treatment. This fact partly explains why, despite progress on the sanitation front, over 80% of wastewater from human activities remains untreated (UN Water and Sanitation – Sustainable Development Goals, 2019).

One irony in this overall picture is that water use has also increased worldwide by about 1% annually since the 1980s, driven by population growth, economic development, and changing consumption patterns. According to the United Nations,

rising demand for water in the industrial, domestic and agricultural sectors signals that people are living better, thanks to progress in harnessing freshwater for growing food and fiber and for public, especially municipal, consumption (UN World Water Development Report, 2019).

How can both these conditions – an improving standard of living on the one hand, and declining potable water availability on the other, be explained? Two reasons are usually cited. First, more than 2 billion people live in countries experiencing extremely high water stress, and about 4 billion people experience severe water scarcity during at least one month during the year. For the most part, this is directly attributable to rising water demands (a sign of economic progress) and the worsening effects of global climate change (UN-Water Policy Brief on Climate Change and Water, 2019; Gleick et al, 2020). Water stress and scarcity are caused not only by hydrographic variability (e.g., climate-change) and demographic factors (i.e., growing and/or migrating populations), but by *economic and political* disparities. Many countries simply cannot afford to upgrade water infrastructure without external assistance.

Second, water infrastructure deterioration is not the only threat to water safety. Many of us dispose of drugs, personal care products, and other common household products directly into public water systems, placing extraordinary burdens on our wastewater treatment systems, as well as in some cases posing palpable yet difficult-to-detect risks to human and ecological health. Chemically-complex and commercially-utilized products ranging from fire-fighting foam to water-proof coatings for garments are also contaminating streams, lakes, reservoirs and other water supply sources, compounding these problems (Benson et al, 2017; Post et al, 2017; U.S. EPA, 2020). Thus, even when water supplies are adequate, their quality may pose health and ecological risks that undermine public trust and confidence.

This discussion points to another underlying challenge: water stress, while sometimes used as an inter-changeable term for “scarcity,” is a distinct problem related partly to physical shortage, but also tied to additional problems of quality, availability, and access. To effectively solve stress, regardless of the particular technical approaches one chooses to adopt, the role of *governance* is critical. In addition to selecting particular innovations, governance also determines the rules that regulate what constitutes an appropriate quality of water for various end uses; the levels of stress appropriate before the state intervenes to allocate, ration, or find additional sources of freshwater; and the methods of collaboration with private sector entities appropriate to develop supply alternatives. Figure 1.1, conceived by a consortium comprised of the CEO Water Mandate, Alliance for Water Stewardship, Nature Conservancy, Pacific Institute, World Resources Institute and others, depicts relationships among these various issues and sectors involved in water governance – and is instructive for our discussion.

Figure 1.1 about here

So, what are the implications of water stress and scarcity for the adoption of water innovations? Four consequences are especially critical. First, innovations are often promoted not by some inexorable logic of technological progress, but in order to meet the goals of international organizations that promote their adoption as means of achieving sustainability. All the non-traditional water supply and demand-management options we have discussed are being pursued, in part, to meet the UN’s Sustainable Development Goals (e.g., Jones, et; al, 2019). This political driver can be a double-edged sword.

On one hand, it entices decision-makers to adopt innovations that can attract international investment capital. This may serve as an incentive for commercialization of innovations by countries especially successful in developing them: like Singapore or Israel. On the other, it can lead to efforts to overlook or even actively suppress sources of potential

public opposition to such innovations for fear that decisions over water supply must be made expeditiously in order to satisfy urgent water needs – and so as not to deter financiers seeking a return on their investment. In short, water stress not only exacerbates water availability and magnifies efforts to pursue adoption of water innovations, it may also exacerbate environmental injustice by inhibiting opportunities for wide-scale public debate.

Second, the combination of stress-induced climate change and scarcity, economic challenges in securing means for alternative water supplies, and pressures to rapidly develop worsens mistreatment of women, who bear much of the burden of providing potable water supplies to families in developing countries (Kayser et al., 2019; Caruso, et al., 2016). In rural Mexico, for example, where some 5 million people lack access to clean water, women and children are principally tasked with collecting water for households. This activity takes time that could be better spent in school or in political engagement. Meanwhile, men decide how water rights are allocated – making access to clean, potable water a gender rights issue, and not solely a public health or economic challenge (Sustainable Development Goals Fund, 2017). While water innovations could become labor-saving measures as well as equitable means of provision, this can only be the case if all citizens have a voice in their adoption and implementation.

Third, as alluded to earlier, growing public concerns over the safety and security of their drinking water is a powerful constraint on the widespread acceptance of water supply innovations. The modern-day track record of many communities – even in developed nations – underscores the fact that some of these apprehensions are not without justification. The most recent and widely acknowledged case study illuminating these concerns is the case of Flint, Michigan. Residents of Flint, Michigan, whose trust in the safety of their drinking water has only been gradually restored after a notorious case of lead contamination that first

came to the public's attention in 2015, were advised in August 2019 to boil water as a precaution against impurities after a pipeline rupture reduced pressure in the city's water lines. The advisory ended after sampling indicated that there was no danger of contamination, but the city is still replacing lead and galvanized steel water delivery pipe (Olson, 2016).

The Flint case is especially significant because – as many analyses have shown – it resulted from an almost perfect storm of managerial incompetence (the claim that protective measures had been taken to avert the leaching of lead into water supplies, when no such steps had actually been taken), poverty and under-investment in infrastructure (the city's loss of population, jobs, and tax base eroded available resources to upgrade the water treatment system), and a failure of leadership and political accountability (the city's governor-appointment manager initially ignored citizen complaints, while racism exacerbated the disempowerment of many residents toward taking action) (see: Feldman, 2017; Izzeldin and Russell, 2017; Erickson, 2018).

Finally, water stress has sometimes led to extraordinary inefficiencies as governments have sought to cope with supply challenges in radical, even near-desperate ways. Two examples suffice to illustrate this. In 2019 residents of Chennai, India, had to queue up for water delivered by tanker trucks because the city's reservoirs were empty. Persistent drought, worsened by climate change, had virtually exhausted local supplies. The city, which is home to 7 million people, still faces severe shortages, and may exhaust its available groundwater within a few years (Aspinwall, 2019).

Coincidentally, Chennai has been one of India's centers for water privatization. In 1978, an autonomous water board, unaccountable to the city's government, and committed to so-called global "best practice" principles, and economic efficiency as its goal, was formed. Serving as the initial step in water privatization in Chennai (Coelho,

2006), the result was introduction of individual, tradeable rights over groundwater, and increased levels of unsustainable groundwater extraction. While privatization may not have caused Chennai's recent crisis, it is clear that it likely exacerbated it.

While Chennai's case is shocking, it is far from unique. In many ways, it seems to be only one of several harbingers of a larger systemic problem. Only three years ago, the "poster child" for climate-change induced urban water shortages was Cape Town, South Africa. This city of four million residents is still struggling to fully recover from its head-long rush toward a "day zero," when the metropolis was thought to have been on the precipice of a complete shut-off of its water supplies. A combination of aggressive conservation, the return of substantial rainfall, and a dedicated effort to harvest storm-water have, for the moment, averted Armageddon. Longer term, however, the region faces dire choices – and there is evidence of warning signs ignored.

Cape Town's water infrastructure has long struggled to keep pace with growing demands, and when the drought began, city leaders merely advised residents to become "water aware." Over 25 years ago, a government-sponsored Water Research Commission recommended building a wastewater reuse plant as a hedge against local reservoirs becoming depleted in a future drought. Plans were launched to make the city more resilient by diversifying supplies with wells and small desalination plants. These were not slated for completion until after 2020. Moreover, while flagrant water wasting actions have been banned, the city dropped a proposed "drought levy" to fine the worst abusers, and a lack of coordination between national and provincial officials has not helped matters any.

Provincial officials blamed the African National Congress for not building more infrastructure. However, local officials did not recognize the impact of rapid population growth (Cape Town's population has doubled since 1999) on the depth of the crisis. to

re-assure citizens rather than taking more forthright action. An important take-away from both these cases is the recognition that no “new” water is probably to be had – technological innovations such as de-salination and wastewater re-use are likely to be aggressively adopted (see Chapter 3).

To address these challenges, it is not enough to adopt water innovations in order to abate water stress and slake our planet’s growing thirst. We must embrace public concerns over the perceived risks emanating from these innovations and establish a satisfactory institutional foundation for their governance. This foundation must be able to effectively manage risks and, as mentioned previously, allow for a sharing of authority in their management. Experience with water innovations globally has been instructive in highlighting the need for policy-makers to engage relevant stakeholders in adopting innovations; ensure they are operated with appropriate consideration for public concerns over health, safety, and community well-being; and, manage them in a politically-accountable manner.

The Argument Going Forward – framework of analysis

Chapter 2 introduces a framework for understanding four key issues underlying public acceptance of water innovations and their appropriate governance. The framework consists of four components: technological feasibility, economic costs and benefits, health and environmental risks, and public trust, confidence, and accountability. In analyzing innovations through this framework, we pose – and seek to answer – three fundamental questions: (1) what societal conflicts do innovative approaches engender under each of these categories? (2) What are the benefits and burdens of each alternative that can be clearly discerned? And, (3) What social equity issues arise from the adoption of an innovation?

Chapter 2 also examines the overall promises and pitfalls of water alternatives by providing illustrative examples from the domains of desalination, effluent reuse, rainwater harvesting, and demand-side innovations – a discussion of where, how, and why these

options have been introduced and the problems they face. The overall theme of this chapter is that solutions to water supply problems are themselves problematic with respect to feasibility in some applications, direct user costs, possible health and environmental risks, and public acceptability, trust, and confidence.

Chapter 3 examines the concept of water governance by examining the evolution and current role of governance arrangements in providing and managing freshwater – including providing historical perspectives. Governance is composed of political institutions; laws, regulations, and practices; and, the constellation of non-governmental organizations and other beneficiaries of water supply that collaborate to choose and co-administer water supply options. We show how water governance includes not only formal organizations and behaviors that exercise authority for decisions, but the ideological and other motivations that animate protagonists involved in collaborating in making and implementing water management decisions through various means. We call these components of governance power, process and purpose. Case studies of Israel and Singapore are offered as examples displaying these important elements of governance applied to water innovations. These cases are intriguing because they also show how concerns with water security can take priority over demands for sharing authority for innovation management.

Chapter 4 discusses *adaptive governance*, an form of oversight that operates by more inclusive and equitable principles. We contend that this form of governance is needed to effectively manage water innovations in ways that optimize public trust and confidence. This is also true, at least in some instances, in polities that generally embrace water innovations, particularly when site-specific issues arise over their deployment. With its emphasis on collaborative engagement between state and non-state actors so as to integrate specialized and local knowledge, overcome distrust and lack of confidence in institutions,

and render decisions that can be modified in the light of experience, adaptive governance is well-suited for managing water innovations.

We discuss critical features of adaptive governance including mechanisms for collaboration with civil society groups, reliance upon local as well as expert knowledge when introducing innovations, and its reliance upon social learning: learning from error and adapting to evolving public concerns. Australia and California offer intriguing illustrations of the various ways adaptive governance can be employed in fostering innovation acceptability, and the challenges in making it consistently work well.

Chapter 5 examines the issue of public acceptability as a critical factor in water innovations. Contending that acceptability is comprised of three variables: trust in innovations and their management; confidence in those who manage innovations; and engagement with communities and co-participation in innovation management, we argue that public approval must be sought through an inclusive and continuous process of negotiation and communication. We examine the various demographic, social-psychological, and institutional factors that facilitate – as well as inhibit - public acceptability. These include the extent of community support for the decision-making processes by which innovations are adopted; the proposed end-uses for the water derived from them; the perceived complexity of the innovation; and the role of gender, income, education and knowledge, and perceived risk. A series of vignettes from the U.S., Mexico, Brazil, Thailand, Australia, and Sweden illustrate the relevance of social acceptance in water management generally for the governance of water innovations, while one extended case study of China reveals how all these factors: demographic, social psychological, and institutional, interact to explain how water innovations are often implemented and the limitations which social acceptance place on their overall effectiveness.

Finally Chapter 6 looks at future prospects for water innovations, principally through the lens of what we earlier defined as the hydro-social contract: the assumption that law, sound engineering, and good management assures the safety of public water supplies. What do these efforts to introduce and manage water innovations teach us about the future of this informal contract? Is this contract valid? We will contend that four lessons are especially critical. First, decentralized and distributed governance based on a ‘bottom-up’ approach to engagement is important for granting legitimacy to this contract – particularly in those places where public opposition toward various alternatives remains high. Second, no single set of interests must be seen to dominate the “narrative” surrounding an innovation and its management. If an innovation is seen as empowering or strengthening one faction in a community at the expense of others, public confidence will be eroded.

Third, marginalized social groups must be brought into conversations and decision-making (e.g., the Monterey Bay desalination case). And lastly, while innovations must be viewed as supporting water *resilience*, resilience is *socially constructed* and shaped by the dominant values, attitudes and aspirations of a polity. Thus, not only must an alternative be viewed as capable of meeting a variety of community water needs, it must also be seen as providing security in the face of climate variability or other stressors, having a low probability of failure, and as being an appropriately governed remedy.

In sum, all water alternatives have distinct benefits and drawbacks including variable costs; different rates of energy consumption; distinctive environmental, health, and quality of life impacts and risks; and, varying degrees of public confidence and trust. Rather than look for the “best” option, a fundamental lesson from water innovation governance experience is that successful implementation of any set of water alternatives will likely coalesce around what stakeholders view as the most adaptive and resilient solutions. Such solutions are unlikely to be found in a single option. There are no panaceas. No single approach can

address all water supply needs, or overcome every objection. Instead, any desirable approach must ensure a low probability of failure by relying on flexible, multi-pronged solutions that generate few negative consequences, conserve resources (e.g., energy), and incorporate lessons – including failures. – from previous experiences. This is a lesson, as we will see, that emerges from the experiences of many polities, including those that widely embrace innovations as well as those more reluctant to do so.

Prospects for resolving water scarcity lie at the heart of efforts to address many of our planet's emerging conflicts over food, energy, immigration and regional security. Many, as yet unanticipated, problems may arise as our needs for freshwater grow, and as our prospects for satisfying these needs in conventional ways (e.g., the continued diversion of rivers and over-drafting of groundwater basins) diminish. We must be prepared to introduce institutional approaches that permit amicable resolution of the conflicts that newer innovations might generate. Without governance methods as equally innovative as the water alternatives themselves, disputes over their possible introduction may prove intractable to amicable resolution. This would be a loss for many and a gain for no one.

CHAPTER 2 – SOLUTIONS AND PROBLEMS – THE PROMISE AND PITFALLS OF

WATER ALTERNATIVES

Why are new water alternatives needed?

Like other Persian Gulf nations, the United Arab Emirates (UAE) – about the size of Maine with a 9.7 million people – has little freshwater. Although having no natural rivers, the UAE possesses a thriving economy fueled by petroleum and natural gas. Thus, freshwater innovations, though costly, are affordable (Embassy of the UAE, 2020). Almost all the country's potable water is produced by desalination: its scant groundwater supports agriculture.

Despite reliance on desalination, the emirate of Sharjah – the most populous part of the UAE outside of Abu Dhabi – is seeking to up-its-game on wastewater reuse for two reasons. First, its current recycling plant uses one-fourth the power of an equivalent desalter, producing freshwater at 20-30% lower cost while generating less pollution and fewer greenhouse gas emissions. Second, having lower salt content, its water can satisfy such uses as district cooling, steel production, and chemical and ready-mix concrete making. A public-private partnership has launched plans to expand the treatment facility, which collects wastewater from throughout Sharjah. In addition to producing high-quality water, biogas and biosolids can be re-cycled.

While technically feasible and environmentally beneficial, however, wastewater reuse faces two major hurdles: the infrastructure needed to convey the water to end-users is expensive to deploy and “the human psychology . . . reinforced by our cultural background discourages its adoption,” according to Gurvan Dersel, the General Manager at Qatra Water Solutions – the private partner working with the government on plans for expansion of reuse. Can these problems be overcome? Emulating Singapore and Orange County California, where wastewater reuse systems have been in operation for years, Qatra is betting on a supportive legal framework

and public outreach to convince skeptics that, given the region's water scarcity, reuse can become a publicly acceptable, as well as economically viable, alternative (UAE's Qatra, 2020).

UAE's situation is instructive for understanding the politics of water innovations for two reasons. First, engineering feasibility and environmental sustainability do not necessarily make desalination, wastewater reuse or any other alternative acceptable. The cost of a project and its ability to garner public support are also important factors. Second, technical feasibility is itself a variable, not a constant. Even a widely-used technology needs to be improved to remain competitive and to alleviate newly-arising economic, risk-related, or other concerns.

Worries over energy consumption, and long-term water cost, led the UAE to rethink its reliance on desalination in the first place. Improvements in desalination aim at improving efficiency, especially with respect to the performance of reverse osmosis membranes, the principal technology used in contemporary desalination plants, and seek wider introduction of energy recovery technologies. These innovations are dramatically reducing energy consumption for seawater reverse osmosis (SWRO) plants everywhere. In fact, they may eventually result in desalination becoming no more energy intensive than transport of water from Northern California through the Sacramento-San Joaquin Delta southward (Birkett, 2011).

Even so, the UAE's concern with salt-content and thus, limited feasibility for end-uses with desalination, remains a not-yet fully resolved technical concern. Moreover, its quest for additional alternatives reminds us that the technical feasibility of any water innovation is insufficient to *alone* ensure its acceptability. Cost and affordability, capacity to foster resource renewability, ability to overcome perceived risks to health and the environment, and public acceptability are also essential issues that must be satisfactorily addressed.

A Framework for Evaluating Water Innovations – the goal of resilience

As we have seen, the impetus for adopting freshwater innovations is the growing threat of water stress from numerous sources, including global climate change, competition among polities over shared surface- and groundwater sources, threats to water quality, and sub-standard infrastructure. Collectively, these stressors threaten water supply *resilience* – the ability of a provisioning system to withstand and recover from shocks and disruptions caused by climate change or other stressors, while still being able to retain its operating advantages (Ahern, 2011; R. R. Brown et al., 2009; California EPA, 2015; Dobbie et al., 2014; Haimes, 2009; Holling, 1996; Kiparsky et al., 2013).

Studies of water resilience usually focus on the sustainability of large, complex water systems and their hydrological characteristics. Resilient systems are thought to possess three traits: adaptability to changing conditions (e.g., climate change), persistence (a capacity to withstand hydrologic and political adversity), and transformability (the ability to absorb new functions and respond to unforeseen needs) (e.g., Boltz et al, 2019). Studies spotlight macro-scale analyses: river basins or watersheds. While appropriate for illuminating many problems, this preoccupation tends to ignore the role played by specific measures in contributing to macro-scale sustainability (e.g., can stormwater capture enhance water supply adaptability?). It also overlooks the contributions a given remedy may make to the water supply needs in a particular region (e.g., can desalination become both energy-efficient and dependable?)

In response to these concerns, some analysts have begun to focus on resilience from the vantage point of spatial-decentralization. They contend that the most resilient water supply systems are distributed networks that are relatively immune to catastrophic failure: community-based rainwater collection systems, for instance. Others maintain, and in some cases have

developed models demonstrating that, regardless of whether a system is distributed or highly-centralized, major keys to resilience are innovations that: (1) recover energy and transition to renewable low-energy water sources; (2) combine demand-management with supply enhancement; (3) fortify water infrastructure; and (4) conserve or reuse water (Finansyah and Hadi, 2009; Grant et al., 2012; Lafforgue and Lanouvel, 2015; Rice University, 2020; Liu et al, 2020; U.S. EPA, 2021).

There are merits in both approaches. Decision-makers choosing between them (or who seek to combine them) desire innovations that make their polities water resilient. In doing so, they implicitly seek innovations viewed as more beneficial than costly, and whose risks can be safely managed. While some centralized approaches may achieve this goal, so might more distributed approaches. Table 2.1 depicts the four criteria earlier mentioned that must be satisfied to make an option resilient. The following sections consider each of these criteria in detail, how major innovations measure up to them, and challenges each innovation faces.

Table 2.1 about here

Technical Feasibility of Water Innovations

Every major water innovation is technically feasible. All of them have been extensively implemented and performed at a level sufficient to engender confidence on the part of engineers, vendors, public officials, and at least some end-users. Nearly 16,000 operating desalination plants produce around 95 million m³/day of freshwater for human use. Some 48% of this total is produced in the Middle East and North Africa – underscoring the attraction of the technology in water-stressed regions (Jones et al, 2019).

Wastewater reuse and stormwater harvesting are also widely practiced, but account for far smaller volumes of total global freshwater use. Reuse accounts for less than 2% of total

freshwater use, while some 80% of all wastewater globally is still discharged – untreated – into the world’s rivers and estuaries (UNOCHA, 2018; IWA, 2018; Why the World Needs to recycle its wastewater, 2021). Storm-water harvesting, while popular in some regions, has not been widely adopted due to storage challenges, the need for treatment before use in many applications, difficulties in calculating the benefits and costs of infrastructure, and barriers to public acceptability (Goonetilleke et al., 2017; Akram et al, 2014). Despite their technical feasibility, all innovations face continuing challenges with regards to reliability and performance. Moreover, innovation vendors and engineers aim for continuous improvement in design and operation to remain competitive. And, as we will see, economics, risk management, and public acceptance remain key adoption issues.

Economics of Innovations – efficiency, equity, and the burden of cost

There is a long, venerable, and sometimes contentious tradition of weighing benefits and costs of water supply options. Contentiousness stems from the fact that agencies responsible for building water infrastructure have at times been accused of improperly applying benefit-cost analysis, fail to adequately compare different approaches to solving the same problem, and assume that water projects always generate net gains to society (Feldman, 1995; Downing, 1984). Such criticisms – warranted or no – have been levied upon desalination, reuse, and stormwater harvesting projects. Nonetheless, if used appropriately, benefit-cost analysis illuminates the life-cycle costs, benefits, and tradeoffs among options.

The cost of any water supply alternative is always weighed by water resource planners against its potential benefits. In recent years, due to increased recognition of the long-term financial commitment entailed by any alternative, life-cycle costs are also considered in decisions, raising questions as to what actually constitutes an innovation’s “cost,” including

deferred expenses. Who bears these costs is also important. While the economic costs and benefits of a water innovation are of central concern to water agencies, they also impact end-users. The latter is especially the case when communities institute economic incentives to induce demand-reducing behaviors, such as switching to drought-tolerant landscaping and xeriscaped yards and gardens (Hanak et al. 2011). Because these measures face urban design and zoning hurdles, incentives must be coordinated with local regulations to ensure that incentives are attractive to end-users being enticed to adopt these strategies.

Innovation Risks to public health and environmental quality

All water sources, unless they have been treated to a level of purity that reduces the potential for biological, physical, or chemical contaminants, harbor some element of health and/or ecological risk. As noted in Chapter 1, polities in all but the most remote or impoverished regions of our planet, have introduced methods to ensure that such contaminants are detected, treated, and effectively removed – or at least reduced to levels of concentration that pose little or no concern. In poorer regions water quality issues remain a critical public health threat.

There are two important challenges with respect to the governance of health and environmental quality risk relevant to water innovations: *public confidence* in the competence of those who implement them; and the *level of trust* reposed in the protection standards adopted by public agencies that regulate them. The recent Covid-19 pandemic underscores these twin challenges with respect to public confidence in water agencies and trust in potable water regulation more generally (Hanak et al, 2020). Growing threats posed by contaminants of emerging concern (see Chapter 1) add to these challenges.

The perception that governments have failed to act to adequately address these \ threats indirectly affects public perceptions of freshwater supply alternatives. As summarized by a National Academy of Sciences report on graywater and wastewater reuse:

“Despite the benefits of using local alternative water sources to address water demands... many questions remain that have limited the broader application of graywater and storm-water capture and use. In particular, limited information is available on the costs, benefits, and *risks of these projects*, and beyond the simplest applications, many state and local public health agencies have not developed regulatory frameworks for full use of these local water resources” (NAS, 2016: 1).

The mere fact that an innovation harbors some risk is important. Equally important is the perceived availability of means to manage that risk, as we will see. The public will more readily accept a technology viewed as manageable risks.

Public Acceptability of Innovations – Trust, Confidence, Engagement

Many of the issues most salient to lay audiences, whether they be potential consumers of water, rate-payers who fund innovations, or elected officials whose decide to adopt them, are shaped largely by perceptions influenced by the degree to which one is engaged in decision-making. The public must feel welcome at the table where important decisions are discussed, and experts promoting innovations must reach out to various end-users and embrace a wide range of cultural, social, and ethical concerns regarding freshwater and its management (Feldman, 2017).

The most important issues shaping public perceptions are concerns for safety and equity. The belief that an innovation is being applied fairly is essential in ensure that water innovations meet the needs, and overcome the often overlooked concerns, of under-served populations. In water stressed regions, users from diverse social, economic, and demographic backgrounds often

demand that decision-makers engage their perspectives when making decisions regarding innovation adoption. These demands revolve around assurances that innovations are managed with due consideration for health, safety, rate-payer cost, and community well-being, and that proponents are not targeting under-represented communities presumed to have little power to oppose them (Hurlimann and Dolnicar 2010, Dolnicar et al 2011, Linton and Budds 2014, Harris-Lovett et al 2015, Oglesby and Delgado 2020).

Ideally, innovations must also be managed and implemented in ways that conform to sound engineering principles as well as good management practices. As noted in Chapter 1, equity embraces the need to address public concerns through effective risk communication and risk management protocols and procedures. Experience shows that under-represented groups especially want an interactive exchange of views regarding potential risks from any innovation; accurate information explaining how risks are managed; and, assurances that communities can independently monitor any risks (Hadden 1989, Renn and Levine 1991, Mileti et al. 1994, Ng and Hamby 1997, Gross 1994; Environmental Justice Coalition 2005).

Desalination as a Resilient Water Innovation

While various modes of desalination are reputed to have their roots in antiquity, a commercial-scale desalination industry first began in the 17th Century with the issuing of patents for economical desalting methods in the United Kingdom (Williams and Swyngedouw, 2018: 3). To a greater extent than for other water innovations, desalination's technical advancement and penetration into water supply portfolios have benefitted from government-sponsored research, development, and demonstration (RD&D) efforts – particularly in the U.S.

A noteworthy example is the work undertaken at one national laboratory (Oak Ridge, Tennessee), supported by the Office of Saline Water in the Department of the Interior, to

develop high-efficiency reverse osmosis membranes in the early 1960s. Another example of ambitious desalination work at this same laboratory was the far more ambitious but unfruitful effort to wed nuclear reactors to desalination plants to supply copious amounts of water for food production in developing countries –agro-industrial complexes or NUPLEXs, as they were dubbed (Johnson and Schaffer, 1992: 128-9; also, Williams and Swyngedouw, 2018: 4).

Today, energy consumption and the potentially adverse impacts of brine disposal remain major technical hurdles. Efforts to address the first of these issues range from improvements in renewable energy applications to employment of energy recovery systems and advancements in membrane technologies for reverse osmosis (RO) (Terlecki et al, 2011; Qin et al, 2012; Cath et al, 2006). Technical developments to improve RO efficiency include more effective membranes and greater use of energy recovery devices. Newer membranes have a higher *flux* (i.e., a higher rate of water flow per unit area), improved salt rejection, and longer service life. Because pumps are responsible for more than 40% of total energy costs at most desalination facilities, efficiency improvements such as positive displacement pumps – useful in smaller applications – help make desalination more cost-effective in some locales (Gadetor et al, 2019). The importance of energy consumption in desalination is illustrated in Figure 2.1, which depicts the various energy inputs entailed in a typical seawater reverse osmosis (SWRO) plant.

Figure 2.1 about here

A more daunting technical challenge, especially in SWRO systems, are fouling and clogging from sea life in raw feed waters. These can form surface films retarding heat and mass transfer, and cause partial or complete blockage of flow paths. Surface films also increase corrosion or disturbances in flow paths, leading to cavitation and pitting of machinery. Biocides such as chlorine may damage membrane materials such as polyamides. Some species can even

degrade plastic materials such as cellulose, used in some RO membranes. Chemical and physical methods to avert these problems add to desalination costs. (Birkett, 2011: 12; Cote et al, 2005).

Brine disposal remains a serious environmental issue, especially for coastal desalination plants. Brine management efforts comprise from 5-33% of desalination's total cost (Ahmed et al., 2001). Research aimed at finding ways to improve brine disposal – and reduce these operating costs – has focused on reducing the volume of RO concentrates and their pollutant load, and identifying ways to beneficially reuse brine through isolating salts and recovering other commercially useful by-products (Perez-Gonzalez et al, 2012). The latter has proven to be an especially difficult challenge involving employment of several complex and expensive processes to ensure that brine can be used in industrial applications. The cost of these processes may be compensated for by the value of the products derived from brine, especially harvestable metals (Morillo et al, 2014), but this has not yet occurred on a large scale.

Some technical feasibility issues have yet to be entirely resolved. According to the *International Desalination Association*, a United Nations affiliated NGO, while:

The principal technologies used in desalination are based on concepts that are fairly easy to grasp by those with a modest amount of scientific training and/or technical experience. In practice, however, choices of technology and plant design are usually determined by factors that might appear minor to the inexperienced. Similarly, new technologies that show great promise in the laboratory frequently fail for reasons that were earlier overlooked or dismissed as trivial (Birkett, 2011: 4).

This gap between promise and performance is exemplified by the evolution of reverse osmosis membranes. Until the early 1960s, no membranes existed with suitable water permeability, salt rejection, and mechanical properties to permit high-efficiency seawater

desalination. This changed with development of fabrication techniques to produce cellulose acetate film having what is termed a graded or *asymmetric* pore structure with relatively large pore diameters on the side of the membrane away from the feed water, and which taper down to a virtually continuous surface where they meet the feed stream.

This technology permits passage of more soluble water molecules across the active surface, while the tapered pore structure provides mechanical support against pressure. Further research has concluded that the optimal configuration for such a high-performing membrane is the so-called spiral-wound membrane – now the most widely used approach to RO. However, this innovation was preceded by commercialization of flat sheet, tubular, and hollow fine fiber membranes (See: Birkett, 2011). Figure 2.2 depicts the spiral element membranes in use today.

Figure 2.2 about here

Another innovation that may promise improved performance is “forward osmosis” – a process that uses a semi-permeable membrane to separate water from dissolved solutes. Forward osmosis uses a “draw solution” with a relatively high solute concentration. It is claimed that constituents of the draw solution can be separated to produce pure water, while the draw solution can be reused. Drinking water forward osmosis systems are not yet commercially viable (Qin et al, 2012). Commercial forward osmosis systems are expected to have lower operational and maintenance costs than reverse osmosis systems. Energy use and fouling are greatly reduced as the water is drawn, rather than forced, through the membrane (Cath et al, 2006). Membrane fouling, which reduces treatment efficiency in a typical reverse osmosis system, is avoided in an unpressurized forward osmosis system.

Improvements to membrane technologies for SWRO can also reduce the need for post-treatment of unwanted contaminants, helping further reduce the capital costs of SWRO plants

and increasing the usefulness of their product water. To ensure that desalinated water can be safely used on crops, post-treatment to reduce boron and chloride levels is required. Thin-film composite membranes with higher selectivity, particularly for boron, may solve this problem. However, developing these membranes has been difficult (Elimelech and Phillip, 2011: 717).

Further technical innovations are so-called “small-scale” (i.e., less than 100 m³ per day of water produced) plants. Widely-used in Saudi Arabia and the United Arab Emirates (UAE), these plants, generally using RO technologies, hold several advantages. Being small in scale, they can be installed in a modularized and incremental manner as determined by the needs of industrial end-users, inland and coastal development projects, and isolated “off-the-grid” communities in arid regions (Song et al, 2017: 2). They are cheaper to build and maintain, and being decentralized and distributed, more likely to draw on local energy sources, more easily harmonized into a network of other water sources, and useful for desalinating brackish- as well as seawater. However, they are not as efficient with regards to economies-of-scale. Their energy input costs remain high relative to the water volumes they produce (Song et al, 2017: 12).

Energy innovation offers another technical improvement. *Solar stills* for producing freshwater from brackish or seawater in remote, isolated areas, and other renewable energy sources for desalination are valuable innovations. Overall costs of conventionally-powered desalination systems are lower than for renewable sources largely due to the higher volumes of water the former can produce, and the maintenance costs required by renewable energy. Currently, worldwide renewable energy desalination installations amount to capacities around 1% of that for conventional, fossil fueled desalination plants (Hetal et al, 2014). In regions with abundant sunshine such as the Middle East, local water demands, and adoption of RO technologies may make renewable-energy generated desalination cost competitive. In severely

water-stressed regions such as Gaza, it also harbors the potential for assuring water security (Shatat and Riffat, 2012; Hamdan et al, 2008).

Despite technical improvements in membranes, plant reliability, and operational performance, the cost of desalinated water remains generally more expensive than freshwater from other sources. A basic reason for this is the large amounts of energy required in the desalting process. Energy consumption accounts for anywhere between one-third to more than half of total operating cost for a typical reverse-osmosis RO plant – the most common desalination approach (Chaudry, 2003; National Research Council, 2008).

Energy consumption rates are partly dependent on whether an RO project serves as a low- or high salinity plant: in other words, whether it is designed to remove salts from brackish water sources (BWRO) with lesser degrees of salinity, or from highly-saline seawater (SWRO) – belying the site specific drivers of cost. The latter are more energy intensive and thus, costlier (Voutchkov, 2013; Reddy and Ghaffour, 2007: 341). Energy requirements for desalination plant configurations employing non-RO technologies are generally higher. The energy consumption of thermal seawater desalination plants, a less used technology, accounts for nearly 60% of the cost of the water they generate. Translated into consumer prices, this means that, in general, a 25% increase in energy cost increases the cost of produced water by 9% and 15% for reverse osmosis and thermal plants, respectively (Wangnick, 2002). Not only are RO plants more energy efficient, but they are more reliable. Thus, their per-unit water costs are lower (Mansour, 2016). This is a principal reason large membrane plants have been widely built worldwide.

In Australia, for example, several analyses have concluded that desalination makes economic sense for coastal and water-scarce inland communities, especially as a result of the Millennium Drought and its huge demands for substitute water. Because RO is comparatively

economical, it has become the preferred choice of water providers. Similar conclusions have been derived in other contexts as well, most notably China, largely due to RO's lower investment costs, operational ability at low to moderate pressures, environmental advantages when compared to diverting ecosystem-stressed rivers, and proximity to coastal urban areas (Winter et al, 1998; Saliby et al, 2008, Hetal et al, 2014; Bashitialshaaer and Persson, 2013).

Other illustrative examples are the Tampa Bay SWRO plant – the largest membrane desalination plant in the U.S. when it came on-line in 2003 (with a build-out capacity of capacity of 35 MGD), the Carlsbad desalination plant in Southern California, with a capacity of 50 MGD (which went on-line in December 2015), and Israel's Ashkelon SWRO, commissioned in May 2005, with a capacity of 88 MGD. When the owners of these three facilities comparatively evaluated alternatives, SWRO provided the most cost-effective solutions given the full-range of considerations water agencies, government overseers, and private investors were concerned about: capital expenditures, operation and maintenance (O&M) costs, and cost per 1,000 gallons of treated water based on 20 – 30 years of operation (Frenkel, 2011).

Another economic aspect of desalination is its affordability. This is an issue affected by difficult-to-predict factors such as future energy prices and sources and likely water demands within a region (Al-Mutaz, 2000). As discussed in Chapter 1, developing country efforts to achieve universal access to clean water and proper sanitation through legal, institutional, and regulatory reform face formidable barriers – not the least of which is poverty, a paucity of funding sources, and the inequity of having the poor pay the total cost of innovations that provide them with freshwater. Where does desalination fit into this picture? Can its cost be justified in order to make this option tractable in less developed societies?

A growing body of research suggests that small scale, renewable-energy driven

desalination technologies might economically meet local needs in developing countries. In central Java, Indonesia an array of approaches have been proposed combining communal service systems where water is pumped through reverse osmosis filters for brackish groundwater desalination via wind-power. In some communities, this approach is supplemented by solar still technology using household roofs as mini-desalination plants (Finansyah and Hadi, 2009). A half-dozen or so small- to medium-size solar powered RO desalination plants are found in Italy, Japan, Indonesia and Italy producing between 35,000 and 200,000 liters of freshwater daily, while a handful of other solar- distillation facilities are located in the United Arab Emirates, Saudi Arabia, and elsewhere (Lee and Younos, 2019).

Another study found that wind-generated desalination might be practical in other developing countries, including: Barbados, Cape Verde, Egypt, Haiti, Libya, Madagascar, Mauritania, Morocco, Saudi Arabia, South Africa and Yemen – and at least two wind-powered desalination plants are currently on-line; one in Western Australia, the other on a Baltic island in Germany that each produce between 12,000 – 30,000 m³ of freshwater daily (Lee and Younos, 2019; also, Spang, 2006). A stand-alone study of Oman, a country still widely-dependent on groundwater, has found that small-scale solar-thermal desalination facilities in rural areas, combined with gas-turbine plants for additional power, could satisfy growing freshwater demands. Dedicated government financial subsidies would be needed, however (Bhambare et al., 2018). Prospects for public-private partnerships also affect affordability. A study of desalination in Saudi Arabia found that a strong commitment to such partnerships can remove the fiscal burdens of desalination, together with prudent public outreach to encourage per capita water conservation, smarter pricing structures to discourage profligate water use, and reliance where possible on renewable energy (Ouda et al, 2018).

As noted earlier, the ecological impacts of desalination are noteworthy concerns. All desalination plants produce copious amounts of brine which contain heavy metals and concentrated salts. The ecological damage these brines can inflict on near ocean ecology, after they are disposed through brine lines extending back into the sea, has been widely documented. In the Mediterranean, for instance, scientists have expressed apprehensions over the impact of brine on *Posidonia oceanica*, the most abundant sea grass species in the region, and which is especially sensitive to brine. *Posidonia oceanica* is an important undersea “meadow” ecosystem, serving as habitat for numerous aquatic species.

While brine dilution has been widely adopted as the favored means of disposal, a growing consensus has urged alternative – and costly – measures including deep well injection, evaporation ponds, discharge into surface water bodies further inland, and concentration into salt solids and even irrigation of plants with high salt tolerance (Morillo et al 2014). As noted in our earlier discussion on the economics of desalination, recovery of precious metals and other products may, over time, compensate for these costs. In the meantime the full environmental impact of disposal alternatives has yet to be examined. One pioneering study, focused largely on the energy impacts of brine disposal alternatives, suggests that challenges vary by technology. For solar evaporation, large land-disposal area is required, while thermal brine concentration is highly energy intensive and, thus, costly. Alternatives that produce zero liquid discharges would provide a near ideal solution, if recovery of desired by-products could compensate for cost. This is a goal lying in the future (Perez-Gonzalez et al., 2011: 280).

Other impacts from brine discharge include direct effects on marine fauna. Certain types of habitat and organisms are especially sensitive, including “rocky habitat and kelp beds (that) are particularly rich, sensitive ecosystems” such as those found off the California coast (Cooley

at al., 2006: 65). As one review of the extant literature notes, at length:

“(b)enthic organisms in the immediate vicinity of the discharge pipe. . . . are at the greatest risk from the effects of brine discharge (including) crabs, clams, shrimp, halibut, and ling cod. Some have limited mobility and are unable to move in response to altered conditions. Many benthic organisms are important ecologically because they link primary producers, such as phytoplankton, with larger consumers Additionally, juveniles and larvae may also be at greater risk (Cooley et al, 2006: 65).

The magnitude of these risks varies by underwater topography, temperature, ocean currents, plant operating volumes, and other site-specific factors, under-cutting generic remedies. *Impingement* (encroaching on species and their habitat) and *entrainment* (capture of some aquatic species through the intake structures of seawater facilities) are other ecological risks of desalination. Studies suggest that impingement and entrainment remedies can minimize adverse risks if adopted in combination. These measures include deep offshore environmentally friendly submerged intakes, co-located intakes, low through screen intake velocities to permit aquatic organisms to literally swim away, employing small openings into intake structures to prevent larger organisms from being captured, beach and coastal wells, and passive intakes (Voutchkov, 2013: 139-140; Birkett 2011). None of these remedies is a panacea, however, and some argue that both issues pose under-studied and under-evaluated risks (Colley et al 2006). In sum, while some risk to sea life is a normal part of seawater desalination, sub-seabed horizontal intake provides a degree of pre-treatment filtration while causing minimal entrainment of marine organisms (WHO, 2007, Peters and Pinto, 2006).

Human health impacts warrant greater discussion because of the numerous and wide-

ranging risks via various environmental pathways that can affect air as well as water quality. As a starting point, we begin with the health risks posed by desalinated water itself. The desalination process usually provides a barrier to pathogens and chemical contaminants. However, treatment interventions related to stabilizing and re-mineralizing product water can pose special problems (WHO, 2011: 5). The addition of corrosion-inhibiting chemicals comprised of silicates, orthophosphate or polyphosphates may contain contaminants-of-concern. Moreover, some pathogens, such as *Vibrio Cholerae*, survive well in saline waters while some marine algae produce toxins injurious to human health.

The World Health Organization, which serves as the de facto human health standard-setting body on many of these issues, prescribes monitoring and assessment, careful selection of materials used in plant construction to inhibit growth of microbes and biofilms, and adopting state-of-the-art procedures and regulations to inhibit microbial or chemical contaminants from entering potable supplies in drinking water systems (WHO 2011: 9, 15-17). The chemical separation and post-treatment aspects of desalting processes also pose risk. These include exposure to pre-treatment chemicals used to forestall corrosion and introduction of biological or chemical contaminants (Cooley et al, 2006; World Health Organization, 2007).

Boron and Bromide – found in desalinated water at levels higher than those present in conventional water sources – can affect the yield, size, and color of citrus fruit, while bromides produce unpleasant smell and taste in potable water. As noted in chapter 1, Israel, Cyprus, Qatar, Bahrain, the UAE, and in the U.S. – California – have established drinking water limits on boron. In the later, inclusion of health risks and means to mitigate them are required in environmental assessments for project licensing (Voutchkov, 2013: 96; Cooley et al., 2006: 80).

Whether such assessments are adequate for placating public concerns, however, is

another matter. The public acceptability of desalination is a two-sided coin: for those to whom the urgency of a safe, secure, and dependable water supply is paramount, this option may not only be highly preferred but even enthusiastically embraced. For those who view its potentially adverse risks as more important than its potential benefits, enthusiasm and support may be considerably lower. A few examples will serve to amplify these points.

While the economics of applying renewable energy to desalination are not yet favorable on a global scale, local conditions may still favor its application, particularly when weighed against other priorities. This may enhance desalination's public acceptability. The experience of Gaza demonstrates this principle. Faced with dire water shortages, prolific groundwater pollution and over-extraction, dependence on Israel for 5% of its potable water, and most of the remainder provided by vendors who desalinate saline, brackish well-water, the region's two million residents urgently seek a resilient water source (von Mendeazza, 2019).

Through European Union funding and UNICEF support a large RO facility that desalinates groundwater has been constructed in southwest Gaza and currently serves some 75,000 residents of Khan Younis and Rafah. Because electricity is available for only a few hours daily, the plant has thus far been unable to meet its design capacity of some 250,000 customers. An ambitious plan has been adopted to build a large solar field – exploiting the region's abundant sunlight – and also employ electro-dialysis to extract salt particles. When completed, the facility's dependence on external energy supply will decline by some 60%.

Not only is solar power abundant in Gaza, but air quality issues throughout the Levant – in Gaza proper, and the Tel Aviv and Beirut metropolitan regions – make the renewable energy option attractive as an environmentally benign power source (Hamdan et al, 2008). Moreover, if linked to more ambitious plans to develop a SWRO facility in Gaza, and to distribute some of

the product water to the West Bank, regional water security issues for Palestine may also be addressed. This case serves to remind us that technical issues cannot be viewed in isolation from larger societal concerns. Feasibility is partly determined by available funding, strategic urgency, economic benefits, and attention to broader societal aspirations.

Non-risk factors are also important to public acceptability. These may, at first glance, appear to be health issues, but in reality are aesthetic ones. Such factors include desalinated water taste, odor, turbidity, and total dissolved solids (TDS), which can affect palatability and thus, consumer reception. Chemical additives and blending used to adjust for corrosion control, hardness and pH are intended to add to the lifespan of the distribution network (WHO, 2007: 3). However, they may generate collateral water *quality* impacts, underscoring desalination's tradeoffs with respect to economic cost, risk and public acceptance. Despite all these various challenges, desalination's worldwide popularity has been growing (see Figure 2.3).

Figure 2.3 about here

The Resilience of Wastewater Reuse

Wastewater reuse has been practiced since the Bronze Age (c. 3200 BC), mostly for agricultural irrigation, aquaculture, and crop fertilization. Records of its practice are found in China, Egypt, the Indus Valley, Crete, and the Middle East (Angelakis et al., 2018). Beginning in the early 20th Century, risks of environmental transmission of communicable diseases led to formal regulation of reuse and, in part, provided the foundation for later guidelines requiring pre-treatment of wastewater before use – especially for uses with high human contact (Shuval, 1991). Subsequently, advanced wastewater treatment technologies have been adopted to provide potable as well as non-potable reuse options.

Potable uses are not only subject to higher levels of treatment, they have also been subject to greater levels of health effects scrutiny, reflecting public apprehension over direct contact with recycled effluent. This is one reason advanced treatment systems often employ an *environmental buffer* – a surface water body or groundwater basin – to provide a medium for storage prior to use. The primary purposes of such a buffer are to add *time* before reclaimed water is introduced into a drinking water system, allow *blending* with water from other sources, and provide *additional natural treatment* to further remove residual contaminants. In addition, buffers “create psychological distance between the water’s source and its destination (for consumers) by incorporating natural environments into the process (NAS, 2012: 4, 8).” In short, buffers enhance public confidence as well as safety.

Advanced treatment technologies are capable of meeting drinking water standards in most countries, especially projects that employ reverse osmosis (RO). RO treated water is of higher quality than most conventionally treated drinking water with respect to total organic carbon (TOC), total dissolved solids (TDS), and trace contaminants of emerging concern. Moreover, communities can, as one report contends “realize numerous advantages” from its adoption, including increased reliability, a lower carbon footprint from treatment, conserving of limited natural supplies, and fewer increases to the cost of water (Mosher and Vartanian, 2015).

In the U.S., potable water reuse systems have existed for nearly 60 years, with non-potable reuse beginning in the 1920s (Corbett et al., 2006). In addition to Orange County, mentioned in Chapter 1, the Sanitation Districts of Los Angeles County have been using highly treated reclaimed water for potable supply since 1962. Similar reuse systems are found in Virginia, Texas, Georgia, Arizona, and Colorado, with most systems coming on-line since the 1990s in communities facing acute water stress (NAS, 2012: 4). The adoption of wastewater

reuse has also become a wide-spread practice worldwide (Figure 2.4). A handful of nations, Cyprus and Malta most notably, reuse more than 90% and 60% of their wastewater, respectively while Israel, recycles nearly all of its wastewater, mostly for agriculture.

Figure 2.4 about here

While not as widely adopted as desalination, reuse's technical feasibility in specific applications has led to its large-scale application in some sectors. Approximately 45% of urban reclaimed water worldwide is currently used for irrigation with some polities (Israel and Spain, for example) employing 90% and 70%, respectively, of their reclaimed effluent, mostly for agriculture (Bixio et al., 2005). These two polities also have in common severe water stress, over-taxed or nearly non-existent alternative freshwater sources, and large agricultural sectors. There are also growing examples of wastewater reuse in a number of megacities across the globe. This is especially true in developing countries such as the Philippines, Thailand, China, India, Peru, South Africa and Uganda where water demands have been growing, available freshwater sources dwindling, and a combination of national regulation, local political mobilization, financial incentives, and a culture of innovation drive public and decision-maker acceptance (International Water Association, 2018: 21).

Despite the soundness of reuse technology, however, questions have arisen over its reliability, safety, and healthfulness. These questions continue to arise in part because they have so rarely been answered definitively, except in a few locales where reuse has been successfully adopted – such as Southern California. Recalling our Chapter 1 discussion on Orange County, four factors made reuse feasible there: officials allowed full disclosure of its costs, ensuring transparency; the nearly \$1 billion project was brought on-line on time and within budget; its operation converged closely with community aspirations for a dependable water supply to

support continued growth; and, public outreach was built into the project (Fielding et al., 2018). Figure 2.5. depicts the overall schematic for Orange County’s Groundwater Replenishment System – a comprehensive hybrid operation that relies on indirect potable reuse via groundwater recharge as well as harvesting of surface water flows.

Figure 2.5 about here

Underscoring the rarity of this convergence of favorable factors, neighboring communities having many of the same water needs and stressors as Orange County have seen public support harder to come by, and technical feasibility issues more challenging to resolve. Los Angeles has undertaken many attempts to adopt reuse over the past three decades with little success. California’s last major drought may mark a turning point, however. In 2019, Mayor Eric Garcetti unveiled plans for the city to recycle its entire wastewater stream by 2035 in an effort to reduce reliance on imported supplies. This “game-changer,” as a senior manager for the city’s Department of Water and Power (DWP) describes it, is now thought to be possible because years of drought, declining water imports, and the high profile of Orange County’s success have “softened resistance.” If plans are consummated, reuse would be catapulted from its current 2% of Los Angeles’ supply – mostly for irrigating municipal parks – to 35%.

Upgrades to the city’s Hyperion Water Reclamation Plant, new groundwater wells, construction of a 15-mile pipeline, and as much as \$8 billion in financing by DWP to pay for it will be required (Boxall, 2019). One asset is that the project mostly entails retrofitting *existing* infrastructure. Currently, the Los Angeles metropolitan area has an extensive system of twenty water reclamation plants which treat water to secondary and tertiary degrees for discharge. Two facilities are designed to treat hundreds of millions of gallons of sewage daily to basic standards for discharge while the others treat water to higher standards for reuse for irrigation or

groundwater recharge. These facilities can satisfy as much as ten percent of the area's needs.

Projects are planned or in progress for several smaller plants across Los Angeles County to provide additional irrigation supply or to recharge water from smaller-sized facilities (Pincetl et al., 2019; Porse et al., 2018). More promising still, these plants can be operated as a network, with treated water released for downstream diversion to groundwater recharge basins, distributed to serve indirect potable needs, or passed through untreated to larger plants. This elaborate, interconnected reuse system requires a high-level of investment capital to ensure economies-of-scale and affordability – and thus, is more appropriate in highly-developed polities.

Wastewater reuse can also reduce water pollution – an often under-discussed issue. Reuse averts pollution of source waters and reduces the volumes of untreated wastewater discharged to rivers, streams and estuaries. For these reasons, the United Nation's Sustainable Development Goals (SDGs) explicitly urge wastewater reuse as a means of improving water security and health in developing nations. For agriculture in particular, recycled wastewater can provide valuable plant nutrients and enhance crop yields (Asano and Bahri, 2011: 68).

Economically, potable reuse is generally lower in cost than desalination. It is also often less expensive than importing freshwater via diversion or other forms of water transfer. Moreover, reuse can meet or exceed existing water quality standards for potability (or even non-potable applications) with comparative ease – if internationally prescribed and rigorously sanctioned standards are followed (WHO, 2006). Nonetheless, as we shall discuss, its lower cost is not always a sufficient factor to inducing public acceptance (see SIDEBAR).

In the U.S. the volume of recycled wastewater for beneficial use is predicted to increase 37 percent, from 4.8 billion gallons per day in 2020 to some 6.6 billion gallons per day by 2027 due to its many environmental and economic advantages (Maya, 2020). This suggests that cost is

an important feasibility issue. However, whether reuse is appropriate for a specific locale depends upon more granular economic considerations including potential uses for the reclaimed water and the relative stringency of waste discharge requirements imposed by regulators – a factor likely to affect the cost of reuse more than might be the case for other water supply methods (Asano and Bahri, 2011: 64).

As with desalination, a key economic issue for wastewater reuse is energy consumption. The level of treatment beyond secondary purification methods for reuse, and the installation of reclaimed water distribution systems, can add to its initial cost. Singapore – a city-state which relies upon both desalination and wastewater reuse exemplifies this Singapore’s need for water self-sufficiency (Chapter 3) has pushed up its energy requirements, making it imperative for the city to reduce energy consumption in the water cycle. As a result, it has embarked on a dedicated program to improve membrane technologies and energy recovery in its wastewater treatment plants (Lafforgue and Lanouvel, 2015: 629).

SIDEBAR: Wastewater reuse – *if it’s cheaper, why isn’t it embraced by the public?*

Boise, Idaho might not come immediately to mind as a city on the forefront of water supply innovation. However, the city’s public works department plans to adopt recycled water as a principal potable water option. Climate change impacts in the Treasure Valley high desert region coupled with projected population growth were good reasons to look toward reuse.

Recycled water use is actually widespread throughout Idaho, mostly for crop irrigation and in at least one case, for watering grass in urban parks by using highly-treated wastewater (the city of Meridian). Interestingly, the city’s public works director acknowledged that the reuse option -one among six evaluated by the city – is not necessarily the least expensive option Boise could have adopted. It may be the most resilient alternative, however, since a new water renewal facility able to process up to 5 million gallons per day in the industrial area in southeast Boise is expected to make the city more attractive to new businesses, and some of the recycled water would be pumped back into a local aquifer to keep water levels steady if there is more water available than necessary for industrial uses.

Said Steve Burgos, the city’s public works director: “Boiseans are willing to pay a little bit more if there is an added value,” he said, about water renewal upgrades. “While this isn’t the cheapest option, this is the lowest cost option of the portfolio of options we considered. We

certainly heard loudly and clearly there was interest in pursuing multiple uses of the water.”

Debate has not ended, however. While the city convened a 23-member citizens’ advisory group before embarking on its plans, some key stakeholders were not represented on the panel. The city considered putting treated wastewater into the Farmer’s Union Canal, which irrigates crops in the northwest edge of the city, but neighbors felt left out of the talks about the project raised concerns about “contaminants of emerging concern” in the wastewater – especially PFAS-family compounds and endocrine disruptors. While the city has agreed to monitor for such contaminants, concerns have not been entirely alleviated.

While plans remain in flux, the city is also looking at upgrading its entire water delivery and treatment infrastructure – another long term project – and is not ignoring how improvements will be funded. At a projected cost of between \$890 million and \$1.3 billion over two decades of construction, the city’s plans include a total rebuild of one of the city’s existing water renewal plans, new facilities capable of reusing water, and improvements to the Boise River to meet EPA regulations. Water rates will increase short term but, it is claimed, will cost less longer term. Boise’s challenges with water resilience are becoming a familiar story nearly everywhere.(Carmel, 2020).

Communities considering greater use of reclaimed water – Houston, Texas is a recent example – take energy consumption issues seriously. One widely-cited study has concluded that energy costs for future advanced purification systems will likely be significant. Thus, the savings realized by supplementing fresh water shipped from a distance with the direct potable reuse from municipal wastewater may reduce these costs. As the study’s authors caution:

.... The model (used in this study) shows there will always be a tradeoff between the acquisition of potable water, the energy required to treat it, the cost of transporting it without affecting its quality, and attempts to find a reasonable balance between those factors (Rice University, 2020).

While less energy intensive reclamation systems may reduce overall costs, they are not a panacea. Applications of reuse that aim at fully potable use often find that the most economical methods for achieving potability are to combine reuse with other methods of freshwater provision. Kuwait affords an illustration – its situation being somewhat comparable to that of

the UAE cited earlier. The Sulaibiya wastewater reclamation and reuse project is a cornerstone of Kuwait's wastewater reuse network.

Sulaibiya was constructed to allow unrestricted non-potable uses. It is the product of a 30-year concession from the Kuwaiti government to a private consortium to design, build, own, operate and maintain the facility. Initially producing 375,000 m³/day of wastewater, it will eventually be upgraded to a capacity of 600,000 m³/day. Sulaibiya applies advanced treatment processes – ultra-filtration and reverse osmosis and delivers water of potable quality at an approximate cost of US \$0.65 per m³ as compared to US \$0.40 per m³ for conventional wastewater treatment and pipeline costs. It also produces tertiary treated wastewater at a cost of US \$0.38 per m³, and has thus proven to be an economical source for certain end-uses because it mixes reclaimed wastewater with brackish water, offering the blended supply for irrigation and groundwater recharge (Asano and Bahri, 2011: 70).

There are two other economic issues associated with reuse. The first is the need for an environment conducive to financial stability. The second – and more forward-thinking – is the possibility that wastewater reuse can provide a foundation for what some call a *circular economy*: one that maximizes the value of a resource through a product's entire lifecycle while also minimizing waste generation (European Commission, 2007). One means of ensuring financial stability is linking the waste management aspects of reuse (production of copious amounts of solid waste) to markets that then reclaim these products for other purposes. This can permit faster cost-recovery, reduce the financial risks of a project, and ensure long-term sustainable operation. As we saw for desalination, developing mixed public/private or public/public partnerships also helps to ensure stable, reliable investment, service delivery and low operation and maintenance costs. It also ensures equity by keeping the price of reclaimed

water affordable (Asano and Bahri, 2011: 71).

A current example in the American Southwest underscores the value of such partnerships. While some water agencies in Southern California have successfully pursued reuse, a larger scale region-wide proposal is currently under development by the Metropolitan Water District of Southern California (MWD). This *Regional Recycled Water Program*, a partnership with the Sanitation Districts of Los Angeles County, would purify wastewater for industrial use and groundwater basin recharge. The program would begin with a demonstration facility in Carson, California that currently treats between 250,000 and 300,000 acre-feet annually, and would eventually become one of the largest advanced water treatment plants in the world (MWD, 2021; Rothberg, 2019; Roth, 2020). (See Figure 2.6)

While cost estimates are pegged between 3 and 4 billion dollars, the Southern Nevada Water Authority (SNWA) has expressed strong interest in co-funding the project as a means of reducing consumption of Colorado River water stored at Lake Mead. SNWA, anchored by the city of Las Vegas, would co-fund the project in exchange for additional water that MWD would leave in Lake Mead as a result – benefitting the entire region. While the project will take over a decade to develop, aside from the overall appeal with respect to regional water resilience, the combination of MWD and SNWA enables an alliance among two agencies able to afford a project of this scale. While the project underscores the high costs of large-scale technological innovations, it also illuminates their possible benefits – if you have few other viable alternatives and believe an innovation is publicly acceptable, such an investment may make sense.

Figure 2.6 about here

The most widely-articulated risks associated with wastewater reuse are to human health. In summarizing the body of investigations regarding these risks and the best means to mitigate

them, four conclusions may be drawn. First, there remain many unanswered questions regarding the actual risks of both direct (treatment-to-end user) and indirect (storage in reservoirs or groundwater basins prior to distribution to end users). Ambitious efforts at resolving the uncertainties associated with these risks have concentrated on the need for regulatory guidance covering permitting, hazard mitigation, and operator training based on the best science regarding treatment technologies, blending of product water with other sources, and improvements to public outreach (Mosher and Vartanian, 2015: 3).

A second difficult-to-resolve issue with regard to wastewater risk is that, regardless of the safety of various regulatory and technical systems for risk reduction, there is always the possibility of system failure. Real-time remote sensors and autonomous water-control systems can provide close monitoring of treatment systems. However, were these systems to fail – a possibility for any new technology – public trust and confidence, critical factors in acceptance of wastewater reuse, would likely erode (Water Technology Futures, 2015: 21). Effluent reuse treatment processes usually have multiple independent modes. Each mode is intended to remove or inhibit a specific type of pathogen or chemical constituent. However, failure of even one system may inhibit the performance of subsequent stages. Research is needed to ensure that human exposure to contaminants is minimized in the event of a “deviation from performance specifications” for a particular unit process in multiple-barrier sequence (Water Technology Futures, 2015: 60).

Third, national-level guidance is needed to garner public confidence in the efficacy and safety of reuse. Politics that have adopted national-level risk guidance frameworks have a better track record of encouraging wastewater reuse adoption than have those that haven’t (Mosher and Vartanian, 2015; NAS 2016: 175, 177). A parallel truism is that local adoption of indirect and

direct potable reuse is more likely if state regulators, who generally enforce drinking water safety standards in countries like the U.S., provide uniform guidance regarding the conditions under which reuse is appropriate, and the standards that must be met by local governments. Uniform regulatory standards help bolster public confidence (NWRI, 2015: 10; Kenney, 2019: 121).

A particular challenge with respect to uncertainty in the U.S. is that the Safe Drinking Water Act has not yet established standards for all potentially harmful constituents that may be present in wastewater. Given the rapid growth in recent years in the number of such constituents found in consumer and industrial items, and that bare finding their way into sewer-sheds, this is hardly surprising (e.g., NAS 2016: 175). California has adopted state-level guidance and is a recognized leader in developing regulations and underlying investigations in support of uniform health protection criteria for direct as well as indirect potable reuse (Crook et al., 2020: 15).

Australia is one of a handful of countries that has adopted risk-based non-potable wastewater reuse guidelines. The result has been a scale of re-use options – each having a different regulatory standard –adopted by states and communities for agricultural applications, landscaping and park irrigation, and domestic uses (NAS, 2015: 177). The standards are based on advisory guidance provided by the World Health Organization which uses “disability adjusted life years” (DALYs), a common summary measure of population health, to compare disease outcomes from different contaminant exposure pathways.

Although the guidelines have no legal standing, their adoption provided Australia with a “shared national objective” that allows states to adopt their own regulatory tools. In managing risks to human health, the guidelines use DALYs to convert risk of illness into burden of disease (NAS, 2016: 178). One result has been widespread adoption of recycled wastewater in the latter half of the early 2000s for urban and residential use (e.g., flushing toilets, and outdoor use) in

response to the Millennium Drought. Melbourne, the country's second largest city, reused 23% of sewage inflows in 2008 alone, exceeding the Victorian government's goal of 20% reuse by 2010. When the drought effectively ended by 2009, domestic uses of recycled wastewater declined dramatically (Low et al., 2015).

A final risk issue pertains to on-site wastewater treatment and direct potable re-use – an approach which minimizes the need for large, expensive, hard to maintain sewer infrastructure. One remote rural community in Zermatt, Switzerland has adopted remotely operated satellite wastewater treatment plants as a means of combining local wastewater treatment and distributed water supply (Hering et al., 2013: 10723). The approach has proven to be an effective means of providing a resilient and safe water supply in a location with few affordable options.

Among all the issues proponents face in adopting wastewater reuse, however, public acceptance remains the most daunting. To a degree greater than for other innovations, public perceptions often skew highly negative, exemplified by the phrase “toilet-to-tap.” Primal influences on these perceptions include trust and confidence in the technology, in those managing it, and in the end-uses prescribed for recycled wastewater. Given the diverse social, economic, and demographic backgrounds of those harboring these perceptions, these concerns can only be accommodated by actively engaging the interests and perspectives of these groups.

This issue has been examined in a variety of contexts – from Australia to Israel, California to Europe, and Singapore to Latin America. A consistent finding is that reuse must be managed with due consideration for concerns over health, safety, rate-payer cost burdens, and community well-being. Reuse must also be introduced in ways that do not single-out under-represented communities (Robinson et al, 2005; Hurlimann and Dolnicar 2010; Dolnicar et al 2011; Linton and Budds 2014; Harris-Lovett et al 2015).

Reuse must also be politically-accountable by being managed in ways that conform to sound engineering and good management principles. Equity must be addressed through dedicated risk communication and risk management programs. Under-represented groups especially want to engage in interactive exchange of information regarding risks from any innovation, as well as how these risks are being safely managed (Hadden 1989, Renn and Levine 1991, Mileti et al. 1994, Ng and Hamby 1997, Gross 1994).

Effective risk communication programs acknowledge specific regional and demographically-resonant concerns. In Australia, for example “public health and the environmental effect of microbiological agents” together with chemicals such as endocrine disruptors have been prime concerns of the public. Water quality and end-user costs have also been found important. Recycled water is perceived as riskier from a health perspective than desalinated or other sources of water, despite the fact that non-potable uses have been widely and effectively adopted (Higgins et al., 2002; Dolnicar and Schafer, 2006).

To date wastewater reclamation has been mostly applied to non-potable end-uses – agricultural and landscape irrigation, industrial cooling, high-technology manufacturing, and in-building applications such as toilet flushing. In all cases, the value of reuse is weighed within a larger context of necessity and opportunity on one hand versus public concern on the other. A central tenet of water reuse practice is that wastewater must be appropriately treated to meet fit-for-purpose specifications to protect public health, the environment, and end-user needs (U.S. EPA, 2020; Asano and Bahri, 2011: 70). Exogenous issues include continued and worsening drought, fears that a dependable supply of “new” water may actually induce additional urban growth, and, perceptions of reclaimed water safety. Resolution of these enduring issues will likely determine long-term prospects for adoption of reuse.

Rainwater harvesting as a Resilient Alternative

Rain- or stormwater reuse – the labels are often used inter-changeably – can take a variety of forms. A common technical distinction is between low- and high-energy requirements depending, in turn, on the level of treatment required before end-use. Unsurprisingly, higher levels of treatment are required for potable use, and in some cases to protect sensitive ecosystems. In general, low energy stormwater reuse schemes work by capturing or “harvesting” water before it becomes contaminated by contact with the urban landscape, in some places referred to as *rainwater harvesting*. Low-energy processes remove contaminants and treat the harvested water to the extent needed for its intended use (Grant et al., 2013; Gilbert et al., 2006). Residential irrigation from rainwater tanks – a practice widely-adopted in some parts of the world, most notably in Australia – is a good example. Runoff is captured from relatively less-contaminated surfaces such as building roofs before coming into contact with the urban environment. The harvested water is then applied to a “quality appropriate” activity such as landscaping or non-potable household uses (Gilbert and Clausen, 2006; Grant et al, 2013).

Among the benefits of stormwater reuse are reducing adverse impacts of urban runoff on the environment. Urbanization results in what are sometimes distinguished as quantitative and qualitative impacts.. The former include increased runoff and higher peak flows which increase flood vulnerability. The latter include transportation of physical, chemical and biological pollutants generated by natural and human-generated processes. Because stormwater reuse entails storage of stormwater flows, its can strengthen flood resilience as well as reduce pollutant loads to surface waters (Goonetilleke, 2017; 15).

Stormwater wetlands and bioretention or biofiltration systems can treat stormwater for non-potable uses, or for pretreatment upstream of water treatment facilities that permit potable

reuse. Wetlands have been used for this purpose prior to storage and recharge of groundwater basins for some time, while so-called bioretention systems, which filter water through soil or sand-based media, have also been used for urban landscape water applications. These have the virtue of being able to remove sediment, nutrients, and heavy metals from runoff (Hatt et al., 2006; Grant et al., 2013). There are also environmental benefits associated with storm water reuse, including restoration of pre-urbanization flows, nutrient and pollution retention, and capture and partial treatment of runoff, thus intercepting more rapid flows of runoff from the typically impervious surface characteristic of most urban areas.

Recent research on the global application of stormwater reuse has also pointed to the technical and societal challenges in making its adoption more feasible. Rainfall in many places tends to be seasonal, and thus unreliable as a dependable source of supply. Overcoming this impediment requires adequate storage to ensure water availability during dry periods – Singapore, as discussed in Chapter 3 – is one of the few places that has conscientiously re-engineered its built environment to fully exploit this potential. No less important is that in regions already reliant on harvesting stormwater for groundwater basin recharge – Southern California for example – climate variability and change are becoming increasingly important factors in water supply planning. Even where overall average annual precipitation is predicted to remain the same under climate change, more intense storms may be expected, underscoring the need to understand so-called Atmospheric Rivers and their unpredictability (OCWD, 2020).

Managed groundwater recharge is a viable option for storage where sub-surface conditions are favorable. From a water quality standpoint, depending on the sources of contamination accompanying runoff, stormwater can become highly polluted: in some cases more polluted than secondary treated sewage. Even when industrial contaminants are not a

severe challenge, the high sediment loads carried by intense stormflows can pose major water quality problems (OCWD, 2020). These issues add to the cost and complexity of treatment and dictate limited end uses. As one analysis notes, “reliability of supply at an economical cost, compared to other water supply options” is critical (Goonetilleke, 2017; 15). In all cases, stormwater reuse works best when it is managed on the basis of *water fit for purpose*: using different grades for intended uses. This allows water managers to vary the level of treatment and thus, the highest expenditure, on those methods treating water intended for human consumption.

While stormwater is theoretically “free,” projects to collect, treat, and distribute it are not. Project costs depend on scale, system design, and plumbing requirements (especially in the case of domestic uses that combine harvested stormwater with other sources). While these costs are generally better quantified than are the benefits of stormwater use, there is a paucity of solid and complete information for both, and foremost applications (e.g., Low et al., 2015).

In general, stormwater projects for non-potable uses such as landscaping and parks are cost-effective substitutes for potable water use, especially during drought, Melbourne, Australia’s experience with stormwater harvesting projects during its Millennium Drought exemplifies this. During a typical year, approximately 440GL of stormwater flows off from Melbourne’s urban landscape into the city’s rivers and to the Antarctic Sea. The metropolitan area’s 4.3 million people consume some 356 million gallons of potable water annually (equal to three-quarters of this total flow). Thus, decision-makers agreed that substitution could have a significant impact on conserving potable supplies. Melbourne undertook significant efforts to harvest stormwater runoff for toilet flushing and ornamental landscaping (Grant et al, 2012; Office of Living Victoria, 2013; Ministerial Advisory Council, 2013).

Melbourne’s experience is also instructive with respect to factors that should be

encompassed in economic analyses. While estimates of the benefits and costs of all water supply approaches vary, Melbourne adopted an assessment approach that sought to holistically determine the environmental, human health, public acceptability, and “livability” benefits of stormwater harvesting, avoided costs through its adoption, and the value of benefits generated (Ferguson et al, 2013). City officials found that a key to cost effectiveness lay in economies-of-scale, dictating large projects. Legally, however, many projects require acquisition and management of land parcels under the jurisdiction of several local governments.

The *Victorian Water Act of 1989* provides state ministerial authority to mandate conjoint drought planning by local water agencies. Joint Drought Response Plans (DRPs) specify water restrictions based on surface water storage level and mandates water agencies serving a common region to enforce water savings programs. This framework helped Melbourne introduce region-wide – and thus more efficient – stormwater management plans (Australian Bureau of Meteorology, 2011; Low et al, 2015).

In the U.S., by contrast, water districts and municipalities are rarely required to collaborate on stormwater capture and use projects. This results in making projects too prohibitive in cost and also precludes efficient placement of facilities within the spatial-span of a single stormwater management agency. Since any practical effort at agency cooperation must include cost- and benefit-sharing mechanisms, and since most U.S. communities lack requirements to analyze the environmental benefits and costs of urban runoff compared to other water sources, capture and use systems are often undervalued (STORMS, 2017: 8-9, 40).

Another economic consideration is “averted costs” by cities seeking to optimize regional water supplies and reduce out-of-basin imports. Stormwater infrastructure can have the benefit of averting the need for imports – an important benefit especially for downstream coastal cities

that must maintain groundwater basins while averting over-drafting on one hand, and seawater infiltration on the other. In parts of Southern California, for example, where the cost of imported water is high, averted costs provided by stormwater infrastructure is an important component of benefit-cost assessments (STORMS 2017: 37, 40).

Estimating benefits and costs for stormwater projects is generally done on a project-by-project basis due to variability of local hydrology. Urban areas with underlying aquifers are generally better situated to capture and store stormwater, leading communities with aquifers to adopt harvesting as a cost-effective storage solution and a clearer path to overcoming existing storage barriers for capture and use (STORMS, 2017: 9; Ferguson et al 2013). Likewise, flood control detention basins can be retrofitted fairly easily to maximize groundwater recharge or support ecosystem services and other community benefits, making them economical.

One reason stormwater harvesting and reuse remain proportionally small globally is because costs and benefits are difficult to systematically assess. Recent research has sought to address this problem by developing life-cycle assessment tools to furnish a more consistent cost profile across applications. Efforts to encompass labor, materials, energy and environmental costs, and hydrologic performance with the goal of providing better guidance for decision-making are a positive development (Krieger and Grubert, 2021). The application of quantitative economic tools alone, however, is insufficient. Non-market valuation techniques are needed to evaluate community and environmental benefits of stormwater, such as *Multi-Criteria Decision Making* analyses that encompass market and non-market values (Goonetilleke, 2017: 15).

Lastly, while stormwater is a “natural” supply source, the most formidable risks revolve around its suitability for various applications. Potential issues surrounding domestic use include potential effects on water demand, downstream water availability, aquifer recharge, and

ecological stream flows (NAS, 2016). Whether there are adequate regulatory frameworks to address its beneficial uses while managing collateral risks remains an open question.

An important health risk of stormwater capture revolves around hazards from biological and chemical sources from roof runoff. Remedies to this risk pathway are hindered by the lack of data on human pathogens and the risk associated with various uses. Design and treatment standards are generally well accepted for nonpotable use of runoff collected from land surfaces, and no treatment other than coarse solids removal is needed for subsurface irrigation where human exposures are minimal. For beneficial uses of roof runoff with low to moderate exposures, however, additional pathogen data and risk analyses are required to establish a consistent set of “best practices” for on-site stormwater use.

Demand-side water innovations – final reflections on resilience

Water resilience requires innovations that attenuate demand as well as augment supply. Demand-side innovations share with supply side options the need to be viewed as feasible, cost effective, low risk, and publicly acceptable. Every demand-side alternative currently in use – from water saving tools that measure and monitor water use and detect leaks to devices that save water, such as low-flow indoor appliances and outdoor irrigation systems, as well as landscape alterations – are technically feasible. However, each of these innovations impose various economic costs, risks to environmental quality (in the case of measures combining water conservation with stormwater harvesting, for example), and impacts to community appearance, property value, and/or data privacy (factors affecting public acceptability).

Smart water systems, as noted in Chapter 1, rely upon digitalization of water and sewer flow data, and a high degree of automation – entailing diverse risks from systemic as well as single component failures. Because they rely on Internet-based platforms, data breaches, cyber-

attacks, and threats of sabotage to the security of water distribution and treatment systems is always possible – however remote these risks (de Vitry et al, 2019; Susha et al, 2019). There are a number of public trust and confidence issues associated with these systems for which policy solutions are either uncertain or insufficiently developed.

Few water agencies have fully-integrated data management systems. According to one study data often remains siloed, and is not employed in a robust, comprehensive system for water supply planning. Questions related to security are usually relegated to a small sub-set of skilled operators and technicians who possess “tribal knowledge” within an agency. High-level leadership familiarity with data management and security problems ends to be lacking. In short, while an *Internet of Water* may become a promising way to enhance long-term planning, in only a little over half of sampled water agencies are assets management, customer interaction, and operations embraced within a comprehensive, smart system (McRoberts and Zhou, 2019).

Another challenge is that law enforcement and security systems have not totally caught up to the cybersecurity needs associated with water agencies. As recently as 2018, the Departments of Justice (Federal Bureau of Investigation) and Homeland Security warned that the Russian government is targeting the water sector as part of a “multistage” disruption program – while a survey of some 20,000 utilities revealed a heightened fear of cyber threats to their operations. In both cases, there is widespread consensus that water agencies lack the resources to fully avert or manage these threats (Germano, 2019).

For their part, so-called distributed technologies whose use has been growing in urban areas across the globe, alternatively termed *Low Impact Development*, *Sustainable Urban Drainage Systems*, and by other names, can enhance water resilience by diverting non-potable rainwater to highly-specialized community needs such as landscaping and parks. These

approaches may be considered conservation and demand-side measures inasmuch as they save precious drinking water for household and domestic uses that would otherwise be used to irrigate public properties. Adoption of these and other low impact water services may also be considered resilient water options since they fortify communities against possible shocks from climate change and other environmental stressors, and are less susceptible to catastrophic failure (Everett et al, 2015; Kiparsky et al., 2013; Pincetl et al., 2019).

Because cities are especially subject to many of these water stressors, in the last couple of decades, efforts have been introduced in urban centers in the southwestern U.S especially to invest in low-impact development programs in order to reduce water consumption. Many of these programs were first introduced during intense drought – such as that recently experienced in California in the period 2011-2017. These programs generally provide economic incentives to customers, such as cash rebates to replace lawns with drought tolerant landscaping.

One such “cash-for-grass” program offered by the Irvine Ranch Water District (IRWD) in Orange County and initiated in 2010 (a year before California’s 2011 drought), led to the replacement of 130,000 m² of lawn area with drought tolerant landscaping and resulted in an annual water savings of between 130 - 222 megaliters (ML) (Grant et al., 2020). While harboring the potential for significant water savings, such programs, and the incentives that spark their adoption, do not necessarily lead householders to replace turf with drought-tolerant landscape.

Cultural drivers of landscape choice, household conservation behaviors, perceived costs of participation, neighborhood norms and zoning or community covenants, and demographic characteristics (e.g., income) all influence participation. Moreover, with regard to public acceptance, leadership messaging is important in overcoming societal constraints. Following

California Governor Jerry Brown’s emergency 2015 Executive Order mandating reduction of California’s urban potable water consumption by 25%, mass media coverage and Google searches for the terms “drought tolerant landscape” and “rebate” dramatically increased, as did participation in the IRWD turf replacement program and similar programs throughout the region (Duong et al., 2017).

Finally, distributed systems can enhance the effectiveness and flexibility of innovations that straddle the supply-demand innovation universe: stormwater harvesting being an example. However, while approaches for harvesting and reusing stormwater may be economical, as we discussed earlier (Braden & Ando, 2011; Jaffe, 2010; Lamond, 2017), studies are needed to determine the distribution of the benefits and costs of these decentralized approaches and to ensure their equitable implementation. Current incentive-based approaches such as those employed by water agencies in Southern California may penalize lower-income families who do not have large irrigated landscapes to replace. And, the effects of decentralized approaches on property values is be mixed, with some nearby owners experiencing negative effects on their property’s valuation. This also raises questions about the spatial and demographic distribution of the benefits from low-impact water saving measures – and that remain to be answered (Irwin et al., 2017; Zhou, 2017).

Coda – where does governance fit into this?

All water innovations entail choices. While many of these choices are made by individuals electing to adopt various demand-side measures, or by water agency officials opting to invest in one or more supply-side innovations, ultimately – governments decide what options are selected. As we saw at the outset of this chapter with the example of the UAE, governments: establish guidelines for assessing suitable performance of a technology; weigh-in on debates

over health and safety via regulation; help consummate industry partnerships leading to innovation development and adoption; and – most of all – set a course for a polity's economic development investments which, in turn, determine future water needs. The latter include choices over what industries to nurture, what cities to grow, and which populations to serve via new water sources of water.

Chapter 3 explores these issues in the context of water governance – how decisions over water supply and demand are made by polities. We first examine this issue through an historical lens so as to have a better understanding of the cultural and social – as well as hydrological – factors that lead governments to foster investments in water innovations, choose from among competing technologies, and decide who should most benefit from their adoption. The roles of power and decision-making process in policy-making, the varied conceptions of public good embraced by decision-makers, and the overall purposes of water provision will be discussed as a means of better understanding how polities make water innovation decisions.

CHAPTER 3 – WATER GOVERNANCE – HISTORICAL THEMES AND RELEVANCE TODAY

Day Zero

In three months the distribution system supplying water to a million homes, some 75% of your city's four-million residents, will be shut-off. Officials call the event *Day Zero*: the date the region's reservoirs are slated to fall below 13% capacity. In preparation, 200 emergency collection points have been established to distribute a six-and-a-half-gallon per person per day ration. The military and police are on alert in case riots erupt and to control unruly crowds gathered at distribution points. Plans have been made to store emergency water supplies on army bases (Cape Town told, 2018; Welch, 2018; Feldman, 2018).

There's been a run on stockpiles of bottled water, and hardware stores have exhausted water tanks and pool covers. Well-drillers are overwhelmed with requests to mine groundwater and dehumidifiers, sold as "water from air" devices, can no longer be found. Businesses have put up signs advising customers to conserve water, farmers have cut back on irrigation, tourists have been asked to restrict personal washing, and residents are sharing stories about how they plan to cope with the emergency – all while queueing up at local springs to collect water.

This doomsday scenario is not the script for a blockbuster disaster movie. In 2018, Cape Town, South Africa faced a once-in-a-384-year-drought attributed to early warnings of global climate change. As if by a miracle, Day Zero did not occur. A combination of voluntary and involuntary measures (e.g., rationing; banning of car washing) adopted by city and regional governments, together with limits on agricultural water withdrawals, and – more fortuitously – the return of precipitation to the region, averted a looming catastrophe (Edmond, 2019).

While Cape Town was given a reprieve, the underlying causes of the crisis have not

been fully addressed. Leaders of the country's major parties, the African National Congress and Democratic Alliance, assumed future precipitation patterns would resemble the past. And, despite warnings that population growth and climate change would impact Cape Town's freshwater, decision-makers failed to alter public perceptions or divert their attention from what they viewed as more pressing priorities (Welch, 2018).

Ironically, South Africa's government adopted proactive measures prior to the drought. Cape Town reduced water withdrawals from reservoirs, repaired distribution system leaks, and promoted end-use efficiency through pricing reform. The federal government prioritized demand reduction in its National Development Plan, targeting a 15% cut in urban use by 2030 (against a 2012 baseline). This was to be achieved through efficiency improvements, installation of low-flow fittings, leak prevention, and local rainwater harvesting in low income communities. Water innovations were not neglected either. Plans for adding desalination plants were drawn up and even reuse of acid mine drainage was slated to increase. Using recycled effluent to recharge groundwater basins was also determined to be cost-effective (National Water and Sanitation Master Plan, 2018: 8-9; Donnenfeld et al., 2018: 11, 16) Figure 3.1.

Figure 3.1 about here

Despite plans to make the city and surrounding Western Cape region more water resilient, however, delays in implementing projects aggravated stress. Portions of the Lesotho Highlands Water Project (LHWP), a diversion and storage project; the Mkhomazi Water Project – a dam, tunnel, and pipeline project; the Western Cape Water Supply System, consisting of a new dam; and emergency desalination plants for Cape Town slated for completion in 2018, were all delayed. In short: “forestalled action combined with extreme weather events” worsened the crisis (National Water and Sanitation Master Plan, 2018: 10, 47).

Project delays were partly caused by failures in *governance* – public sector decision-making and its shortcomings worsened the crisis. Governance is most effective when it is inclusive of a wide array of interests, accountable to stakeholders, and based on sound science (Sadoff et al., 2008: 83; Huitema et al., 2009; Bichsel, 2016). In South Africa’s case, this ideal fell short in three ways. First, incorporation of key stakeholder groups in long-term water supply planning was limited. Membership in rural water user associations generally reflects land ownership and thus, remained largely geared to the interests of white commercial farmers. While not directly affecting Cape Town, lack of representativeness in decision-making reflects the overall legacy of black South African exclusion from the *process* of making vital decisions.

Second, South Africa’s water sector is comprised of numerous entities responsible for diverse functions ranging from water supply, sanitation, pollution control, planning, dam operation and maintenance, regulation of use, and data collection. Fragmentation and lack of effective coordination make it difficult to resolve financial and other issues, particularly at the local level: a fact reflected by a lack of skilled technicians and continued failures in water supply and sanitation provision (National Water and Sanitation Master Plan, 2018: 14-38).

Third, long-term science-based plans were not aggressively pursued. One NGO contends South Africa still lags in water conservation and end-use efficiency, wastewater reuse (60% of South Africa’s wastewater is untreated), and groundwater use (Donnenfeld et al., 2018: 16-27). In sum, while Cape Town serves as a warning of what might come to pass if we ignore warnings of climate change, it also serves as a teachable moment regarding the role of governance in responding to water needs – especially during crises.

This chapter examines governance and its connection to water innovations. We first embark on a historical review of governance from ancient times to the present. We show how

political, technological and environmental change has long influenced – and been influenced by – innovations to deliver and ensure the quality of water. We then discuss two case studies of water innovation governance from which larger lessons regarding feasibility, economics, environmental impact, and public acceptability may be derived: Singapore and Israel.

Water Governance – the intersection of hydrology and politics

Governance encompasses the political and legal institutions, non-governmental entities, and constellation of laws, rules, and practices that shape decisions regarding the allocation and distribution of water, protection of its quality, regulation of demands, and management of ecosystem and societal aspects of water. Studies of water governance focus mainly on *formal* institutions and practices (Obertreis et al., 2016; Huitema et al., 2009; Lu et al., 2014).

However, there are good reasons to include other factors traditionally regarded as elements of *politics* in water governance, as we shall momentarily see.

No single model of water governance applies to every polity. In general, however, all water governance is characterized by three components. These are: *the process of decision-making*: how water-related issues get the attention of officials and become transformed into policies; *power* – the resources and other means strategically-placed interests bring to bear on water access and infrastructure issues; and, *purpose* – the objectives protagonists in decision-making seek such as reliable, safe, affordable, and resilient water supply (Feldman, 2017).

The process of decision-making for water innovations encompasses actions by numerous parties whose role in policy-making varies. Process is often technocratically-driven, favoring certain types of engineering or other expertise and thus, accountable to a relatively narrow set of voices. In recent years, technocratic dominance has led to criticism by groups contesting an innovation's impact and the alleged failure of officials to accommodate diverse, under-

represented groups. This is especially true in many developing countries – South Africa is one among many examples (e.g., Economy, 2010; Mostaghim and Sandels, 2014).

This technocratic paradigm may be thought of as standing in opposition to a *democratic* paradigm. The latter favors greater inclusion of under-represented groups in decisions regardless of their technical expertise; advocacy of water provision as a human right; and, concern with water as a long-term justice issue rather than a commodity requiring large-scale infrastructure (Williams and Swyngedouw, 2018). This is one reason why critics of technocratic dominance often embrace *adaptive governance* as an alternative for innovation decision-making (Chapter 4).

Power in water governance tends to be unequally exercised, with economic development interests and established bureaucracies directing outcomes. Nonetheless, accommodation among interests favoring and opposing innovations typically occurs due to the need for consensus when seeking approval for funding and implementation. As we've seen, lack of consensus has been an impediment to some desalination projects in California and to wastewater recycling in Jordan and the UAE. These examples also illustrate that authority over water innovations is most effective when it has *discursive legitimacy*: when it is exercised in conformance with over-arching norms such as the rule of law, economic rationality, and respect for diversity and inclusion (Purdy 2012; Grafton and Hussey 2011).

Purpose is the most elusive component of water governance. Protagonists often disagree on the objectives of water policies, and on water supply projects of various types – from dams to desalination plants. While desalination, wastewater reuse, and water harvesting projects have as their primary purpose augmenting water supply, what is often contested is for what *purpose* the additional water is needed. Is it to satisfy future economic needs efficiently (e.g., UAE and reuse)? Provide water independence and security (e.g., Israel, Gaza, and desalination; Los

Angeles and rainwater harvesting)? Accommodate climate variability (e.g., storm-water management in Australia)? Or, is it to protect a freshwater source whose ecological well-being is threatened by over-use (e.g., desalination on the Monterey peninsula)?

In most instances, water innovations serve multiple purposes. In any event, some segment of the populace whose goals are not fully embraced is likely to contest these purposes and demand consideration of additional ones. Water governance studies tend to ascribe one or more over-riding purposes for water policies to specific polities in order to explain why certain innovations are adopted. Accounts of water policy in the western U.S., for instance, frequently note that agencies and stakeholders in the region traditionally prefer large-scale storage projects to support reclamation, urban supply, flood abatement, and hydropower (e.g., Powell, 2008).

While broad-brush characterizations of the dominant purposes for water innovations may be warranted, we should not ignore dissenting views. In the American West, competing voices frequently favor water conservation; preserving wild and scenic streams; and, adopting “soft” water infrastructure (e.g., rainwater harvesting projects); as well as restoration of harnessed rivers (Repanshek, 2012; Gumprecht, 2005; Kibel, 2007). Moreover, not only are policy purposes contested, but so is the structure of overall governance itself.

Debate regarding whether water supply alternatives such as desalination facilities should be managed and funded by the state or by private markets, or through hybrid governance arrangements is increasingly common (e.g., Bichsel, 2016; Loftus and March, 2015). In sum, because the process of governance is generally technocratic yet contested; the deployment of power centralized and unequal; and purpose conflicted, disputes over water alternatives frequently arise. These disputes have as their foci the role of public participation, equity, and risk in decision-making. This has also been true in the past.

Water governance in ancient polities – a global-historical view

Concern with protecting water quality and assuring dependable supply via codified laws, rules and regulations – as well as physical infrastructure – can be traced to antiquity.

Understanding this legacy and its connection to the present is crucial for understanding the governance challenges that continue to face the implementation of water innovations. Egyptian, Greek, Roman, Hittite, Mesopotamian, Chinese, Peruvian, and other ancient civilizations were strongly preoccupied with providing water supply and assuring drainage of wastewater in cities and towns. Measures to provide water for irrigation as well as public supply constituted improvements as pioneering in their own way as are modern innovations.¹

As discussed in Chapters 1 and 2, rainwater harvesting – considered a contemporary innovation – began in many ancient societies, most notably in the Middle East. Evidence that this practice was considered innovative is even found in the Old Testament. The book of Isaiah refers to a reservoir built in the city of Jerusalem “between the two walls for the water of the Old Pool” – most likely a reference to Hezekiah’s tunnel which brought water from the spring of Gihon in the Kidron Valley on the east side of the city to Siloam on the west. The project was undertaken to ensure that water could be delivered inside the city’s walls while protecting supplies from besieging armies (Book of Isaiah 22: 11). For their part, the Hittites, whose civilization occupied a portion of present-day Anatolia, constructed deep, oblong-shaped reservoirs in the city of Hattusa for collecting aquifer seepage caused by rising reservoirs during winter and spring for later use during summers, another striking innovation (Harmansah, 2020: 233).

Throughout the ancient world, large- and small-scale diversion projects, aqueducts, public baths and latrines, storage pools, terraced channels, cisterns, wastewater culverts, and

¹ Interestingly, farmers in Western Peru are seeking to restore that region’s 1,400 year old stone canals or amunas to reroute mountain runoff to as many as 80,000 people in drought stricken communities in Huarochiri province. A measure giving renewed life to an ancient water innovation (see: France 24, 2021).

elaborate and varied agricultural irrigation projects were developed. Irrigation was especially important in that the ability to harness and divert streams to water crops and raise livestock was a fundamental driver of development. Coupled with land clearing and soil fertilization, crop watering permitted societies to transition from foraging of wild plants to cultivation of farms that produced surplus food and fiber, thereby permitting the growth of urban settlements (Taiz, 2013: 167-181).

Infrastructural innovations were often accompanied by systems of water governance in the form of laws, rules, regulations and treaties (the latter between polities sharing river basins). These systems dictated how infrastructure was to be managed and provided means to avert and resolve conflicts. There has long been debate over how these water governance frameworks functioned with respect to our three aforementioned components: process, power, and purpose.

Classic studies, the best known of which is the seminal work of Karl Wittfogel provocatively titled *Oriental Despotism*, contend that large-scale irrigation systems, particularly in non-Western societies, were autocratically managed by monarchs. They were assisted by wealthy aristocrats who harnessed the labor of indentured serfs and slaves to build and maintain infrastructure and allocate water supply. The political fortunes as well as the legitimacy of leaders in these so-called *hydraulic societies* rested to a high degree on how well they managed water, undertook measures to avert floods, and assured that adequate water supply was available even during drought (Wittfogel, 1957).

Contemporary analyses suggest that water governance in ancient polities was more complex, nuanced, and collaborative than Wittfogel and his disciples acknowledge. These analyses point to methodological and other flaws in his analysis. These range from over-preoccupation with technological determinism (and thus, an ignoring of political factors), an

ethnocentric focus on a selective number of societies, and an ideological bias rooted in his anti-communist predisposition reflected, some say, by a deeply held antipathy toward any regime viewed as directed by so-called “oriental” autocrats (e.g., Bichsel, 2016; Obertreis et al., 2016).

Despite criticism of Wittfogel’s interpretation of ancient polities’ governance of water, one preoccupation of his analysis endures: political regimes had important roles in shaping water provision systems and these systems, in turn, have altered water governance (Obertreis, et al., 2016: 169). As a general rule, administrators who oversaw aqueducts, reservoirs, and diversion systems in ancient polities were also charged with enforcing water allocation policies, but in a much more intricate and accommodative manner than Wittfogel described.

Two examples that document the complexity of water governance in ancient polities are Mesopotamia and Rome. In Mesopotamia, an ample documentary and archeological record exists proving that irrigation and other water infrastructure was built and managed by local communities and maintained by local elites, except during exceptional periods of dryness or flooding. Each city-state built its own weirs to direct water into reservoirs, canals, storage tanks, and other engineered works (The Rise, Fall, and Transition of Empires, 2019; Rost, 2017).

At the provincial level water was usually centrally-governed. In order to manage rivers for flood control, navigation, and irrigation governors appointed special staffs to build, operate, repair, and oversee the proper use of projects (Rost, 2015). Because water and water courses were considered communal assets for which actions and mis-use by some could adversely affect the welfare of others, provincial governments found it necessary to establish laws and to ensure that dams, sluices, canals and other water works were operated for common benefit. In short, water governance in Mesopotamia as in other parts of the Mediterranean world was partly exercised by an elite. However, establishment and maintenance of infrastructure was shared with

representatives of the user population through local management of hydraulic installations under the authority of a “hydraulic community” (Braemer et al., 2010).

Laws acknowledged that these systems could not be operated, nor maintained, by a single individual acting alone. Moreover, they tended to emphasize the liability of individuals, and thus, their obligation to compensate those harmed by actions that caused damage or loss due to misuse. In short, the perceived need to require compensation for failure to safeguard, secure, and maintain waterways and water infrastructure was a key element of water governance practices in Mesopotamian societies (Kornfeld, 2009: 12).

Prior to the introduction of locally managed irrigation, Mesopotamia had low water supply. Spring floods brought silt as a result of snow melt in the highlands of Anatolia into low-lying regions, clogging rivers and streams. Moreover, much of the region suffered from poor soil and salinity. Harnessing the Tigris and Euphrates supplied clean, reliable water, allowed crops to be grown where water was not naturally available, and enabled people to make the transformation from hunter-gatherers to farming – especially given the need for irrigation year round (Kornfeld, 2009: 9) (see Figure 3.2).

Figure 3.2 about here

Early innovations – especially with regards to irrigation – also contributed their share of environmental problems and thus, public concerns: another parallel with modern innovations. Despite the attention paid to these system’s governance by paid inspectors who repaired damages to infrastructure and sought to ensure that farmers did not misuse the system, high soil salinity eventually diminished agricultural productivity. In other cases, spring flooding filled canals with silt, eventually diminishing the capacity of irrigation systems and their functioning.

In contrast to Mesopotamia where the major preoccupation was the need for water innovations to sustain agriculture, Rome was more of an innovator with respect to urban water provisioning. The city's first major aqueduct was constructed in 312 BC by Appius Claudius Craecus, a patrician censor (a public official charged with, among other things taking a census of the population). While a growing population was one impetus for building aqueducts and other public works, it was not the only one. Typhoid fever, malaria, sewage disposal, and other problems prompted a search for various innovations to protect public health. Prior to the building of aqueducts, Rome had constructed large sewers along roadways to carry away human and animal wastes. However, when rainwater proved inadequate for this task, a more efficient source of water to flush-away wastes accumulating in these sewers had to be found.

Craecus oversaw two other superintendents of senatorial rank who served as technical advisors. This technocratic triumvirate was assisted by staffs of bookkeepers, guards, mathematicians, and architects who were invested with responsibility for determining the quality of any water source to be diverted to the city, performed medical exams of current users of these sources to ensure they would be safe for large-scale use, and oversaw the labor of thousands of Greek, Italian, Hebrew, Arab, Spanish, English, French, and German slaves who actually built these projects (Man and Water no 1, 1970: 5). In addition, "branch lines" ran from the main aqueducts in Rome and other cities in order to provide water to rural, agricultural communities whose produce supported cities supported these cities' populations (Kamash, 2012).

The Aqua Appia, named for Craecus, established several governance precedents affecting later water projects, including Rome's famed public baths. These included close attention by public officials – including the emperor – to future water needs, formal drafting of construction plans, and most especially, competent supervision of projects. The latter is exemplified by the

appointment to the office of water commissioner of the famed Sextus Julius Frontinus by Emperor Nerva. While the office itself was established by Agrippa – probably in 33 B.C., by the time Frontinus was appointed to the office, corruption and faulty business practices were widespread, necessitating political reform (Rogers, 2018: 12).

Frontinus’s reign was noted for his personal commitment to curtailing water theft; a fervent preoccupation with turbidity, purity, and palatability of water; and, dedication to long-term planning. Under his seven-year regime, water users were required to obtain licenses, public fountains were strictly limited in number, breaking into channels was made illegal and subject to heavy fines, and inheritance of water rights was banned (Man and Water no. 1, 1970: 22-3; Biswas, 1985). Figure 3.1 depicts the elaborate water system of Rome circa 1st Century A.D.

Figure 3.3 here

Governance of Rome’s water system was widely approved by the public. Historians and archeologists have determined that Rome’s water governance system was undergirded by much more than the palpable benefits provided by water services. It was supported by an underlying *water culture* characterized by widely shared values over water and water use. The latter included a fondness for the “utilitarian and restorative powers” of clean, abundant, and flowing water; acceptance of the distinction between private and public water sources – the latter seen as legitimately subject to regulation and management on behalf of a broader public good; a common aspiration to use and display water in beneficial ways (Rogers, 2018); and an ongoing fear of *hydraulic insecurity*. The latter led to preoccupation with harnessing waterways and water sources to assure protection from riverine flooding and weather-induced water shortage (Purcell, 1996). The theme of security strongly parallels contemporary water innovation governance concerns, as we shall see.

In addition to irrigation and domestic and urban supply, antiquarian polities exploited water resources for canal building and other navigational improvements and harnessing of water for power (e.g., milling of grain). These enterprising activities, particularly in China and parts of the Middle East, led to water quality degradation from river siltation caused by removal of stabilizing rock (Mithen, 2012). Such impacts underscore tension between water regulation to protect public welfare on one hand, versus promotion of elite economic interests on the other.

Again, Rome provides a well-documented illustration. Aventicum, an ancient city of around 20,000 in modern-day Switzerland near the shore of Lake Murten was a regional agricultural center. Archaeological evidence shows that residents cleared the landscape around the city for farming and to expand urban population. Nutrients eroded from the intensively-cultivated and irrigated landscape found their way into the lake, causing it to become devoid of oxygen and suffocating lake fauna. Pollution continued right up through the late Roman Empire, around 300 CE, and natural conditions were not restored for centuries (Joel, 2018) – a harbinger of more modern nutrient problems caused by irrigation.

In sum, in many ancient polities decisions over water and water innovations formulated by public officials were infused with moral weight by virtue of these officials' perceived role as guardians of public welfare (Mithen, 2012). Decisions was framed by custom, ethics, culture, and in some cases even religion in defining “just” ends for water use and the appropriate means by which state power should be exercised on behalf of water as a public good (Linton, 2010; Arnold, 2017). Water governance was closely linked to concerns over public health, hygiene and well-being. This established a precedent for later practices.

Toward modern governance: water quality innovations take center stage

As societies began to modernize, water governance continued to undergo refinements reflecting the growing complexity of decision-making on environmental issues. The increasing number of stakeholders demanding a voice in water provision and treatment is one example of this growing complexity. A second source of change was the advent of water stress – initially manifested on a local or regional scale as population centers grew in size and subsequent impact on local water sources. Urban growth generated stress in three major ways.

First, it generated large volumes of animal and human wastes that, untreated, contaminated local wells and streams. Second, low-density horizontal development, popularly referred to as urban sprawl, led to the creation of large impervious surfaces through street and commercial district paving (contributing to pollutant runoff and diminished groundwater recharge). And third, increased population led to dramatic increases in the overall consumption of water per capita as societies modernized and as more water was consumed for the production of food, fiber and by the 19th Century, energy – a trend that has continued well into our own era (Satterthwaite, 2000).

As awareness of the advantages accruing to public health in treating, purifying, and intercepting pollution from waterways grew, a broad change in public attitudes and decision-maker expectations regarding the proper balance between encouraging enterprising interests on one hand and fostering health and environmental well-being on the other. Adopting protective policies was viewed as a kind of check upon economic excess and a means to link science and engineering to risk-based regulation of water. Cumulatively, these policies fostered various social, cultural, economic, ecological and institutional changes which reflected growing awareness that clean water is essential to public health and well-being (Rotmans et al., 2001; Loorbach and Rotmans, 2006).

By the late-19th Century, this evolving awareness and set of societal changes resulted in new treatment and waste management innovations. A key feature of these innovations was a widespread attitude change in mass society facilitated by the growth of chemical engineering, public health, and other fields of scientific endeavor: a conviction that sewage was not something to be simply collected and transported away, but to be *treated* so as to remove contaminants. This latter innovation – first introduced in large metropolitan areas such as London – gave rise to a newer conception of risk: from a mechanistic conception of health and environmental impact measured through dose-response models used in epidemiology to a broader conception that embraces *public trust* in governance institutions charged with managing water and wastewater, *confidence* in the ability of technologies to measurably improve sanitary conditions, and *concern* with stigma and other adverse impacts to quality of life stemming from living in unclean environments (Huitema, et al., 2009; Renn, 2017).

There is a final issue that arose during this era which is also important to consider with respect to its impacts upon water governance: growing privatization of water services. For much of the modern era, in part as a result of concern with adequate infrastructure to supply and treat water to ensure its health and purity, publicly-owned water utility districts were the most common means of providing water services. In recent decades, however, a number of communities have turned to privatization as a means of reducing costs and, in some cases, improving service. Privatization has become a target of those who contend the transformation of potable water into a marketable commodity exemplifies the growing concentration of power over water in fewer hands, and the diminishing of water access as a basic human right, especially in developing countries (Bakker, 2010).

Giant water projects in Ethiopia, South Asia, and elsewhere, and growing control over municipal supplies in India, the Philippines, and parts of Africa and Latin America are usually cited as examples of projects that favor the interests of international investors and large commercial enterprises. However, local governments worldwide are increasingly relying on public-private (i.e., corporate) partnerships to furnish water, especially in cities, making categorical distinctions between private and public control problematical at best, and simplistic at worst (Morgan, 2012; Lu et al., 2014; Robinson 2013). Water improvements indirectly contribute to this privatization trend, since innovations like desalination are becoming controlled by a small global network of private companies (Williams and Swyngedouw, 2018: 8).

Human rights NGOs point to evidence that charges for water services are consistently higher in places where water services are corporately controlled. Moreover, these corporate interests tend to hold an economic monopoly over water sources and services – not only in cities, but in entire basins where water rights can be diverted after purchase (Baer 2015; Shiva 2009). They also rightly note that governments favoring so-called “market-friendly” policies toward water management – such as Chile under the extreme neo-liberal policies of the former Pinochet dictatorship – redefined water rights by formally transforming them into private property (i.e., the 1981 Water Code). This policy allowed the unfettered buying and selling of water which accrued to the advantage of large mining companies and irrigated farms with the resources to monopolize control of water. As a result, indigenous peoples were disenfranchised until reforms adopted in the 1990s restored their ownership of ancestral lands and water rights and compensated them for their loss of resources (Bauer, 2005; Gallardo, 2016).

Two conclusions may be drawn from privatization relevant to the governance of water innovations. First, tensions between risks to society (including quality of life) and economic risks

to businesses are increasingly being resolved at levels of governance where private interests that build and operate desalination and reuse facilities are in inordinately powerful negotiating positions. They often collaborate closely with public agencies anxious to satisfy water needs but short on capital. Growing fiscal pressures on governments facilitate the privatization process, especially for desalination (Williams and Swyngedouw, 2018: 14).

Second, polities keen on privatization of water services are generally preoccupied with water security due to climatic, geopolitical or other concerns. They view privatization as an efficient, expeditious means of achieving security, and they place confidence in the private sector's capacity to safely manage innovations. This is partly ascribable to the priority placed on national control over water supplies. It is also facilitated by a political culture that promotes a high degree of trust in technology. The two cases we presently discuss illustrate both issues.

Governance of water innovations I – Singapore

Singapore affords a unique case study of water innovation governance. Highly dependent on desalination, wastewater reuse, and rain-water harvesting through urban design and land-use adaptations, this island nation serves as a robust laboratory for understanding water innovations can be implemented on a broad scale through political will and necessity. The country has not only transformed itself into a water innovation hub in less than 50 years, but it has done so while also maintaining a high degree of public consensus over these innovations.

Singapore has a population of 5.7 million living on a landmass of 720 km,² giving it the world's second highest population density (7,804/km²) of any nation-state. This density is one factor explaining its choice of water options. Its paucity of land area leaves little space for surface reservoir storage – an alternative the country has aggressively pursued. Moreover, having

few natural freshwater sources other than rainfall to support its burgeoning population, water security has long been one of its highest political priorities.

Singapore traditionally acquired its water from the state of Johor in neighboring Malaysia, a practice that began in the late 1920s before the former's independence from Malaya (in 1965). Under the terms of two bilateral treaties dating to 1961 and 1962 Singapore was granted, through 2011, the right to almost the entire flow of two rivers – the Tebrau and Scudai. The agreements allowed Singapore to pay land rent on their watersheds while, in turn, supplying Johor with treated water equivalent to 12 percent of the raw water it drew. The 1962 agreement provided one other innovation: Singapore could impound and use up to 250 million gallons/day from the Johor River until 2061 (Tortajada and Buurman, 2017: 1; Ng and Teo, 2020: 271).

However, not long after these agreements were consummated, disputes arose over water pricing and control. Veiled threats by Malaysia's first prime minister to cut-off water supply if Singapore's foreign policies did not accord with the former's interests – coupled with other officials' warnings that existing water agreements could be declared "null and void" at practically any time – exacerbated fears of water insecurity (Ng and Teo, 2020: 272). These threats also served to re-awaken older memories of the 1942 Japanese invasion of Singapore and subsequent cutoff of its water as a means of forcing its capitulation. Both sets of events led Singapore to look for ways to reduce its dependency on Malaysia for water supply (Lafforgue and Lanouvel, 2015: 623; Asano and Bahri, 2011: 67)). (Figure 3.4)

Figure 3.4 about here

The drafting of a 1972 *Water Master Plan* initiated the country's first comprehensive attempt to address future water needs while reducing dependence on Malaysia through three innovations: desalination, recycled wastewater (i.e., NEWater) and a dedicated program of

catchment management for rainwater harvesting. The resulting strategy, referred to as the “Four National Taps” (i.e., continued, but diminishing, imports, desalination, rainwater harvesting, and wastewater reuse) instituted a planning process that viewed “. . . supply sources in their totality, (taking) into account other aspects such as water quality and production and management costs (Tortajada and Buurman, 2017: 2; also, Tortajada and Joshi, 2013: 288). Government agencies examined all aspects of water provision and sought wide-ranging, integrated solutions.

Specific action to introduce alternative water sources began in 1998 through a joint effort by the country’s principal water agency, the Public Utilities Board or PUB, the Ministry of the Environment, and the National University of Singapore. The three entities explicitly touted several governance-related objectives in their work. These included a “parallel emphasis on supply and demand management, including wastewater and stormwater management; institutional effectiveness; planning on long time horizons; and an enabling environment which includes a strong political will, effective legal and regulatory frameworks, and an experienced and motivated workforce (Tortajada and Buurman, 2017: 2).” (Figure 3.5).

Figure 3.5 about here

An early product of these efforts was the *Singapore Water Reclamation study* (NEWater Study). Its objective was determining the suitability of re-using wastewater that has undergone stringent purification and treatment through advanced dual-membrane (microfiltration and reverse osmosis) and ultraviolet disinfection. As a result of the study, PUB commissioned NEWater factories at the Bedok and Kranj wastewater plants in 2002, while in 2004 a third facility was opened at the Seletar Water Reclamation Plant. All three began supplying NEWater to manufacturing facilities in Singapore (Asano and Bahri, 2011: 67). A total of five reclamation plants across Singapore now supply 40% of the country’s water needs, a figure projected to

increase to 55% by 2060 – before expiration of the Johor diversion agreement. Production costs are less than half those of desalinated water (Dueriss, 2013; Lim and Seah, 2013).

NEWater is mainly used for industrial and commercial purposes, although following the recommendations of an international review panel in 2002, it has been introduced for indirect potable use. Since its purity is higher than tap water, it is especially practical for certain types of industrial manufacturing processes important to Singapore's economy, and which require ultra-pure water. Thus, NEWater is mostly supplied to various microprocessor wafer fabrication plants and other semi-conductor industries (PUB, 2021; Tostada and Nambiar, 2019) – giving added meaning to the phrase “fit for purpose.”

Despite the fact that NEWater is pure enough for potable consumption, it is used only sparingly and indirectly for domestic supply. Small amounts of NEWater are blended into raw water reservoirs, naturalized and further treated in conventional waterworks to create drinking water. This is mostly done during dry months. Some 2.5% of the country's wastewater is consumed as drinking water, a figure that has been only incrementally increased over time (Lafforgue and Lanouvel, 2015: 627; Lim and Seah, 2013: 59; Tortajada, 2020). We discuss the significance of this issue in the next section.

Desalination is another major component of Singapore's water mix. The first desalination facilities were built in 2005 and 2013, respectively, and three plants are currently in operation having a combined capacity able to meet some 30% of the country's water demands. Two additional plants are slated for completion by 2030. In 1998, when the country committed itself to an action plan to implement water innovations, it decided to implement reverse-osmosis (RO) as its favored approach, similar to most other adopters internationally (Ng and Teo, 2020: 274).

The plants are designed, built, owned and operated by private-sector companies, from which PUB purchases the water. The Tuas desalination plant, with a capacity of 136,000 m³ per day (36 MGD) disposes its concentrate through a specially designed ocean outfall (Voutchkov, 2011; 500). Because of their high energy-consumption, the plants are used as backup facilities to handle spikes in demand – Tuas has its own power plant which, by generating surplus energy, may help reduce Singapore’s energy costs for desalination (Lafforgue and Lanouvel, 2015: 624).

While all of Singapore’s water innovations are costly, the especially high cost of desalination – a major source of drinking water – is largely responsible for Singapore’s further refinement of a significant demand-side innovation: an increasing block rate fee structure to encourage conservation and reflect the true costs of water provision. While bloc rate pricing was first introduced in 1973 and targeted water waste, in 1991 and again in 1997, revisions to this pricing policy were adopted – with the latter increase explicitly based on the marginal cost of desalination (Tortajada and Buurman, 2017: 5). This conservation “tax” has been applied to all water consumed in Singapore. A final means of assuring the economical use of desalination is by seasonal alternation with rainwater harvesting. While the latter is used mostly during the wet season, the former predominates during dry periods (PUB, 2012: 8).

Rainwater harvesting has proven to be perhaps the most innovative of all approaches Singapore has adopted. This alternative has been aggressively pursued through both catchment management and a complex land-use regulatory regime. Through a network of rivers, canals and drains, rain that falls on 65% of Singapore's land area is channeled to 17 reservoirs (PUB, 2020). This catchment area is slated to eventually increase to 90% of the country. Early reservoirs were constructed in the Central Catchment Area, a relatively pristine and protected watershed. However, subsequent reservoirs were developed, first, in the less densely developed western part

of Singapore with the last phase of storage being built in the more densely developed eastern part, including the Marina Reservoir in the Central Business District.

Even though sanitary and storm sewer systems are segregated, constant monitoring of the latter is necessary to mitigate local flooding, a necessary safeguard since Singapore has high annual rainfall. Some of the country's catchment areas have been transformed into urban recreation sites to bring Singaporeans closer to water, and so that they can better appreciate and cherish the resource. The Marina Reservoir is the city's largest catchment and also serves as a major recreational site (Water Technology Futures, 2015: 46).

Because harvesting water from urban catchments engenders numerous water quality challenges, precautions have had to be instituted ranging from demarcation of protected areas to banning of pollution-causing activities. A *Water Catchment Policy* (adopted in 1983) limited development within catchments to 34.1% of land area, dwelling unit density, instituted rigorous pollutant control regulation, and also began utilizing water treatment to ensure that lower-quality stormwater could be safely re-used (Tortajada and Joshi, 2014: 1768; Ng and Teo, 2020: 273; Goh et al., 2017). An *Active, Beautiful and Clean (ABC) Waters program* launched in the early 2000s seeks to slow runoff and utilize current rainwater harvesting approaches more effectively, including bio-retention ponds, bioswales and floating wetlands (Tortajada and Buurman, 2017; 3). Singapore remains one of the few countries in the world to harvest urban storm-water on a large-enough scale for potable supply.

Figure 3.6 about here

Salient aspects of governance: process, power, purpose, public confidence

To fully understand water innovation governance in Singapore, we must first recognize the uniquely high degree of centralization of decision-making which characterizes every aspect

of the country's water management system. Centralization is not only a fundamental structural feature of water governance, it also dictates how decision-making *power* over water is exercised, and the *purposes* to which power and process are directed.

Prior to independence, in 1963, Singapore's preoccupations with water security and economic development hastened efforts to repose responsibility for all basic utilities – water supply, electrical power, and gas – in a single Public Utilities Board (PUB) (Tortajada and Joshi, 2014: 1765). PUB's Water Department was responsible for water supply, drinking water treatment, customer distribution and delivery, and system maintenance. By the 1980s, responsibility for wastewater management was also assumed by PUB and in 2001, the agency became a statutory board under the country's Ministry of the Environment, subsequently renamed Ministry of the Environment and Water Resources (MEWR) in 2004 (Tan et al., 2009).

MEWR and PUB together constitute an archetypal model of unified, technocratic governance which has as its principal objective providing integrated management over virtually every aspect of Singapore's water. Some observers suggest that PUB "is one of the few agencies in the developed or developing world that manages all aspects of water resources, including resource management, supply, sanitation and drainage." Moreover, they note, PUB's considerable *power* is legitimized (or to use our previous language, has *discursive legitimacy*) because it's internal operations and external benefits resonate with the country's political culture. In short, PUB embraces "anti-corruption;" its management style is viewed as highly effective; and, its personnel appointments are merit-based and its staff are competitively remunerated and highly trained (Tortajada and Buurman, 2017: 7).

This characterization is echoed by reports produced by PUB which tout such achievements as PUB's patenting of an internationally-acclaimed desalination system (variable

salinity plant) suitable for both brackish and seawater, its investment in basic as well as applied research on tropical rainfall and its impacts on system reliability, and its rigorous education and training programs designed for general workforce development (PUB, 2012). Despite being internal self-assessments, there is no reason to discount PUB's claims, nor their broader governance impacts. The high degree of institutional integration PUB has achieved has directly resulted in the development and introduction of water innovations which have been deemed safe, secure, and trustworthy. Singapore's fully sewerage system enables collection of waste and storm water for reuse, while recycling plants initially developed to treat wastewater to high-standards now provide reliable supplies to industry. Moreover, integration of water and wastewater management in a single agency has enabled Singapore to develop these large-scale recycling initiatives more easily than would otherwise have been the case (Lim and Seah, 2013: 59).

With respect to the purposes of water innovation policy, aside from the obvious goals of water security, independence, and renewability of its water supply – all elements of resilience, another distinctive attribute of water innovation governance in Singapore is the country's concerted focus on *technology development and diffusion*. Water technology development is supported by a network of organizational connections among agencies and private sector entities that are directly funded by the state. PUB collaborates with private sector enterprises and a variety of research institutes, over 20 of which are directly connected to PUB. In recent years, a major goal of these collaborations has been to identify lower-cost alternatives for desalination and recycled wastewater production through promotion of various energy-efficient processes.

The Ministry of Environment and Water Resources has established an *Environment & Water Industry Development Council* (EWI) led by PUB, while the country's *Economic Development Board* has formally declared Singapore a global *hydrohub* – or, center for

“business opportunities and expertise in water technologies.” A bi-annual *Singapore International Water Week* commonly attracts better than 200 firms in the desalination, recycling, and water treatment fields (Tortajada and Buurman, 2017:7). These activities underscore how water innovations are viewed as sources of entrepreneurial growth and export capital. Moreover, there is an explicit focus on both basic (i.e., upstream) research and downstream (i.e., applied technology development) in its innovation ecosystem (PUB, 2012).

One indicator of the economic potential of these collaborations is the fiduciary relationship between PUB and Meiden Singapore, a subsidiary of Japanese electrical components and ceramic membrane manufacturer, Meidensha Corporation. This cooperative agreement has led to commercialization of a technology which helps to collect, treat, and ultimately reuse sewage sludge. First operated on demonstration plant scale, the development uses ceramic membranes to treat and recycle industrial used water, enabling achievement of a “consistent, high-quality output of recycled water (Water Technology Futures, 2015: 32).”

Another example of an enterprising policy is a provision in the country’s *Public Utilities Act* which stipulates that all water fittings and certain products (e.g., taps, mixers, washing machines) must bear labels indicating their water efficiency rating. This regulation is a means of encouraging efficiencies in water products, and thus serves to encourage the manufacture of water-saving products. In short, PUB and other related entities have spearheaded the growth of a vibrant water industry in Singapore which has taken on the financial risks of supporting innovation development, fostered private-public partnerships in innovation development, and advanced technology diffusion (Water Technology Futures, 2015).

Singapore’s limited use of reused wastewater for potable consumption is, in fact, a notable innovation in itself. Recycled effluent is widely utilized for industrial applications,

mostly for semiconductor manufacturing as earlier noted. Nonetheless, Singapore's government has gone "out of its way to build public confidence and to show that NEWater (is) perfectly safe to drink" (Ng and Teo, 2020: 274). A wide-range of activities has consistently disseminated this message. These include media-savvy public education and information campaigns, public outreach efforts to promote the safety of NEWater through highly-publicized expert review panels, a popular visitor center used by public schools and general public tour groups located at the Bedok NEWater plant, and other efforts (Lim and Seah, 2013: 60; Ng and Teo, 2020: 274).

With respect to expert review, independent validation studies of NEWater's purity and safety have established that the recycled effluent produced by PUB has had no adverse effects on fish with respect to carcinogenic or estrogenic effects, while no tissue abnormalities or other adverse health effects have been found (Khan and Roser, 2007; Mosher and Vartanian, 2015: 143). Following early forays into recycled water use, Singapore went to considerable lengths to study reuse efforts in Southern California and elsewhere to learn how to improve its implementation and later, to refine its own technologies (Tortajada and Nambiar, 2019: 7). Efforts have even gone to the length of semantic engineering – employing the terms 'used water' instead of 'wastewater', 'NEWater' instead of 'recycled water', and 'water reclamation plants' instead of 'wastewater treatment plants' (Tortajada and Buurman, 2017).

Small quantities of NEWater are bottled and distributed to the public. The bottles are not for sale, and MEWR says it has no plans to alter this practice. Instead, they are distributed at major events to help raise awareness about NEWater. In sum, Singapore's NEWater program has engendered favorable public perception and positive domestic media coverage – largely due to its role in moving Singapore toward water independence and water security, reinforced especially during recent dry spells due to the buffer provided to reservoirs through NEWater

(e.g., Smith et al, 2018; Tortajada and Nambiar, 2019: 21). NEWater’s relatively limited use as a potable source is likely due to a combination its greater economic value as an industrial manufacturing asset, and the effective roles played by desalination and rainwater harvesting in providing ample public supply.

A final governance observation regards public participation. Given the centralization of water governance, public engagement with respect to water innovations in Singapore, including wastewater reuse, is largely unidirectional. Invitations to engage emanate from PUB and other agencies downward to the public: the reverse is rarely the case. Nonetheless, public engagement as a tool of decision-making remains broadly important. In the early 1990s, Singapore prepared a *Green Plan for Environmental Protection and Improvement* which was formulated with input from various government agencies, ministries, private sector groups and directly – by members of the public at a series of hearings.

Best characterized as a “sustainable city” visioning effort, extensive public consultation encouraged policy-makers to adopt a similar process for other environmental campaigns. While this experience marks the initiation of public consultation as an engagement tool for environmental policy-making in Singapore, its goals have largely been focused on public education and raising awareness about water self-sufficiency (Tortajada and Joshi, 2013; 2014). Consistent with the country’s technocratic approach to water governance, and its wide consensus over water policy, such visioning appropriately fits Singapore’s political culture.

Governance of Water Innovations II – Israel

Israel’s accomplishments in water resources development and innovation have closely paralleled other technological, economic and administrative achievements. Like Singapore, the country is heavily reliant on recycled wastewater, which is used mostly for agriculture, and

desalination – a major source of public and municipal supply. In pursuing these and other wide-ranging innovations: from rainwater harvesting to demand-side and water loss reduction strategies, a preoccupation with water security has been a prime policy motivator.

After achieving independence in 1948, Israel pursued a variety of approaches to water security building, in part, on practices first initiated during the period of Zionist-inspired settlement. As one observer has noted, “water entered the collective consciousness of Zionist pioneers in (many) ways,” including explicit references to the need to develop water resources articulated by leaders such as Theodore Herzl, and by dances and other folk practices honoring water’s importance. The latter were first embraced by early Jewish settlers (Aliyah) in Ottoman Palestine during the late 19th and early 20th Centuries (Siegel, 2015: 14-16).

Although occupying a region where annual rainfall varies from 1,000 millimeters per year in the north to less than 100 millimeters in the southern Negev, the country is, on the whole, climatically semi-arid to arid (Feitelson, 2013: 17). Average annual water supply is about 250 m³ per person, or 50-55% below what experts regard as the threshold for severe scarcity (Tal 2006; Luckmann et al., 2015; Greenwald, 2021). Moreover, future climate patterns are likely to be no better – while population (now 9.3 million) continues to grow. Rainfall in eight of the 10 years from 2004 to 2014 was below average, and climate variability is expected to cause temperatures in the region to rise 5 to 11 degrees Fahrenheit by 2100, reduce rainfall by some 30 percent, and increase the intensity of drought (Chenoweth, 2011; Sowers et al., 2010).

Major surface water sources include the Jordan River, whose mainstem and tributaries are shared – in part – with Syria, the West Bank and Jordan, and a series of mountain and coastal aquifers shared with the West Bank and Gaza. Various dams and canals in Syria and Jordan, including the Unity Dam on the Yarmouk river on the border of Syria and Jordan, the King Talal

Dam in the Zarqa Basin and the King Abdullah Canal running east and parallel to the Jordan River – together with Israel’s diversions of the Sea of Galilee – have all contributed to an unsustainable diversion of water throughout the Jordan basin (Kool, 2016). (Figure 3.7).

Figure 3 .7 about here

At the time of independence, modest water development had occurred at local scales sufficient for supporting small-scale kibbutzim and urban settlements. Soon thereafter the central government began investing heavily in water infrastructure to support the needs of a burgeoning population and to promote large-scale agricultural development (Feitelson & Fischhendler, 2009; Feitelson, 2013). Decision-makers also declared the provision of water to be a matter of national security, requiring a unified system of governance to pursue strategies able to guarantee reliable provision in the face of various stressors. From the early 1950s, Israel’s Water Planning Authority, an agency committed to water project development and its connection to agricultural cultivation, served as an active centralizing force (Shlaim, 2014: 79).

Linkages between water resources development and national security are exemplified by conflicts with Syria over withdrawal rights from upstream tributaries of the Jordan River. In the early 1950s Israel sought to divert these waters, lying in the 1948-designated demilitarized zone separating the two countries, to support agricultural expansion in the Galilee. The country’s *Water Planning Authority* collaborated closely with the Defense Ministry, which skirmished with Syrian forces in the region, animated partly by larger “geo-political concerns” (Feitelson, 2013: 18; also see: Shlaim, 2014: 93-5). Discord arose again when, in June 1964 Israel began diverting water from the Sea of Galilee through its recently completed National Water Carrier. Syria responded by undertaking a diversion of the Jordan (Morris, 2001: 303).

In this same period, Israel embarked on three major water innovation tracks: conveying freshwater from the north to cities and farms in the south; harvesting rainwater; and reusing wastewater. While conveyance is thought of as a conventional approach to water supply, the National Water Carrier must be acknowledged as Israel's first major water innovation and a precursor for others. An ambitious aqueduct system, the project delivers water from the Sea of Galilee to population centers near the coast, including Tel Aviv, as well as portions of the Negev.

During Israel's first water governance era, extending from 1948 to around 1964 (when the National Water Carrier was completed), "ideology dictated water development" (Galnoor, 1978: 345). Water investments were viewed as necessary building blocks to assure economic growth. Given the nation's urgent interests in food and water self-sufficiency, development of a national irrigation system was a top priority. The state's heavy irrigation subsidies amounted to between 3-5% of total gross capital until the 1970s (Becker & Ward, 2014; Galnoor, 1978).

Also during this early period, plans were initiated for innovations aimed at reducing the underlying causes of Israel's water stress. In effect: given limits on natural supply, how could water use be lessened and water-use efficiencies increased? In the agricultural sector, the most significant of these innovations was drip irrigation, which enabled higher crop yields with lower evaporation rates and less overall water use (Feitelson, 2013: 22) (Figure 3.8).

Figure 3.8 about here

The reuse of wastewater as a supply source for crop irrigation arose more gradually. A 1970 cholera epidemic in Jerusalem sparked public concerns over the country's inadequate sewage treatment programs. However, serious study of the feasibility of using sand as a medium to augment secondary treated wastewater, principally for groundwater basin replenishment, began in the 1950s at the Shafdan wastewater facility serving the Tel Aviv metro region.

Paralleling these efforts, the Ministry of Agriculture began advocating for the use of reclaimed wastewater, from Shafdan and other treatment facilities, for agricultural use (Feitelson, 2013: 21; Siegel, 2017: 82-3). Following extensive testing, reuse became widely adopted in Israel within a few years, facilitated by Israel's 1959 Water Law which grants the state wide authority over water and wastewater allocation and control (Luckmann et al., 2016).

Still reliant on sand filtration, or *soil aquifer treatment*, wastewater is treated at Shafdan and elsewhere via a multi-step process terminating in aquifer storage. Israel currently reuses approximately 90 – 95 percent of its water, mostly for crops (accounting for 55% of total agricultural water use), a small portion for industry, and the remainder to augment in-stream flow for rivers like the Yarkon, a major artery that passes through Tel Aviv, and for fire suppression. Some 67 wastewater treatment facilities employing tertiary treatment distribute the reused effluent to remote rural areas (Fluence News team, 2020; Simpson, 2018; Greenwald, 2021).

Reused wastewater is not consumed as drinking water— as is the case in Singapore – a decision made many years ago by the Ministry of Health (Weinberg, 2021). Nonetheless, Israel's wastewater reuse practices are not without their share of concern. Within the past decade academic studies reported by Israeli media have determined that fruits and vegetables grown in soils irrigated with reclaimed wastewater expose consumers to minute, barely detectable quantities of pharmaceuticals: in particular carbamazepine, a xenobiotic (Paltiel et al., 2016; Shamah, 2016). In short, consumption of produce irrigated with treated wastewater “provides data that could guide policy and risk assessments (Paltiel et al., 2016: 4476).” The country's current reuse treatment standards, set in 2010, mandate removal of salts, boron, metals, organics, and pathogens through a combination of tertiary treatment and disinfection (Zask, 2021).

Social science research suggests that public support for wastewater reuse depends to some extent on the degree of perceived direct bodily contact. On the whole, Israelis support reuse, and they acknowledge its water saving benefits, economic advantages, and environmental value but they are reluctant to consume it directly (Friedler et al., 2006). However, at least one revealed preference study finds that given a choice, Israelis prefer produce irrigated with desalinated rather than recycled wastewater and, more to the point, would prefer their produce be irrigated with conventionally-sourced freshwater (Ellis et al., 2020). A more practical concern is that the sustainability of wastewater reuse will eventually encounter an upper-bound. As population growth plateaus and conservation continues to improve, there will be less wastewater to recycle, making reliance on other options necessary (Siegel, 2017: 92-3).

Water harvesting and storage via rainfed reservoirs is another more recent strategy, supported through donations solicited by the Jewish National Fund, a charity established in 1901 which has long been active in reclamation-related activities (Morris, 2001: 109). Starting in the 1980s, over 250 reservoirs were established in wetter regions such as the Galilee, allowing the system to collect 125 million cubic meters of water per year or some 34 billion gallons annually, roughly 7% of Israel's total water. Combined, these reservoirs can meet the needs of over 1.2 million people each year. In times of drought, especially, reservoirs store recycled water and serve as basins to catch run-off water when it rains. More than 50% of Israel's reused wastewater for agriculture is stored in these reservoirs (Jewish National Fund, 2004).

Desalination was first contemplated for adoption in the mid-1960s, but was initially rejected due to its high cost. After securing control of the Golan Heights during the 1967 war, the country suddenly gained access to the Banias spring, an upstream feeder of the Jordan, further diminishing the urgency of desalination (Feitelson, 2013: 200). Following a severe drought in the

late 1990s, however, the option was revisited. A Knesset committee concluded that the country faced an urgent water shortage as well as a political crisis caused by fragmented, poorly coordinated water governance efforts (i.e., a lack of integration among the various agencies charged with different aspects of water quality, protection, and supply).

The committee recommended aggressive pursuit of desalination in August 2000 and also advocated governance reform of the entire water sector (The Parliamentary Committee 2002; Feldman, 2017). Emergency powers were granted to allocate water and develop new projects, and “...an independent, professional water authority,” the *Israeli Water Authority*, was established. Structured as an inter-ministerial committee with super-ordinate powers over water management and allocation, it replaced the State Water Commission in 2007.

Israel’s first desalination facility was built at Ashkelon with subsequent plants at Hadera and Sorek – currently the world’s largest desalination plant. Targets for desalinated water production have gradually increased from 505 million m³ in 2013 to 750 million m³ by 2020 and 1.1 billion m³ by 2030 – some 85 -90% of municipal and industrial supply (Israel Accountant General, 2020). The cost of desalination, roughly \$0.60 per 1,000 liters (1 cubic meter) for seawater and \$0.30 per cubic meter for brackish water, has become a politicized issue in recent years as pressures to “de-subsidize” water use have gained prominence. Heavy government investment in desalination has contributed to a surplus of water production due to the large number of plants built since the early 2000s. However, “sunk costs” of these plants continue to be levied on water users – a situation that might not exist if the country had adopted an “optimal” desalination output 60% lower than current levels, according to one study (Reznik et al., 2016). Other research suggests that, regardless of cost, the benefits to municipalities and industry from

access to high quality desalted water, including assurance against shortage, and the fact that Israelis can afford it, more than compensate (Dreizin, 2006).

Several measures to reduce water demand have also been pursued. As in Singapore, many of these demand-side measures were partly sparked by massive adoption of desalination and concern over its cost. To set the stage for adoption of desalination, an aggressive program was begun to cut annual water quotas for farmers in the early 2000s, ending decades of subsidies. The Water Authority adopted a two-tiered household rate system: those who use more pay slightly more per unit (discarding an antiquated tax on surplus household uses). In addition, water saving devices have been widely distributed. Currently, water rates are uniform and progressive across the entire country, and vary by sector, with industrial and agricultural users paying less per unit of water (Greenwald, 2021).

An example of a commercially-successful and innovative technology in the water demand area is *Distant Meter Reading*, a tool that permits users and water agencies to intermittently monitor water use. While providing early detection of water losses in Israeli cities, it also helps lower customers' water bills (Siegel, 2017: 49-51). This and other demand-side innovations have been encouraged by another major institutional change introduced by the Water Authority: municipal utilities are no longer responsible for maintenance of local distribution systems. Local private corporations have been formed, and all monies collected by them are directly invested in infrastructure improvements. Water rates have also increased an average of 40 percent in Israel – providing another inducement to aggressively pursue water savings.

Salient aspects of governance: process, power, purpose, trans-boundary issues

Many aspects of water innovation governance in Israel are highly centralized, especially planning and implementation for desalination and wastewater reclamation projects. It could be

argued, in fact, that Israel's "circular" approach to water management: capturing wastewater from municipalities whose supply originates from diversion, desalination, and other sources, and then recycling it for agriculture, requires a highly-integrated management system. Concentration of decision-making process in a few agencies is an inevitable as well as desirable result.

Despite this tightly-knit system of water innovation governance, many facets of decision-making have become increasingly decentralized and distributed while also remaining largely technocratic in their operation. 21st century governance reforms in water policy in Israel have encouraged economic efficiency, entrepreneurial investment, and innovation partnerships between government agencies such as the Israel Water Authority and private sector enterprises, largely through *Mekorot*, the national company responsible for the distribution of water.

Establishment of the *Israel Water Authority* as successor to the *Israel Water Commission* in the early 2000s led to the adoption of marginal cost pricing for water services, an end to many forms of subsidization of water to farmers, and most importantly, establishment of a network of 55 municipal water corporations which removed political control over water services and wastewater fees from local elected officials, and helped foster innovations. Notable among the latter was introduction of devices to detect and avert local water losses and leaks, as well as "smart" systems to monitor overall system performance (Siegel, 2017: 46-8).

The most distinctive aspect of Israeli's water innovation governance system, however, may be its overall legal framework – one which has ensured that *power* over decision-making ultimately resides with the national government, and not with private entities or water users themselves. The pioneering Water Law of 1959 established a fully centralized water system for the country by providing the "legal framework for state control, protection, conservation, and regulation of the water supply" (Galnoor, 1978: 346). In effect, all the country's water, including

wastewater, raw sewage, and rainfall belongs to the state which has the power to allocate supplies to various users through licensing, rationing, and regulation of rates. The law also established what amounts to a command and control structure that has enabled the central government to aggressively pursue wastewater reuse, determine how much water each user is entitled to receive, and provide for a comprehensive national metering system. A further consequence of the law is that the national government, working with *Mekorot*, designated as the entity responsible for wholesale water distribution, holds a “natural monopoly” over water (Feitelson 2013: 20; Greenwald, 2021).

Like Singapore, commercialization of water innovations through public-private partnerships has become a cornerstone of Israel’s economy. Commercialization of innovations may be regarded as another core *purpose* of Israel’s water governance system (Siegel, 2017: 196ff). Notable examples are TAHAL, founded in 1952, an infrastructure company and spinoff of the government enterprise which built the National Water Carrier, and IDE Technologies – formerly Israel Desalination Engineering – founded in 1965. As part of the Government’s 1999 decision to build large scale seawater desalination facilities, IDE designed and built the country’s first large-scale facility in Ashkelon as well as the Hadera and Sorek facilities.

Both companies have invested heavily in water, energy, and other large-scale engineering projects worldwide. IDE was the principal vendor for the nearly \$1 billion Carlsbad, California desalination plant which went on-line five years ago, and is the largest RO facility of its kind in North America. Moreover, both companies have significantly expanded their original missions to become global engineering enterprises (Siegel, 2017: 118, 226). IDE Technologies operates, and has offices in over 40 countries and engages in desalination, industrial water supply and wastewater treatment well as energy-related projects, while TAHAL, since sold and now

headquartered in Amsterdam, is one of the largest infrastructure companies in the world and is involved in water, wastewater, energy, solid waste, and agricultural related projects in 30 countries (IDE technologies, 2018; Tahal Group, 2016).

A final governance issue with unique resonance in Israel is trans-boundary management of water innovations. As part of the 1994 Israeli-Jordanian peace treaty, the former supplies Jordan with 55 million m³ of water from the Sea of Galilee. Falling water levels in the Galilee, however, coupled with concerns over the continued decline of the Dead Sea, has led to discussions between the two nations – and the Palestinian Authority – on increasing water transfers to Jordan’s capital of Amman and a proposal to replenish the Dead Sea. This two-part plan entails, first, building a pipeline from the Mediterranean to the Sea of Galilee, thus permitting greater transfers of freshwater from existing Israeli desalination plants to Jordan and, second, construction of a desalination facility in Aqaba, Jordan (Figure 3.9).

Figure 3.9 about here

With an estimated cost of \$10 billion, two-thirds of the project’s cost would be split between Jordan and Israel with the World Bank funding the remaining one-third. Labelled the *Red-Sea/Dead Sea Project*, it’s objective is pumping water via a pipeline from the Red Sea to Amman, with a separate diversion to the Dead Sea (Markel et al, 2013). Cumulative actions by Israel, Jordan, and Syria have since the 1950s have led to the sea’s decline in peak flows by some 90 percent, and mineral extraction (chiefly by Israel Chemicals) has added to desiccation of the sea through the pumping of some 61 billion gallons of water per year into evaporation pools that leave behind huge quantities of potash, bromine and other chemicals (Policy Document, 2006). The Dead Sea’s importance as a tourism, recreational, and historic resource prompted this proposed reclamation project. Diplomatic impasse between Israel and Jordan over Palestine,

coupled with concerns over costs and possible adverse impacts from mixing desalination plant brine with Dead Sea waters have delayed the project and underscore how broader relations between polities affect the viability of innovations (Chazan, 2019; Katz, 2021: 179).

Less ambitious with respect to water innovation, but nevertheless of high political importance, under phase II of the Oslo Accord, in 1995 Israel, Jordan and the Palestinian Authority established a water infrastructure agreement intended to defuse conflict over water while opening the door to more equitable water sharing. The charter of the *Joint Water Committee* – renewed in 2017 – seeks to remove water and wastewater from the region’s cycle of violence and undertaking gradual steps to ensure provision of adequate water supplies to local communities in the West Bank and Gaza. Water and wastewater treatment systems are conjointly managed and Palestinians and Israelis mutually respond to demands to repair infrastructure in the occupied territories and to desist from harming anyone engaged in their operation or repair.

The 1995 agreement acknowledged “the existence of a water shortage for both sides and the need to develop and create additional sources of water” including recycling of sewage effluent and desalination. Moreover, an Israeli offer of a desalination plant in the Hadera area to supply water directly to the West Bank, and the sale of water from the Ashkelon facility for Gaza, Palestinian reaction has been understandably cautious regarding the water security implications of such joint ventures (Israel Water Authority, 2009: 4, 7). The 2017 extension of the Joint Water Agreement includes a strategic planning mechanism that will operate through 2040 and provides for new infrastructure to accommodate population growth and plans to permit more well drilling and extension of water transfers to Palestinians (Israel Water Authority, 2009; TOI staff, 2017).

Because the JWC has limited authority to address water sharing, or even to curtail further Israeli settlement in the West Bank, it has not generated a high degree of confidence among Palestinians (Selby 2013). Inequities in national allocation and sharing of water supplies has not been fully resolved, data on water availability remains opaque, and there is no policy coordination for the areas in greatest need (e.g., Gaza), and the Jordan River (Ehrenreich 2011; Schwind, 2019). Currently, some 6% of water in Israel is shared with Palestine and Jordan.

Three issues remain divisive and are likely to impede efforts to share water innovation benefits. First, Israelis consume on average three times as much water per capita as Palestinians living in the West Bank – with an even worse disparity for those living in Gaza. Second, the Palestinian Authority has argued that financial constraints impede development of both institutional capacity and infrastructure to ensure adequate water supply. And third, Israel contends that the amount of water it provides to the Palestinians exceeds the amount the Interim Agreement requires under Oslo. If there is an inkling of positive news in any of this, it is that violent conflict has not erupted over water in the region for decades, and that parties concur that other avenues toward a permanent solution must be found (European Parliament, 2016). What role water innovations might play in such a permanent solution remains to be determined.

Conclusions – Lessons for Water Resilience from Singapore and Israel

The ultimate goal of Singapore and Israel's water policies generally – and their implementing of various water innovations in particular – is resilience. Both nations have consciously sought to develop water alternatives to provide a stable, reliable supplies of water in the face of numerous stressors ranging from climate variability to population and economic growth. Moreover, their pursuit of these alternatives, further confirming their quest for resilience, began even before they achieved their political independence. As much as socio-demographic

and climatic factors drove them to seek resilient water options, the strongly felt need to insulate themselves from external threats to their water supplies has likely been the single most powerful impetus for their actions. For both polities, water security and water resilience have gone hand-in-hand.

We conclude by considering the efforts of these two polities with respect to choice of water innovation in light of our four resilience criteria in Chapter 2: technical feasibility, economics, environmental impact, and public acceptability. An innovation's cost and affordability, capacity to foster resource renewability, ability to overcome risks to health and the environment, and public acceptability are essential. Meeting these criteria is especially critical when a society pursues these options in combination, as has been true in both nations.

Singapore and Israel targeted technically feasible water alternatives early on. Feasibility served as the initial criterion in studies their governments undertook before any options were selected. Singapore, to a greater degree than Israel, considered water innovation feasibility through a more holistic framework from the very beginning of its selection process – adopting the now familiar “four taps” approach to its water supply policy. By contrast, Israel adopted a more sequential approach, studying – and adopting options as needed and after they were proof-tested. One lesson from the experience of both polities is that commitment to resilience through aggressive adoption of technically-feasible water innovations requires intensive capital investment; a highly-trained managerial elite; and well-funded, consistently supported infrastructure. Both countries made such commitments very early following their independence.

Economics has also been an important consideration in innovation governance. Debates over how users should help to finance options were partly prompted by the high cost of desalination, although efforts to promote greater water use efficiencies was also a spark for this

issue in Israel. While neither nation has been deterred by the cost of water innovations, both pursued policies designed to recover a considerable portion of this cost, by recalibrating water rate structures to encourage marginal cost recovery and efficient end use, and promoting investment in export-focused water innovation industries with large global footprints in research, design, demonstration, and full-scale deployment of various water technologies.

With respect to environmental and health risk, both countries have been markedly concerned with the human health impacts of water innovations and have gone to considerable length to ensure the safety of freshwater supplies produced through wastewater reuse, desalination, and rainwater harvesting. Of necessity, Singapore has gone to extraordinary lengths to ensure that rainwater catchments are fully protected from pollutants. While both countries limit wastewater reuse as a source of domestic consumption, each has undertaken vigorous measures to assure the public that reuse is safe. Both countries have elected to supply recycled effluent to *fit for purpose* needs best suited to various economic priorities: microprocessor manufacturing in Singapore, agriculture in Israel.

Finally, public acceptability has been the most surprisingly sanguine characteristic of both nations' efforts to develop water innovations, reflecting the perceived urgency among their citizenries to secure and propagate limited water supplies on one hand, and protect water security on the other. An issue we will later explore is whether the embrace of technocratic governance for water innovations – the concentration of decision-making authority in the hands of an engineering elite, together with reliance on private-public partnerships for technology development, water pricing, and choice of water provision method – *impedes* public engagement or reflects a high degree of *satisfaction* with water governance.

At this chapter's outset, we cited the drought-related challenges facing South Africa, a country far less developed than Israel or Singapore. The efficacy of its water governance was less than optimal due to failures to consistently incorporate key stakeholder groups in long-term water supply planning; fragmentation of authority for various activities essential to water governance and innovation management; and, failures of long-term plans to aggressively pursue science-based alternatives. Singapore and Israel have clearly overcome the problem of governance fragmentation and both exalt science and technology-based water alternatives.

With respect to incorporation of key groups, water governance is controlled by a few – a precedent established in ancient polities concerned with water resilience. Strategically-positioned groups within government dominate policy. This is as true in Singapore and Israel as in South Africa. However, in the first two cases, powerful groups acquired their authority through technical merit and business prowess, not skin color. In many polities as we have seen, some groups derive their authority from their control of capital required for building water infrastructure, legally enshrined rights to water, or other assets that grant them inordinate influence in decisions. In all cases, *discursive legitimacy* is crucial for interest group access to decision-making – a connection to the dominant governance values of a polity.

The concept of *advocacy coalition frameworks* has partly evolved from this tradition by advancing the claim that various policy actors sharing a set of normative or causal beliefs, and who act in concert, can leverage changes in public policy – including water policy (Menahem & Gilad, 2013). This normative framework functions well so long as there is a widespread consensus over the purposes of water policy, and the manner in which power and process are exercised in its support. As we will see in Chapter 4, such consensus, outside of the cases we have explored here, is difficult to bring about, in part because consensus is something that must

be acquired through widespread and conscientious public engagement activities by government.

CHAPTER 4 – ADAPTIVE GOVERNANCE – NEW SOLUTIONS TO NEW CHALLENGES

Not in my backyard?

It's a cautionary tale. Even in a country that embraces water innovations, public opposition to specific projects can arise. Residents and local officials in Israel's western Galilee have protested a government decision to build what would be the country's largest desalination facility at a site between Acre and Nahariya. Claiming that the location is in the heart of prime agricultural land, and in close proximity to residential and military housing, critics say the proposed project compromises a unique coastal environment and will deter tourism.

In 2016, the Mateh Asher Regional Council joined with residents in opposing a multi-agency site selection committee's choice of this site, overseen by Israel's Interior Ministry and decided after a decade-long survey of 20 locations. A former Knesset member from the region criticized the committee for “. . . an absurd plan that will cause intense harm to this rapidly-disappearing pastoral area (Joffre, 2019).” The planned facility would have a 2.5 mile long pipeline and return drainage residue to the nearby Shavei Zion marine reserve. Is this case an example of *not-in-my backyard* syndrome, as one Israel Water Authority official has charged (Grossman, 2016; Surkes, 2019)? Or, is it an expression of indignation toward a project harboring the potential for adverse impacts to an entire region, and of disdain toward officials who failed to listen to citizens? In either event, conventional governance methods have thus far failed to amicably resolve this dispute, nor have protestors managed to alter the location.

The state of Texas currently has no seawater desalination facilities. However, it too is experiencing public opposition to a proposed desalter. Plans to build at least one facility near Corpus Christi (Figure 4.1) have been launched by the local water agency which currently serves 500,000 people in a seven-county region and soon expects to see demands exceed supply in dry

years. The city and its port authority have begun the permitting process for a 30-million gallon-per-day plant, and have obtained a \$222 million loan from the state's Water Development Board to pay for it. A path to permitting remains far from clear, however. Among the criticisms are increased ratepayer costs, a desire by some for a privately-financed facility posing less fiscal risk to the city, and environmental concerns over brine disposal, expressed by the Coastal Bend chapter of *Texas Campaign for the Environment* and *Save the Bay for the Common Good*.

Figure 4.1 about here

These familiar criticisms of desalination are exacerbated by charges that Corpus Christi's mayor and city council ignored public concerns. A vote on a charter amendment to ban any desalination project in the region is pending. Even the state concedes that "public opposition due to environmental concerns" affects permitting of this project: a clear challenge to local water governance (Cargo, 2020; Freeman, 2020; Texas Water Development Board, 2020: 7, 11).

Wastewater reuse projects are also subject to public opposition due to their perceived public health risks, as we have seen. An unusual case is that of Tampa, Florida which has already built a facility that produces 50-million gallons-per-day of highly treated reclaimed water currently discharged into Hillsborough Bay. The city wants to re-direct this discharge into the Floridan Aquifer through a series of recharge wells creating a freshwater "bubble" that would function as a buffer against brackish and saltwater intrusion. The adroitly-named *Purify Usable Resources for the Environment* or PURE project would also help maintain higher minimum flows on the Lower Hillsborough River to improve habitat. And, it would replenish a local reservoir ensuring adequate supply during drought (PURE, 2021).

The proposed project is an alternative to a previous plan that would have converted reclaimed wastewater from Tampa's *Advanced Wastewater Treatment Plant* into drinking water

without aquifer recharge: a less popular *direct* potable reuse option which, as discussed in Chapter 2, provides no buffer between the water's source and its destination. That earlier proposal was also opposed by Tampa's cross-bay neighbor, St. Petersburg, which feared Tampa's exit from a regional compact if it achieved water independence. Although PURE embraces *indirect* use, and its water would be regionally-shared, local opposition remains due to perceptions that the project is being implemented too hastily, has inadequately engaged the public, and lacks transparency (Frago, 2021a, b). Tampa is seeking outside review of the project's merits and additional public engagement. Time will tell if these strategies are effective.

Finally, although there are fewer examples of public opposition to rainwater harvesting projects, protests can arise when such projects are *not* embraced by authorities, while citizen groups believe they should be. India affords a good example. In 2017, a series of demonstrations in Hassan, Karnataka saw diverse groups of activists demanding that the district government embrace rainwater harvesting throughout the region, especially for all government buildings. A response to critical drinking water shortages throughout the region, these demands were similar to those expressed nearly a decade earlier in Mumbai, which mandated water use restrictions due to chronic supply shortages in that city (Rally Highlights, 2017).

In 2002 Mumbai's water agency, the Brihanmumbai Municipal Corporation, made rainwater harvesting mandatory for all buildings over 1,000 meters² in area. In 2007 the agency extended this mandate to buildings greater than 300 meters.² However, a lack of adequate monitoring and enforcement of the policy has contributed to the city's failure to keep up with rising demands. The resulting water use restrictions imposed by the city immediately led to protests. Nevertheless, it would not be an over-reach to argue that failure to adequately implement rainwater harvesting – as well as construction delays for three large dams which,

prior to their completion were criticized as uneconomical and inadequate – underlay the frustrations which ultimately led to these protests (Walton, 2009). What lessons might these diverse examples harbor for adoption of water innovations and their governance?

To adopt, first adapt

These cases illustrate some of the problems that arise when water innovations are proposed without sufficient consideration paid to concerns regarding their siting, cost, need, and impact. They also underscore, to different degrees, the limitations of *conventional governance* approaches to water innovation that are characterized by technocratic decision-making processes, unequal power with respect to dissenting voices, and conflicted or muddled purpose.

Two lessons from these experiences are especially noteworthy. First, public officials must be collaborative in order to ensure that water innovations are successfully adopted. And second, those responsible for decisions, especially local officials, must be good listeners when engaging with the public. This is true in places where innovations have not yet been adopted, as well as in places where they have been. Every decision to site a desalination, wastewater reuse, or rainwater harvesting project raises unique, site-specific technical feasibility issues as well as questions regarding benefits and costs, perceived risks, and public acceptability.

Collaboration and listening are hallmarks of *adaptive governance* – an approach to decision-making as novel and inventive in its way as the water innovations officials seek to adopt. Adaptive governance is characterized by cooperation with influential civil society groups, social learning through efforts that permit public participation in decision-making and foster information exchange between citizens and officials, and policy experimentation. The latter includes willingness to embrace flexible policy outcomes, and adjustments to initial plans, in

order to enable water innovation adoption in light of unforeseen social and environmental challenges (Huitema et al, 2009; Kallios et al., 2009; Hatfield-Dodds, et al., 2007).

Adaptive governance employs bottom-up, multi-actor collaboration as opposed to the top-down “decide-announce-defend” style of governance that often characterizes interactions between agencies and citizens, especially when large, complex public works or other infrastructure – such as transportation systems, modifications to a nation’s electrical grid, or large water projects – are being considered. Under conventional governance, such projects, which often contain an element of environmental or other risk, are sometimes planned with little involvement of stakeholders. This incites opposition, resistance, and the not-in-my-backyard or NIMBY syndrome (Cascetta and Paglieria, 2013; Local Government Association, 2021).

In order to better understand the advantages of adaptive governance, it is useful to first consider the problems encountered in the cases cited earlier. Despite their divergent contexts and the innovations in question, all of them tended toward *mal-adaptive* decision-making in four respects. *First*, at their inception, they were launched by a governing authority that believed an innovation was needed to address regional water needs such as chronic drought or growing demands. After initial investigation, the authority decided to move ahead with siting an innovation in a specific location. It relied on conventional methods for implementation – highly-prescriptive and sometimes opaque environmental and land use permitting procedures, and complex, highly-technical assessments of what an option would cost and how to pay for it.

Second, opposition to these initial plans arose in response to the proposed alternative and, in some instances, to the perceived need the alternative was purported to address. Local officials and non-governmental groups are, thus, mobilized to act and – together – they seek to modify, delay, or overturn a project until technical, economic, risk-related, or other public acceptability

issues are addressed to their satisfaction. *Third*, criticism of the water innovation takes two distinct but inter-connected forms: disapproval of the *outcome* being prescribed (i.e., the project) and frustration with the *process* through which the outcome was selected (i.e., the perceived unrepresentativeness, inequity, or lack of inclusiveness of the decision-making approach).

Lastly, if the governance authority fails to address these issues and does not modify the decision-making process in ways more inclusive of alternate viewpoints and sources of information, impasse results. We now turn to what makes adaptive governance particularly suited to address these mal-adaptive issues, citing specific examples along the way. We begin with an overview of the approach's focus on collaboration between state and non-state actors.

Adaptive governance as collaborative governance

Adaptive governance emphasizes collaboration between state and non-state actors in order to integrate specialized and local knowledge. It seeks to transition away from what we previously described as a technocratically-dominated process of decision-making toward one more amenable to lay concerns. It is also designed to overcome distrust and lack of confidence in the institutions that manage innovations, and, thus, render more equitable water management decisions.

Elements of adaptive governance have been in use for decades, especially in natural resources management. In water policy specifically, we find rudiments of its application in so-called *polycentric governance* schemes which acknowledge that water and other common pool resources, such as fisheries or forests that are shared by multiple jurisdictions, require improvised agreements in order to be managed sustainably. Collaboration among stakeholders from multiple jurisdictions who live and work within a single basin or watershed poses a challenge because establishing a governance entity that enables equal representation and

participation by all players – and communities – is difficult given the conflicting interests and values of stakeholders (Huitema et al., 2009; Ostrom 2010).

In general, polycentric governance seeks to overcome this challenge in three ways. First, it relies on improvised collaborations based on negotiated rules of exchange rather than centralized hierarchical governance institutions (Araral and Hartley, 2013). These rules negotiated among different government units can include, for example protocols establishing how the costs and benefits of a water innovation such as a desalination plant will be equitably shared, as well as how stakeholders will be represented in decisions pertaining to facility siting, community involvement in ratepayer obligations, and monitoring of health and environmental risks of a facility once it begins operation. Recall, these issues arose in the case of the proposed desalination facilities near Corpus Christi, Texas, for example. Such rules have been acknowledged as important during the environmental assessment phase of a facility (e.g., Voutchkov, 2013:166-170). They can also serve as a more permanent component of citizen review throughout a project's life.

Second, negotiated rules can be developed by new entities with powers to impose fees or levy taxes on water innovation projects. However, if deemed more suitable, they may entail working through existing public authorities such as local water agencies, in much the way decision-makers committed to the PURE project in Tampa, Florida seek to do in their efforts to build trust (McGinnis 2005). In any event, an important key is that the collaboration be anchored among spatially proximate actors committed to a geographically defined partnership, and who concur that a critical element in their search for common rules and operating principles is a commitment to the long-term management of risks engendered by some innovation, service, or technology.

Some term this polycentric governance partnership a *convergence ecosystem* (Roco et al., 2013) to denote that what is being sought is a networks of actors who collaborate through institutional innovations permitting the free movement and exchange of ideas on a peer-to-peer level. This not only generates more sustainable innovations, but it also builds confidence among participants from different backgrounds and strong working relationships.

Third, polycentric governance schemes recognize that there is a friction point with regards to institutional trust which revolves around what constitutes appropriate knowledge and expertise to profitably weigh in on decisions. For example, while hydrologists have explicit, timely knowledge regarding the impacts of drought on a region's water supply and the need for alternative sources of provision, local farmers might have a more astute understanding of soil moisture, the health of local streams, local land-use issues, and effective drought *coping* experiences and tacit knowledge that could be incorporated into decisions. In short, both sources of knowledge are likely to be relevant for managing water, especially under terms of an agreement that crosses jurisdictions and affects multiple stakeholders. Polycentric governance emphasizes collaboration among civil society, nonprofit, and industry groups in an effort to integrate specialized and local knowledge (Dietz et al., 2003).

Adaptive governance departs from polycentric governance in three respects. First, it emphasizes *public participation* as a means of hastening community buy-in over risks, costs, and benefits of strategies to achieve environmental protection or other objectives. Second, beyond merely acknowledging the need for expert and lay information sources, adaptive governance emphasizes *co-production* of knowledge by fusing expert information with local knowledge as a means of providing social learning, or in other words, learning from relevant experiences. Lastly,

adaptive governance stresses *policy experimentation* as a means of breaking-down barriers to innovations caused by over-reliance on path dependent, risk-averse decision-making approaches.

Adaptive governance rejects the notion that the “best” policies emerge from a technically rational, apolitical process of top-down technocratic decision-making. Instead, policies that effectively bridge stakeholder interests in one community may be diffused to others if a supportive environment for collaboration is identified— even for large spatially diffuse problems such as climate change. A key is combining good science with community-level concerns when formulating decisions regarding innovations intended to advance a specific community’s welfare. While science should seek to address public concerns, the concerns expressed by the public should also drive the science (Brunner and Lynch, 2010). This is a lessons that emanates directly from the cases briefly discussed earlier.

Using wastewater reuse as an illustration – science should address the specific long-term health and safety concerns of salience to the public. These concerns can only be properly investigated, however, if scientists first engage the public and ask them what specific problems regarding safety they want answered. Moreover, answers need to be provided in ways the lay public comprehends. We now examine the intricacies of public participation, knowledge co-production, and policy experimentation through case studies from Australia and California.

Public Participation and Engagement – Australia

Demands for enhancing public participation in water-related problems have emerged from efforts to boost citizen engagement in watershed management. One goal of these efforts has been to better incorporate the concerns of civil society groups in discussions between regulators and scientists aimed at improving the effectiveness of river restoration and identifying cost-effective pollution mitigation strategies (e.g., Koontz et al., 2004). Such efforts have included

publicly-engaged watershed restoration and pollution offset programs in Nigeria, northeast Brazil, eastern North Carolina, the Colorado River (USA), and Europe's Rhine and Danube basins. Until recently, few of these participatory engagement efforts in restoration and pollution reduction have entailed consideration, or adoption of, specific water innovations.

A pathbreaking exception is taking place in the state of Victoria, Australia as a result of that country's early 21st Century Millennium Drought, and is illustrated by environmental restoration efforts in the Maribyrnong River watershed north and west of Melbourne. It revolves around the use of surplus reclaimed wastewater to restore in-stream flow. The Millennium Drought was so significant an event that we devote a separate case study on its further relevance for urban water innovations later in this chapter.

The Australian government established the importance of community representation in water policy as early as 1970 by making public consultation in water quality rule-making a decision-making requirement (Smart Water Fund, 2013). However, the Millennium Drought of the late 1990s catalyzed more adaptive efforts by exposing shortcomings of traditional governance approaches in light of evolving environmental conditions thought to be caused by climate change, and by public demands for more aggressive environmental protection measures (Australian Government. Environment Protection Act, 1970).

In recent years, portions of the Maribyrnong watershed, including Jackson Creek and the Werribee River, the former rising northwest of Gisborne, Victoria, has suffered from diffuse nutrient pollution from urban and agricultural runoff. This is a ubiquitous problem throughout the region. Growing urbanization of the area, which is increasingly composed of a commuter workforce serving Melbourne, intensification of farming practices, and climate change are likely to exacerbate these problems. During the Millennium Drought, water supplies in Rosslynne

Reservoir, a major storage project on Jacksons Creek, fell to 3%, compelling reservoir managers to restrict water releases to emergency flushes only.

Early on, a possible solution to these problems was envisioned as lying within one of the watershed's major pollution sources: the outfalls from the water recycling plants located near the communities of Sunbury, Riddells Creek and Gisborne, and operated by Western Water – the principal water agency then serving the region.¹ These recycling facilities provide secondary treated effluent for non-potable agricultural uses (Figure 4.2).

Figure 4.2 about here

A catalyst for this proposed strategy started with efforts by Western Water to classify its treated effluent as supplemental environmental flow: a strategy that would enable its release to constitute a form of in-stream flow enhancement for Jacksons Creek and the entire Maribyrnong watershed. However, regulatory constraints inhibited immediate adoption of this strategy. Adding to the regulatory pressure on Western Water was that the agency anticipated that by 2018, urban growth would result in an increase of the amount of recycled water generated by Gisborne WRP, leaving it with little choice but to discharge surplus effluent to Jackson Creek, even if these releases were partially “out of compliance” with Victoria’s water quality standards. The state EPA’s expectations were that over time, water agencies in the region would progressively reduce nutrient concentrations in local streams to comply with these standards.

To fully comply with then current water quality standards, Gisborne WRP would have had to increase capacity to provide an expensive tertiary level of treatment and also provide new options for reuse (e.g., in-home residential use). Western Water proposed an innovative

¹ Since 1 July 2021 part of *Greater Western Water*, a new company formed by bringing together Western Water and City West Water companies (<https://www.westernwater.com.au>)

alternative. Availing itself of Victoria's environmental protection guidelines, it proposed an offset scheme that would allow continued discharge of recycled water from Gisborne WRP in a manner that produces net environmental benefits to Jackson Creek through a trade-off between treated wastewater effluent as opposed to other, more harmful, pollutants (Feldman et al., 2015; Victoria EPA, 2008).

Adoption of this innovation entailed both risk and uncertainty, underscored by the fact that use of recycled wastewater for environmental flows in Jacksons Creek and elsewhere in the Maribyrnong watershed began in 2018, years after first being proposed (Western Water Annual Reports, 2017/18; 2018/19; 2019/20). On one hand, the offset scheme was a money-saving measure for Western Water. On the other, it was a test case to determine whether discharging advanced secondary effluent would mitigate the adverse effects of waterway pollution, generate other positive environmental flow outcomes, allow environmental gains to count as a beneficial use, and thus, allow Western Water to achieve 100% beneficial reuse of effluent.

The offset program afforded greater flexibility in complying with environmental objectives. However, it also invited controversy. Consequently, Western Water and Victoria decided to embark on an enhanced stakeholder engagement process that initially comprised a series of workshops bringing together stakeholders with divergent values, knowledge, and concerns to share perspectives, frame problems, and discern solutions. Industry as well as community groups such as indigenous community representatives participated in these workshops. They were followed by an elicitation of public values through community surveys. This phase provided an essential governance element as regards the acceptability of offsets, especially since anticipated demographic changes in the region may lead to further variation in local community values (Alluvium, 2015: 7, 30).

Other components were later added to the engagement process. The first was a consultation process with local government councils regarding where and how to use recycled water for irrigation and for maintaining the health of local creeks and rivers, objectives deemed important by communities in order to support the recreational value of waterways. This process resulted in the installation of moisture probes at Western Water owned farms to enhance irrigation management, improve crop yields, and increase profitability. Additional outcomes of this process included the expansion of local irrigation networks, provision of recycled water to local recreation reserves, sports fields and gardens in properties governed by councils in the cities of Hume, Macedon Ranges Shire, and Melton. It also led to joint evaluation of local priorities for expanding alternative water sources and enhancing “live-ability outcomes.”

This consultation process adopted the moniker *Integrated Water Management Forums* and comprised facilitated discussions embracing Victoria’s Department of Environment, Land, Water and Planning (DELWP) as well as local water corporations, local government councils, catchment management authorities and *Traditional Owners* (i.e., Aboriginal community representatives on a range of projects centered around the Maribyrnong, Werribee, and Coliban Rivers (Western Water Annual Report, 2018/19; 2019/20). Discussions embraced community economic development and environmental protection concerns and other domains that could benefit from recycled water use.

Western Water also joined a *Regional Catchment Strategy* developed by the Port Philip and Westernport Catchment Management Authority (PPWCMA). This encompassed the larger basin of which Western Water is a part. Western Water also implemented several projects consistent with the overall intent of the strategy. As of 2020, Western Water’s seven recycling facilities have produced some nine million liters of recycled water from over 11 million liters of

sewage, 57% of which (5.2 million liters) is being reused by customers or by Western Water itself for in-stream flow enhancement. The agency's recycled water plants are licensed to discharge water to adjacent waterways including Jacksons Creek, Five Mile Creek (Woodend Recycled Water Plant) and Werribee Creek (Melton Recycled Water Plant). All discharges must comply with discharge limits for various water quality parameters (Western Water Annual Report, 2018/19: 38).

Lastly, Western Water appointed a *Recycled Water Advisor* whose responsibility is to “build strong relationships with customers” to ensure they are complying with EPA guidelines for recycled water use “whilst supporting the beneficial application of recycled water.” Of long-term environmental justice significance, the agency has also undertaken efforts to further engage the Aboriginal community and continues to explore ways recycled water use might support furthering its cultural values. Efforts include a Reconciliation Action Plan (RAP) to enable infrastructure planning projects to move forward in ways that incorporate Aboriginal “traditional ownership” principles. These include the Western Irrigation Network project, the Western Water Grid Expansion and Sunbury's Water Future, supported by Integrated Water Management Fora (Western Water Annual Report, 2017/18: 5, 31; Western Water Annual Report, 2018/19: 35).

A final verdict on the success of this adaptive governance engagement process is not yet possible. It is too early to fully evaluate its environmental performance as well as long-term impact on public engagement. An organizational culture transformation can be discerned in Western Water's stated commitment to “realise the benefits of recycled water” through “continue(d) working with the community and stakeholders towards fully integrating recycled water into our portfolio of water sources, both within and outside of our service region” (Western Water Annual Report, 2019/2020: 47). In sum, participation and engagement through adaptive

mechanisms may enable greater incorporation of a wider range of concerns. However, this does not automatically lead to wholesale policy change overnight, and has certainly been Victoria's experience with recycled wastewater governance thus far.

Social learning and knowledge co-production – California

A particular benefit of adaptive governance, proponents claim, is its emphasis on co-production of knowledge. Co-production contends that expert information about an innovation's technical efficacy, economic performance, and environmental and human health risks should be supplemented by local knowledge and understanding regarding the acceptability of these risks, community experiences with previous innovations and their impacts, and local sensitivity to social equity. One European study on the acceptability of wastewater reuse, focused on northern Italy, affirms the importance of co-production. Assessing perceptions of the benefits and risks associated with treated wastewater reuse for irrigated agriculture among farmers, investigators found that enhancing people's knowledge is insufficient to ensure its acceptance. Instead, understanding the actual water needs of potential end-users, and their knowledge regarding the practical value of water is essential. Farmers are likely to have more knowledge about how crops can benefit from water reuse than academics who do not actually farm. Moreover, positive experiences in using recycled wastewater are important in establishing support, and further underscores the need to encompass expert and lay knowledge in decisions (Michetti et al., 2019).

Co-production entails the generation of new technologies and their application through collaboration among scientists, engineers, and nonscientific lay audiences. The goal is to better incorporate the values of both communities, thus allowing lay audiences to independently verify the usefulness of at least some types of expert information while helping scientists and engineers improve their products – the end result is termed *social learning* (Lemos and Morehouse, 2005;

Feldman and Ingram, 2009; Dietz et al., 2003; Araral and Hartley, 2013). This mutual process of *social learning* has, as its goal, the production of amicable, trustworthy outcomes in efforts to introduce and manage water innovations.

A good example of co-production and social learning is afforded by the experience of Orange County, California's Groundwater Replenishment System or GWRS, managed by the Orange County Water District or OCWD (see Chapters 1 and 2 for an earlier overview of the project). Observers characterize the GWRS as a successfully introduced water innovation that effectively utilized information exchange through an adaptive governance approach (Harris-Lovett et al, 2015; OCWD, 2014). OCWD employed a robust outreach campaign characterized by community surveys, information dissemination to local groups, education on the technical features of potable reuse, and elicitation of public concerns. It also employed a citizens' advisory committee and focus groups to improve the effectiveness of risk communication and to assure users that the GWRS would provide a safe, secure, competently managed water supply.

In no small part due to these efforts, the technology employed by the GWRS: a sequence of treatment processes anchored by microfiltration, reverse-osmosis, and ultraviolet light coupled with hydrogen peroxide, was constructed in 1999 – building on a previous wastewater replenishment system that injected treated effluent into the county's groundwater basin beginning in the early 1970s (A History of Orange County Water District, n.d., 51). These outcomes are only a part of the story, however.

While various co-production efforts led to a successful implementation outcome in this instance, a reasonable question is: why haven't comparable efforts on behalf of potable wastewater reuse resulted in similar outcomes elsewhere? Risk communication and public outreach strategies have been adopted in other communities that have pursued water innovations,

particularly wastewater reuse, including other Southern California communities. Successful adoption of potable reuse has until now rarely resulted from these efforts, however. This would suggest that candid information exchange does not in itself “win hearts and minds.” What made Orange County’s experience different, we contend, is that decision-makers understood and conscientiously applied knowledge co-production approaches in uniquely effective ways. Evidence for this claim takes three major forms.

The first was recognition by decision-makers of the importance of establishing the legitimacy of GWRS by addressing specific, locally-held norms regarding the appropriateness, propriety, and overall desirability of the project. An illuminating assessment of the GWRS based on interviews with project participants concludes that legitimacy, as a sociological concept, was central to the project’s success. More than building trust and confidence, legitimacy entails “embedding a new technology in the shared social belief systems, moral standards and cultural conventions of a given group, through a set of strategies that go beyond traditional public relations or educational outreach” (Harris-Lovett, et al., 2015: 7553; also, Johnson et al., 2006).

Specifically, Orange County Water District officials recognized that: “Water utilities cannot build legitimacy for potable water reuse based on hollow promises (p. 7553).” Generating confidence in an innovation such as the GWRS requires strategies that allow an honest exchange of expert and lay knowledge so as to establish a water innovation’s rightful place in the mix of water supply sources in intelligible, credible, and sensible ways. It must also acknowledge that, given a community’s values and beliefs, some innovations may simply be unacceptable.

With specific respect to information exchange, Harris-Lovett and colleagues suggest that the district was particularly adroit at establishing *pragmatic legitimacy* through demonstrating how this innovation was in the best interest of the public. Pragmatic legitimacy entails providing

targeted information from proponents to audience; eliciting feedback from community leaders back to innovation proponents (i.e., the water agency); and, demonstrating the agency's trustworthiness through proactive and forthcoming admission of previous problems and forthright explanations of how they were addressed (Harris-Lovett et al., 2015: 7555).

Co-production of knowledge is most tellingly described through participant recollections. Harris-Lovett and colleagues' finding in this regard is worth quoting at length due to its careful discussion of how diversity, inclusion, and substantive concerns were embraced:

The utility targeted community and business group leaders within their 2.4 million customer service area and informed them about the benefits of the potable water reuse system in simple language . . . with more than 1200 presentations that were translated in Spanish, Vietnamese, and Chinese The talks were targeted to the interests of their specific audience, and emphasized the idea that the technology would guarantee a safe, reliable water supply into the future, which was a key interest of all inhabitants of Orange County (Harris-Lovett et al., 2015: 7555).

Demonstrating trustworthiness through agency action, and communicating and responding to community concerns – what Harris-Lovett and colleagues describe as the “dispositional dimension” of pragmatic legitimacy – are exemplified by a single story involving the district's previous management of a carcinogenic contaminant found in its water:

While OCWD (the water agency) carefully planned the above legitimization strategies, others emerged as a result of the district's responses to technical challenges. In particular, in the year 2000, OCWD detected N-nitrosodimethylamine (NDMA), a potent carcinogen, in their treated water, and realized that some of this compound had actually been created in their water treatment process. Though this situation could have threatened

the legitimacy of OCWD's potable reuse efforts, the response of the utility to the incident ultimately enhanced its dispositional legitimacy. Instead of hiding the problem, the management decided to publicly disclose it, and proved to both regulators and the public that they were competent in dealing effectively with the contamination . . . (Harris-Lovett et al., 2015: 7555).

In sum, GWRS proponents educated residents about the need for potable reuse, convinced key community groups as to how it would meet their needs more effectively than other alternatives, (by providing a reliable, independent source of water supply for the region – i.e., *water security*), and addressed public concerns honestly and fully (Markus and Torres, n.d.).

As noted earlier, knowledge co-production also took other forms. A second was the district's effort to learn from successful potable reuse efforts elsewhere. A process of *social learning* was tacitly adopted by the agency. This process began, appropriately enough, by drawing upon the experiences of the water district's own *Water Factory 21* which, when opened in 1976, was the first California project to purify sewer water to drinking water standards while also serving as a barrier against seawater intrusion in the region's groundwater basin.

Lessons incorporated into the GWRS from *Water Factory 21* included how to effectively avert seawater intrusion and consistently assure high-levels of water purification. Public outreach lessons were no less significant. *Water Factory 21* welcomed annual visits by water industry officials from around the world who had the opportunity to learn about the facility's advances (the GWRS also does this, and has a visitor center which provides tours for the general public) (Building on Success, 2021). Moreover, *Water Factory 21* furnished the district with 25 years of water quality data which, together with its own experiences in public outreach including over 2,000 community presentations, helped solidify support for the GWRS and earned the trust of

“the health, scientific, environmental and water quality communities, (and) from chambers of commerce, service organizations, educational institutions and local, state and federal leaders, and policy makers (Project Supporters, 2021).”

Other experiences GWRS drew upon included those of the Water Replenishment District of Southern California’s Montebello Forebay Groundwater Recharge Project; Upper Occoquan Sewage Authority in Fairfax, Virginia; Hueco Bolson Groundwater Recharge Project in El Paso, Texas; the Scottsdale, Arizona Water Campus; the West Basin Municipal Water District’s sewer water purification facility in El Segundo, California; and Singapore’s NEWater project (see Chapter 3). Social learning benefits GWRS acquired through these comparative case studies included how best to employ health studies to confirm the safety of purification methods; treatment efficiency improvements to increase reliability; the need for long-term elicitation of public concerns; integrating the project into a supply system comprised of numerous source water components; ensuring the safety of a multi-step purification process; and “. . . careful, thorough, project specific assessment that includes contaminant monitoring, health and safety testing and system reliability evaluation (Building on Success, 2021).”

Lastly, the Orange County Water District embarked on deliberate, careful, and well-reasoned efforts to avoid the mistakes made by other agencies that tried but failed to implement potable reuse projects. The district found that many of these failures could be ascribed to poor messaging: communications that lacked consistent and reinforcing ideas; outreach that failed to fully address target audience concerns; and, botched efforts to address the specific apprehensions of under-represented groups. This is well-documented in an internal white paper prepared by the Orange County Water District during planning for the GWRS. Explicit acknowledgment of the

importance of knowledge co-production is underscored by a statement in this paper which summarizes the importance of prioritizing community concerns:

First identify the issues key stakeholder groups may have with a proposed project. This is done by utilizing polling and focus groups to identify those issues and then *developing talking points and collateral materials that can answer any questions that may materialize*. The initial focus then needs to be on identifying key stakeholder groups, going out and giving presentations on the project and obtaining written support letters from those groups. . . Outreach must be flexible and continually evaluated so that it can change as conditions change and new issues and opportunities arise (Markus and Torres, n.d.)

Of particular salience here is that the process of learning from unsuccessful projects took place in real-time. Other agencies in the region, notably in San Diego and Los Angeles, proposed ambitious potable reuse projects during this same period as the GWRs. In each case, concerns over equity arose – strikingly noted by the OCWD white paper. For San Diego, it was claimed that the project would primarily serve Black communities, while in Los Angeles, adverse risks to the health of San Fernando Valley residents was claimed. Independent assessments of opposition to reuse projects in both communities confirms OCWD’s assessment. A survey commissioned by the *San Diego Institute for Policy Research*, for instance, found high levels of opposition among African Americans, while San Fernando residents – largely white and middle class – also expressed vigorous opposition to reuse, anchored in the recharge of a groundwater basin with a history of legacy contamination from various industrial activities (Nienstadt, 2007).

In sum, these examples illustrate a conscientious attempt by the Orange County Water District to synthesize expert studies with a thorough understanding of lay concerns, an

inclination to learn from peer successes as well as failures, and an acknowledgment of the importance of community concerns. Moreover, knowledge co-production not only exposed public concerns toward potable reuse but equally important, it uncovered positive reasons the greater Orange County community could support such a project. Interestingly, these reasons resonate with our findings regarding the importance of water resilience discussed in Chapter 3.

While OCWD convincingly demonstrated that the GWRS would, over time, prove to be a cost-effective alternative, fortuitous circumstances also intervened. Environmental decisions by U.S. courts – which resulted in reducing water transfers from the Delta and Colorado River within a year of the GWRS coming on-line – dramatically increased the cost of imported water. Coupled with the beginning of a six-year drought, the economic advantages of GWRS became especially apparent sooner than expected.

In addition to cost-effectiveness, a salient issue in a county with a reputation for fiscal conservatism, the advantages of reuse as part of a diversified portfolio was an attractive and resonant talking point (Markus and Torres, n.d.). As in Israel and Singapore, while technical feasibility of the project was an important criterion to Orange County residents, the perception that managers charged with overseeing the project were highly competent was equally important.

OCWD went to extraordinary lengths – again, as did Israel and Singapore – in assuring the public that reuse is safe precisely because the technology was reposed in technically competent managerial hands. Crucially, however, and in contrast to Israel and Singapore (and more in line with Australia), skepticism toward technocratic governance, reflecting the libertarian political culture of the region, required that OCWD pay special attention to the legitimacy of demands for political accountability of the GWRS through public engagement.

Adaptive Governance as Policy Experiment – the Millennium Drought

One criticism of conventional water governance is its tendency to rely on traditional approaches to problem-solving when confronted with unprecedented challenges. These approaches are often slow, risk averse, dependent on over-used problem-solving methods, and characterized by adversity among innovators, water agencies, regulators and intervenor groups. Some polities are able to break from path dependency, boldly adopt innovations, and do so more effectively than their peers (Daigger, 2011; Pahl-Wostl, 2007; Gersonius, et. al., 2013).

A convenient explanation for this embrace of innovation is fear of imminent crisis. However, on examination, this explanation does not turn out to be very convincing. In many polities, barriers to water innovations are often exceedingly difficult to surmount, even in the face of protracted drought or other threats. Resistance to innovation is most often caused by the tendency of government regulators to operate within strict, legally-defined silos, and to be especially sensitive to environmental threats. Resistance is exacerbated by water agencies' aversion toward potentially risky innovations: an attitude conditioned by a combination of financial and regulatory uncertainties (Cantor et al., 2021; Wagner and Fain, 2018).

One polity that appears to have overcome some of these impediments, in part by surmounting the limits of conventional governance, is the state of Victoria, Australia. Melbourne, its capital and the country's second largest metropolis, have introduced a number of water innovations during a protracted period of environmental crisis. Most of all, the city and the state have embraced governance innovations in tandem with adoption of water alternatives. Adaptive water governance has become an evolving policy experiment.

From 1997 until 2009, Australia as-a-whole, and especially the southeastern portion of the country, found itself in the grip of the Millennium Drought, thought by many climatologists to have been the most severe period of aridity and lack of precipitation in – literally – the span of

a thousand years. By June 2009, shortly before the drought officially ended, reservoir storage volumes in the state of Victoria fell to a historic low of less than 26% capacity. Impacts to agriculture, the economy, and regional ecosystems were especially severe (Aghakouchak et al., 2014; CSIRO, 2012; Grant et al., 2013).

Swift action was taken. Melbourne, a city of well over 4 million people, reduced its per capita water demand by almost 50%, and managed, in relatively short order, to adopt a number of innovations including rain- and storm-water harvesting,² wastewater reuse for non-potable uses, and a variety of conservation methods. Adoption of water innovations was facilitated by an institutional framework pre-dating the drought, albeit one which had some limitations, as we will discuss, leading to the need for creative reforms.

In the Melbourne region, as in large metropolitan areas elsewhere, a variety of regulatory agencies oversee the water sector, exercising responsibility over various aspects of the resource. These have included State Ministers of Water, Environment, and Health, and Treasury which collectively oversee the water sector, and The Department of Environment and Primary Industries (DEPI – or, Environment, Land, Water and Planning after November 2014) which supports the Ministers for Water and Environment. An Essential Services Commission regulates water rate increases, and dividends are paid annually to the State Treasury. Water companies (or water agencies) are constituted under the Victorian Water Act of 1989. A clause in that Act allows the Minister for Water to issue a Statement of Obligations (SoO) in relation to water companies' performance and requires them to adopt a joint Drought Response Plan (DRP) that specifies various levels of water restriction based on water storage levels, and also manages water-saving programs (Melbourne Water 2014).

² As noted in Chapter 1, the distinction here is somewhat idiosyncratic. Rainwater harvesting entails capture and use of water falling onto roofs and stored for domestic use. Storm-water is runoff from land surfaces including roads.

Coupled with the DRP and DEPI's influence on drought responses, the Council of Australian Governments' National Water Reform Framework of 1994 promotes a nationally integrated approach to water management. The framework helped to ensure that when the Millennium Drought began, Melbourne could quickly introduce supply and demand-side measures (Australian Bureau of Meteorology, 2011). By itself there was nothing un-conventional about this framework. It employed a technocratic, top-down means of addressing problems.

The framework permitted three large infrastructure projects planned prior to the drought, and in response to general regional demand growth, to be quickly green-lighted. The first was the North–South Pipeline, designed to deliver 75GL of water annually by diverting a portion of the Goulburn River (70 km north of Melbourne over the Great Dividing Range) at a total cost of AU \$1 billion divided between Victoria and Melbourne's water companies (Edwards, 2012; Low et al., 2015). The second was the Wonthaggi Desalination Plant, designed to produce up to 150GL of water annually for Melbourne and surrounding region at a cost of AU \$6 billion, completed in 2012 (Grant et al., 2013). Lastly, the Tarago Reservoir was connected to a new AU \$97 million water treatment plant in 2009, with an operating capacity of 21 GL/year (Viadux, 2017).

Two of these large-scale supply projects almost immediately encountered public resistance. Wonthaggi, the largest desalter in the Southern Hemisphere, has not produced a drop of freshwater for the City of Melbourne – principally because the Millennium drought ended when it went online in 2009. However, from its inception, the project was fraught with controversy. Major public protests began in 2007 and endured throughout the plant's construction period, animated by charges that the government sought to privatize water (the project was undertaken as a public-private partnership with a vendor). In addition, a petition signed by nearly 3,000 people opposing the project was submitted to the Victorian Parliament in

2009 and the Australian Greens, the country's third largest party, opposed the project on environmental grounds (Wonthaggi Desalination Plant, 2021).

Likewise, use of the North–South Pipeline, also known as the Sugarloaf Pipeline after its terminus, the Sugarloaf Reservoir, was suspended following the end of the drought, in part due to regional opposition to water transfers from drought-prone rural areas to drought-prone urban ones. Releases are now based on authorized discharges from Lake Eildon, a storage project on the Goulburn River. Under rules imposed by Victoria, this allocation can only be used “in times of critical human need: when Melbourne’s total water storage is less than 30% on 30 November of any year.” Releases are, however permitted for local fire-fighting (Melbourne Water, 2020a).

These challenges compelled Melbourne and Victoria to pursue governance innovations that acknowledged the challenges caused by environmental as well as societal pressures. As one local water official noted: economic, social, and environmental outcomes were collectively considered together because local agencies were under close scrutiny regarding their decisions, there was wide acceptance that conditions being managed were the “new normal” for the foreseeable future, and improvements needed to be made on several fronts – to water infrastructure, user efficiency, and augmentation of supply (Doolan, 2015).

An agenda-altering event was the State and Federal elections held in 2010, right after the drought broke. The new administration in Victoria decided that the North–South Pipeline was to be used only for critical human needs, refused to order water from the Wonthaggi Desalination Plant, and perhaps most importantly, appointed an independent *Living Victoria* Ministerial Advisory Council in 2011 to develop integrated alternative water sources through an extensive public consultation process. The outcome of this last measure was *Living Melbourne, Living Victoria* – a report recommending strategic priorities to reform the water sector in response to the

Millennium Drought. These recommendations included establishing Victoria as a world leader in integrated water cycle management; changing how Melbourne uses rainwater, storm-water and recycled water – including integrated projects linking them together; integrating water and urban planning to permit all sources and uses of water to be holistically considered; and, “empower(ing) customers through greater choice” (Ministerial Advisory Council, 2011: 2).

The *Living Victoria* Council further recommended a subtle but important re-thinking of decision-making processes. Multiple pressures, it stated, ranging from urban population growth to climate variability and environmental degradation of waterways all led to rising water costs in the region and elevated “important social equity issues in addition to the increased community focus on how water is supplied and managed” (Ministerial Advisory Council, 2011: 7). In addition to modifying programs to address landscape alterations to accommodate water supply constraints; safe, fit-for-purpose water sources; and affordable as well as secure and resilient supplies, the Council proposed that service provision be reformed. Water users would now be provided with information regarding water provision choices, their respective costs, and investment opportunities, ensuring “Transparent, adaptive and flexible decision-making involving consideration of all options” (Ministerial Advisory Council, 2011: 9).

A strengthening of existing governance over water and the addition of greater public engagement were also prescribed. Reconciling both objectives required some political dexterity, the results of which remain unclear. The desire for more integrated water resource planning effectively mandated better amalgamation of policy making, regulation, and service delivery – functions that had previously been kept separate and distinct. However, demands for public engagement implied that water agencies – which remained publicly-owned entities – would be

held accountable for their performance. How well were these objectives reconciled, and what impact did these reforms have on the selection of water innovations?

Institutionally, the Office of Living Victoria established by the Council in May 2012 was provided with AU \$82.5 million between 2013-14. These funds enabled it to successfully advocate for enhanced harvesting and use of rainwater, storm-water, and treated sewage as new water sources – recommendations reinforced by public participation. In 2014, the Office was reorganized into Victoria’s Department of Environment, Land, and Planning and eventually eliminated. At the time, it was unclear if these investments and decisions, politically animated by the drought crisis, would continue to be prioritized. In fact, planning and engagement mechanisms have been continued, but on a more water-agency focused scale.

In 2016, Melbourne Water introduced a series of community engagement panels on waterways and drainage, water services pricing, and water and sewer issues with other panels formed as community interests dictated – all in continuation of the earlier *Living Victoria* effort. Collectively termed *Next Generation Community Engagement program* or *NextGen*, multiple activities were launched including community festivals and focus groups, community-based research, and Customer Councils comprised of water agency representatives, local council representatives, community groups, and developers (Melbourne Water, 2021). One external gauge of the effectiveness of this process was Melbourne Water’s receipt of a 2020 International Association of Public Participation (IAP2) Australasian Organisation of the Year award for “its innovative community engagement program” (Jenkins, 2020; Melbourne Water, 2020b).

Some argue that these governance innovations represented a genuine departure from previous water governance paradigms – one supportive of water efficiency, mindful of energy consumption and nutrient cycles, and fit for purpose water supplies (Brown et al. 2008). It must

also be acknowledged that the lessons learned from the innovations introduced prior to this process, and which faced considerable public resistance, were key in persuading authorities to alter both the process (in becoming more inclusive) and the purpose (embracing equity and accountability) in which water innovation decisions were made moving forward. Novel, “softer-path” innovations which proved to be popular were subsequently adopted, with the caveat that some of these innovations were introduced prior to the *Living Victoria* process.

Four examples of innovations adopted were greywater reuse, wastewater reuse, rainwater harvesting, and enhanced conservation. Greywater systems were installed in some residential units in Melbourne prior to *Living Victoria*. However, rebate programs as an incentive for their adoption emerged during the period of reform – underscoring the influence of calls for more flexible decision-making. Greywater systems can now be operated without any special permit if they employ direct household laundry to landscape transfers – or transfer from baths, showers, and sinks. Permanent greywater systems, however, must be approved by Victoria’s EPA and the local municipality. (Sinclair et al, 2011; ATA, 2005; Victoria, DELWP, 2021).

Wastewater recycling has been aggressively pursued and serves not only as a supplement for freshwater supply but as a means of reducing nutrient loading to Port Phillip Bay, Melbourne’s estuary. A 1997 study by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) commissioned by Victoria EPA concluded that significantly reducing nitrogen loading to the bay would help restore its ecological health and enhance regional water security. Gradual increases in recycled water began in 2002 and increased rapidly thereafter through efforts at the Western and Eastern Treatment Plants managed by Melbourne Water (Figure 4.3).

Figure 4.3 about here

In 2005, a Class A (suitable for home and agricultural irrigation) recycled water scheme was introduced, the Werribee Irrigation District (WID) Scheme and the Eastern Irrigation Scheme, partly dependent on using Werribee River water to dilute recycled water from the Western Treatment Plant (Barker et al., 2011). This plan had to be modified given low flows in the Werribee due to the drought – similar to problems discussed earlier in our discussion of the Maribyrnong watershed. Recycled water for urban uses, including residential use (e.g., flushing toilets and outdoor use) also increased, but more modestly than agricultural uses.

However, as shown in Figure 4.3, urban wastewater reuse continued after the Millennium drought ended and in several areas of Melbourne, in part due to public buy-in as a result of inclusive discussions over water options for the region. Evidence for this claim is provided by a national study of wastewater recycling efforts in Australia which concluded, among other things, that Melburnians deeply distrusted the process by which the Wonthaggi desalination project was undertaken, and had strong inclination to support reuse as both a money saving and ecologically sound means of providing potable water (Kearnes and Beckett, 2014).

Public officials also discovered that even modest efforts to substitute storm-water runoff for potable supply (e.g., by using treated runoff to flush toilets and irrigate ornamental landscapes) could substantially reduce potable water demand. The region adopted a variety of technologies for this purpose including Biofilters (also known as rain gardens and bio-infiltration systems) which, after the drought, were widely adopted for irrigation of gardens, sports fields, and golf courses. In 2013, the Office of Living Victoria allocated AU \$50 million to alternative water projects, mostly for building systems to capture, treat, and use storm-water runoff for potable substitution (Low et al., 2015).

One of the largest water-saving innovations widely embraced during the Millennium Drought was also the lowest in technological sophistication – rainwater tanks that capture and store rainwater flowing off of roofs. Because rainfall is harvested directly from roofs, it does not require the same degree of treatment as storm-water collected from streets or parking lots. It is popular precisely because it allows residents to maintain ornamental plants and gardens despite water use restrictions. The percentage of households in Victoria with rainwater tanks increased from 16.7% in 2007 to 29.6% by 2010 (Low et al., 2015).

Lastly, per capita water use for Melbourne dropped approximately 50% between 1997 and 2012 through various efforts adopted by the city and state of Victoria including: (1) imposing water use restrictions; (2) implementing water conservation measures including a rebate program for water-efficient appliances; (3) providing funding to increase rainwater and storm-water harvesting; (4) reducing environmental flows to rivers; and (5) conducting television, radio, billboards, and print media advertising campaigns to promote water conservation. Without these water saving and environmental flow reductions, studies show that Melbourne’s reservoirs would have emptied by the end of 2009 (Low et al., 2015). Conservation efforts spurred by the Millennium Drought resulted in Melbourne’s water use reduction targets being exceeded. However, sustaining these targets and innovation schemes has proven more difficult. Since the drought ended, Water Conservation Plans are no longer reported by water agencies.

In sum, we can now offer answers to our two initial questions: (1) how effectively were the twin objectives of integrated water resource planning and accountability of agency actions to the public melded? And, (2) what impact did adaptive governance reforms have on water innovations themselves? The second question can be answered fairly simply: Melbourne

considered, and adopted a number of options for water supply at the advent of the Millennium Drought (some of which, as we have seen, were implemented but not used). Early on, desalination and riverine diversion –costly infrastructure options – were adopted in short order, only to be rejected after being built. Whereas, other options such as rainwater harvesting and conservation – alternatives with which Melburnians and Victoria residents had previous experience with, witnessed more favorable public reaction. However, it must be conceded that despite their popularity and wide acceptance, these alternatives were initially implemented by means of *conventional* governance approaches including state policies that mandated inter-agency drought coordination and crisis management as well as proactive conservation measures.

While governance reforms such as *Living Victoria* provided an effective means of public outreach and, in some cases, spirited engagement, the major legacy of such reforms with respect to fostering water innovations was in modeling best practices for community-centered engagement and decision-making. This is exemplified by Melbourne Water’s *NextGen* initiative. *NextGen* has focused on discussions of topical issues, as previously noted. However, its value as a public education and outreach vehicle should not be understated. Digital engagement tools developed under this program enabled Melbourne Water to gauge the usefulness of community engagement efforts, as well as provide real-time data monitoring for customers and the agency on water conservation efforts – a demand-side innovation of some importance. Other assessments of these and related activities reveal that they were instrumental in generating widespread community support for a “water-cycle approach” that encompasses water supply provision, conservation, treatment and reuse – and that further enables individuals to better understand actions they can take by themselves to mitigate water problems. Under the broader umbrella label of *Melbourne’s Water Future*, they also generated support for treating water to

fit-for-purpose grades locally, thereby promoting sustainable resource management and community collaboration (Office of Living Victoria, 2013: 34).

As for how well integrated water management and public accountability were melded in Melbourne and Victoria, the verdict appears to be somewhat mixed. Melbourne and Victoria adopted a wide range of water conservation initiatives. While briefly reviewed here, we know they varied greatly in cost-effectiveness and water saved. What we do not know is whether a smaller number of well-chosen initiatives might have been more effective, less costly, and easier to implement. Such counter-factual findings, which would be valuable to know, have not been determined. We do know that Melbourne's investment in alternative water supply sources will make it more resilient in the face of future droughts, especially since integrated water management approaches have been widely adopted.

However, strict accountability of water agencies to various milestones has become more difficult to sustain since the end of the drought. Public 'fatigue' with continued sacrifice, and the practicality of financing new initiatives, are some of the challenges (Low et al., 2015). In sum, community engagement efforts often work best when they entail cross-sectoral activities that attract public attention. During the period *Living Victoria* was launched, Melbourne implemented a citizen's jury – a panel comprised of a randomly selected, diverse group of people – to recommend a sustainable 10-year financial plan for the city. Among other things, it led to recommendations regarding climate change mitigation and water and forest protection (Dean et al., 2016: 31). These activities have positively impacted engagement in Melbourne's water sector, even if a precise assessment of their gains is difficult to determine.

Summary – How adaptive is adaptive governance?

In reflecting on these cases, we should be cautious in embracing an overly-optimistic view as to the significance of adaptive governance in the oversight of water innovations, or a more pessimistic view of their practicality. In all three cases, adaptive governance was less than consistently applied. On one hand, elements of adaptive governance were successful in responding effectively to the more egregious instances of mal-adaptive governance identified at the beginning of this Chapter, especially with regards to learning from previous mistakes (in the Orange County case). On the other hand, we have also seen how adaptive governance has been selectively employed in water innovation selection, development, and implementation (in the Millennium Drought case).

Protagonists in the Victoria water reuse case set out early on to employ adaptive governance in order to build support for a legally problematic and potentially controversial proposal. They recognized the need to go well beyond ordinary environmental permitting procedures and technical assessments of costs, impacts, and risks. While a conventional strategy of merely filing environmental reports might have been acceptable to Victoria regulators, it would not have passed muster with members of the public or with local government councils.

An innovative series of stakeholder engagement efforts were embraced, likely averting efforts to delay or overturn the project and, most importantly, satisfactorily addressing technical, environmental and other concerns raised by local communities adjacent to the streams where environmental releases of treated effluent were to occur. In effect, the process by which the final decision was rendered was representative because it incorporated a variety of community groups. Moreover, special efforts were made – resonant with other changes in Australia at the time – to embrace the interests of Aboriginal people living in the region and who were obviously affected by various aspects of the project, including its potential impacts on local economic development.

We suggest that adaptive governance innovations in this case, while initially focused on one, selective domain – using recycled effluent to improve streamflow and in-stream water quality – transcended this domain in unplanned ways. Western Water’s appointment of a Recycled Water Advisor with responsibility for strengthening relations with wholesale and retail customers provides the foundation for a broader water stakeholder engagement effort in the basin. Similarly, efforts to engage the Aboriginal community via a *Reconciliation Action Plan* (RAP), which began as an initiative to utilize reclaimed wastewater for environmental protection in these communities, can hopefully enable aboriginal input and participation in broader infrastructure planning issues.

The Orange County Groundwater replenishment scheme via wastewater recycling was the most potentially contentious of these three cases. Opportunities for mal-adaptive responses were readily present, particularly given the track record, well-known in Orange County, of failed efforts elsewhere to implement large-scale indirect potable reuse programs. In itself, Orange County Water District’s (OCWDs) conscientious effort to learn from others’ errors was a huge step forward in adaptive governance. The OCWD built upon the track record established in its earlier wastewater reuse efforts by not taking public trust and incipient political support for granted. Public outreach through a variety of two-way communication forums identified concerns and facilitated a process of candid acknowledgment of their importance and the readiness of officials to address them throughout the life of the project.

Outreach and engagement processes were designed to encourage concrete responses to concerns, and to build into the decisional process a methodical, deliberative means of carefully assessing problems that arose as the project took shape. It also led to confidence-building measures to assure the project would be competently managed. These included external reviews

of its operation, openness to public scrutiny and oversight, and collaboration with health and environmental agencies and NGOs to ensure the safety of reclaimed wastewater. All of these process elements enabled protagonists to avoid costly delays by avoiding artificial milestones; facilitated appropriate project modifications that affirmed claims that project management was trustworthy; and most of all, incorporated a continuing commitment to quality control. No less important, the project was defended in terms that were pragmatically legitimate, emphasizing long-term cost savings to water users and the advantages of water supply independence for the region – not having to rely solely on imported water, in other words, assuring the promise of long-term regional water security.

Selective application of adaptive water governance in Orange County, however, is another matter. In sharp contrast to its experience with indirect potable reuse: the carefully structured efforts at engaging the public; the willingness of agencies charged with the project to take direct responsibility for participation and outreach; and the proactive responses to concerns, recent events surrounding prospective desalination projects in the region point to a less inclusive model of decision-making. We earlier noted that water agencies in Orange County are considering a \$1 billion, 50 million gallon per day desalter in the Huntington Beach. A series of final environmental approvals regarding the plant's impacts to local marine life are pending as of this writing, and split support among regional water agencies and others has arisen over the merits of the project. These include the need for the additional water, the possible cost to consumers (estimated at over \$2200 per acre-foot), and the environmental – including scenic – impacts to the near ocean environment where the plant is likely to be built. Some agencies appear to be embracing the project as future insurance against drought. Others contend that

greater investments in reuse and water efficiency improvements are more economical and environmental paths (Boxall, 2020; Orange County Coastkeeper, 2021).

A key governance concern revolves around transparency of decision-making and the role of public input as a bona fide driver of decisions. One criticism that has arisen is whether political forces have sought undue advantage by overriding or bypassing established regulatory procedures trusted by the public. Investigative reports by local media suggest that California's Governor and staff, working with the vendor for the proposed project, may be exerting adverse influence to sway the process and hasten a favorable licensing decision. Agencies depicted as targets of this lobbying effort include the state's Water Resources Control Board and Santa Ana Regional Water Quality Control Board. In the latter case, a board member who had been highly critical of the project was replaced by the governor (Boxall, 2021).

These are issues well beyond our ability to fully interrogate here. Even if they prove to be true they might not determine the project's fate. Nevertheless, they raise the question as to whether a more open, inclusive, and publicly-engaged process from the outset might have averted this issue from arising. Requiring that a private vendor with a vested stake in an innovation first seek approvals from multiple governance entities stands in marked contrast to OCWD's expansion of an existing potable reuse project. OCWD realized it had to engage the public directly, not merely appease state regulators.

The Victoria and Melburnian response to the Millennium Drought reveals a mix of adaptive and mal-adaptive governance efforts. Early on, large regionally-controversial projects which incited public backlash were pursued through an expedient and largely conventional governance effort. These projects ended up having to be effectively moth-balled as a result of adverse public and political (i.e., electoral) reactions. Afterwards, while a more nuanced

approach was taken to implement less controversial options, decision-making still relied principally on established command-and-control processes that enabled the state government and local water agencies to accelerate, or introduce, needed measures.

The most adaptive efforts undertaken with respect to public engagement and encouraging of community level decision-making were activities to enhance public buy-in of an overall water management philosophy via *Living Victoria*. This philosophy is predicated on a shared vision among members of the public and government officials over long-term water resilience: how to optimize supply diversification, control user costs, and ensure that lifestyle preferences are respected (e.g., rainwater harvesting as a means of retaining gardens). Engagement and community decision-making efforts provide the public with confidence that they have a positive role to play in long-term regional water management, and that public officials will likely never again embark on large-scale, expensive, environmentally problematic projects such as water diversion from rural areas or desalination without first obtaining public approval (although the existence of these projects provide “insurance” of a kind against future droughts).

The anti-government efforts which led to the termination of desalination and diversion may also be interpreted as a victory, of sorts, for public protest and, indirectly, as progenitors of more robust public participation. Community and agency engagement efforts established since the Millennium Drought, and in partial response to these controversial projects, afford decision-makers a means of “early warning” of salient public concerns before matters come to a head. Moreover, they do so in a manner that permits deconstructing these concerns on a distributed, localized manner. They therefore represent a worthwhile adaptive governance achievement that can have durable value in future water-related crises – no mean feat.

The problem of selective employment of adaptive governance tools in this and the other cases is a challenge that must be acknowledged, however. It seems clear, at least if these cases are exemplary, that some degree of technocratic governance may be inevitable when questions of long-term water resilience arise. The temptation to resort to expert, top-down approaches – especially in the midst of perceived urgency for action – is difficult to resist. Chapter 5 will explore means of balancing expertise with adaptive governance through public participation.

Conclusions – What these cases teach about collaboration

If the ultimate aim of adaptive governance is fostering collaboration among multiple stakeholders as a means of achieving water resilience, then it must be acknowledged that this aspiration fell short of the mark in all three cases. While a “decide-announce-defend” style of decision-making was rejected when introducing water innovations, its rejection did not occur voluntarily. Protagonists adopted an alternative form of decision-making only after they realized that a top-down approach would fail. Moreover, when adaptive governance mechanisms were utilized, the decision to do so was generally instituted by the same agencies that would normally embrace technocratic approaches to water governance.

Another paradoxical feature of collaboration for water innovations has to do with those features of adaptive governance that we earlier referred to as akin to *polycentric governance*. The latter is predicated on joining together multiple jurisdictions that share a natural resource – such as water – in a cooperative governance scheme. We earlier acknowledged the difficulty, cited in the literature, in bringing together stakeholders from multiple jurisdictions within a single basin to engage in conjoint governance. Especially challenging is ensuring fair and equitable representation in light of conflicting stakeholder values and the need to accommodate established agencies operating at multiple governance levels. The latter include water districts responsible

for financing, monitoring, and enforcing rules governing water (Araral and Hartley 2013). Polycentric governance scholars suggest that to effectively respond to these challenges active participation by resource users, especially for locally-managed common-pool resources, should be encouraged, while governance structures should be matched to local needs (Ostrom, 2010; Copeland and Taylor, 2009; Grafton, 2000). Our three cases adopted elements of polycentrism in diverse ways.

First, they adopted various types of improvised collaborations based on negotiated rules of exchange among existing agencies and non-governmental civil society groups. In the Victoria water reuse case, this was done, first, by the principal water company negotiating a novel regulatory-compliance agreement with a state-level agency. The efficacy of this negotiated agreement was contingent on Western Water first persuading local civil society groups as well as local government leadership boards to accept the principles enshrined in this novel regulatory scheme – and who participated in its development, refinement, and implementation.

In the Orange County potable reuse case, while a single wholesale water agency was the initiator of the scheme to expand indirect potable reuse, it first sought the concurrence of regional retail agencies whose job would be to purchase and distribute this reused effluent, after its mixture with groundwater, to their customers. This lateral or horizontal polycentrism was combined with other, more *vertical* collaborations – with state-level drinking water regulators (whose approval was, again, contingent on OCWD meeting various health, environmental permitting, and public buy-in requirements). *Horizontal* governmental collaboration was also employed with local government public health agencies and elected officials representing municipalities. Protocols establishing how project costs would be allocated and health effects monitored were among the topics ratified through this polycentric system.

The Millennium Drought case harbored by far the most complex polycentric governance protocols. Prior to and during the early phases of the drought, a combination of state-level agency directives and national authority enshrined in law allowed both layers of governance to compel local water agencies – through a Minister for Water – to collaborate in water supply planning during severe drought. Although instituted through a top-down system of control, once empowered to plan, agencies took it upon themselves to work within these rules to formulate drought mitigation strategies collaboratively.

A second polycentric feature of the adaptive governance efforts seen in all three cases is the manner in which rules were negotiated among various entities. Established public authorities were utilized in spatially-appropriate ways. In the Victoria reuse case, the appointment of a Recycled Water Advisor to directly confer with wholesale and retail customers and adoption of a Reconciliation Action Plan (RAP) throughout the basin to engage with regional Aboriginal groups were conscious, deliberate efforts to generate common operating principles and tied to a vision of economic development and environmental protection to recycled wastewater use.

For the Orange County potable reuse case, collaboration with retail water agencies in the region was built into the project from its inception. Without a reliable customer base willing to invest in and purchase water from the GWRS, the project could not have been financially viable. Likewise, local government support was necessary to build public confidence in the project's safety, and promote the advantages of regional water independence among the public promised by project supporters.

For the Millennium Drought case, once public opposition toward desalination and diversion arose, Melbourne and other parts of Victoria sought to accelerate implementation of diverse innovations as well as engage water users in less technocratically-driven ways. *Living*

Victoria encouraged Melbourne Water and others to embark upon a series of collaborations anchored among spatially proximate actors. This took the form, mostly, of novel community engagement efforts under the *NextGen* initiative, which permitted non-governmental groups to articulate and deliberate on specific priorities in areas under *Melbourne Water's* authority.

To varying degrees, all three cases approached the ideal of a convergence ecosystem (Roco et al., 2013) – a network of actors collaborating through institutional innovations permitting free exchange of ideas on a peer-to-peer level. The degree to which these ecosystems will generate long-term political change with respect to water innovations remains to be determined. *Victoria's* public engagement process via *Western Water* may be leading to a commitment to working with stakeholders on a variety of issues. Whether this engagement will lead to genuine exchanges of ideas that level the playing field of decision-making on a wide-range of water issues remains to be seen. Likewise, Orange County Water District's two-way information exchange with the public and commitment to public outreach were unquestionably positive measures for the governance of potable reuse. As yet, however, the region has not seen a similar engagement model adopted for desalination.

The *NextGen* initiative arising from the Millennium Drought offers the most intriguing example of how a convergence ecosystem might develop. This initiative has generated community support for an approach to innovation governance that embraces water supply provision, conservation, treatment, reuse, and household stewardship – giving hope in the process that local and expert knowledge really can be melded in ways that polycentric governance assumes (Dietz et al., 2003). This leads to a final set of questions: can a convergence ecosystem be developed that embraces participation to a degree sufficient to overcome resistance to innovations, acquire public buy-in, result in knowledge co-production, result in policy

experimentation, and lead to resilience? And, what factors impede public acceptance of innovations more generally? We explore these questions in Chapter 5.

CHAPTER 5 – PUBLIC ACCEPTANCE – TRUST, CONFIDENCE, ENGAGEMENT

Social Acceptance and Innovations

Water innovations are complex technologies for which successful adoption depends on social acceptance. To achieve acceptance, proponents of desalination, rainwater harvesting, wastewater reuse, and demand-side innovations are increasingly called upon to persuade potential end-users that concerns over costs, energy consumption, health and ecological risks, equity, and competent management have been adequately addressed. In some polities, ensuring acceptance requires that users are engaged in innovation selection; provided economic and other incentives to promote adoption; and, furnished adequate information to heighten their understanding of how innovations work. These requirements are similar to those found in efforts to adopt energy and climate innovations where public engagement has also proven necessary (Wustenhagen et al., 2007; Shackley et al., 2009; Coad and Woersdorfer, 2009; Hurlimann and Dolnicar, 2010; Nguyen et al., 2019; Wang et al., 2017).

In polities where citizens acquiesce in technocratic governance, social acceptance is still important. A fundamental difference in these polities, however, is that acceptance is more likely to be passive rather than active, and implicitly rest on a kind of Hydro-Social contract. This virtual or figurative contract is based on the conviction that infrastructure, institutions and policy should be seamlessly linked together to ensure water safety and security – an issue we later examine (Lundqvist et al., 2001; Linton and Budds, 2014).

This chapter explores the means by which social acceptance of water innovations can be brought about. We contend that social acceptance of innovations is important in *all* polities whether they depend upon conventional or adaptive governance. We further contend that some form of adaptive governance is needed in all polities that pursue innovations: in certain cases

due to site-specific controversies that must be resolved; in others, due to the complexity of innovations and how they alter the built environment's land-use and regional planning practices. Ideally, the engagement process leading to social acceptance of innovations requires connecting government and non-governmental actors in a free exchange. This “convergence ecosystem” (Roco et al., 2013) comprises a network of individuals who share confidence in innovations, agree on their necessity, and embrace experimentation to ensure their effective operation.

We first consider how public engagement efforts aimed at enabling inclusive representation and social acceptance work by focusing on power sharing and equity. We then turn to key demographic, social-psychological, and institutional factors that facilitate or inhibit acceptance – including perceptual and participatory dimensions of public confidence, physical connections to water, and governance. Lastly, we offer a case study of one water innovation's experience that illustrates the interplay of all these issues – China's *Sponge City* initiative.

Participatory Decision-making – from exclusion to inclusiveness

Viewing public engagement in water innovation decision-making through the prism of participation in water governance can illuminate how and under what circumstances participation actually leads to acceptance of plans and policies. As discussed in Chapter 3, because the process of water governance is most often top-down, technocratic, and exclusive – participation tends to be limited to a few. Moreover, because power is exercised by select groups of expert and vested stakeholders, the animating purpose for water policy is often narrowly needs-based and focused on infrastructure. In recent years, when decision-makers have been compelled to incorporate some form of direct public engagement in policy-making, the motivation has usually been to promote economic well-being, reduce risks to public health and the environment, and demonstrate responsiveness to demands for greater inclusiveness in

order to generate a broader range of policy options.

Since the early 2000s, a number of studies have examined efforts to expand citizen participation in water management at watershed, basin, and regional scales. Investigations in places as diverse as the European Union, the U.S., Mexico, Brazil, Thailand, and Australia share a strikingly optimistic consensus over how participatory processes in water governance actually work and the challenges they face. Their findings are also relevant to water innovation decision-making. At one end of the spectrum is the experience of EU countries which have widely adopted participatory mechanisms at various governance levels in accordance with guidance prescribed by the EU Water Framework Directive.

One study of how this framework has been implemented in Sweden – a country renowned for high-levels of democratic engagement – supports an optimistic view of its potential. Local water councils, appointed by River Basin District Authorities (RBDAs) engage in wide-open discussion on environmental quality standards and river basin management plans. They also contribute local knowledge to RBDA plans, ensuring that measures proposed for adoption are appropriate to the problem at hand (Carlander et al., 2016). A distinctive finding is that willingness to participate and comply are largely independent of whether or not stakeholders perceive the need for policy change. Dominant motives for participation include a desire for a degree of control over outcomes, and a belief that whatever decisions are reached will be fair and trustworthy. It was also found that trust in the RBDAs correlated with their perceived willingness to invest resources in the process (Carlander et al., 2016).

Water innovations have not been a specific focus of these councils. However, separate initiatives to develop local-level “urine diversion” systems to permit some blackwater reuse have been underway in Sweden for decades. Actively promoted by grassroots environmental

groups, local eco-village cooperatives, innovators, and farmers, these systems hold promise as a distributed innovation for local apartment complexes as well as isolated rural communities and, one assumes, could be linked to the RBDA process at the appropriate time. Despite user satisfaction, wider legitimacy has been elusive largely due to lack of advocacy, outreach, and “weak knowledge development.” Local decision-making has thus far been limited to municipal government councils (McConville et al., 2017: 144-156).

For their part, the governments of Queensland and Australia have jointly undertaken a public engagement process to develop a water quality improvement plan for the Tully-Murray catchment to better protect the basin’s resources – in particular, the severely threatened Great Barrier Reef threatened by warming seas and runoff pollution. The project’s initial goals included ensuring that the plan would be publicly supported, enhancing social learning and collaboration among expert and lay stakeholders, which should in turn help craft pollution mitigation strategies and demonstrate new models of governance adoptable elsewhere in Australia (Bohnet, 2016; see Figure 5.1).

Figure 5.1 about here

Participation was viewed by protagonists as a political necessity, not merely an avenue for enabling engagement. Protecting riparian and near-ocean water quality were acknowledged to be complex problems involving trade-offs among various objectives, diverse value judgments regarding what should be protected, and reconciling distinct needs. Thus, the participatory framework that evolved was carefully structured through selection of a steering committee representative of a wide range of interests, comprised of highly respected community leaders, and charged with genuine authority for decisions over floodplain management and pollutant control strategy (Bohnet, 2016: 189-192).

Important lessons from this experience relevant to innovation governance include the need to “institutionalize” participation to ensure engagement by all relevant stakeholders in a region and clarifying the appropriate uses for expert and local knowledge in decisions. With regard to the first lesson, several levels of governance – local, state, and federal must be in accord in order to ensure that all relevant economic and social sectors are represented. As to the second lesson: balancing expert information with knowledge of local conditions was found to be a process “needing further research attention (Bohnet, 2016: 193).

While the Tully-Murray experience did not directly consider how water innovations fit into efforts to protect the near ocean environment or the Great Barrier Reef, the engagement process’s emphasis on identifying pollutant load targets, enhancing biodiversity, and acknowledging conflicts between consumptive and non-consumptive water uses (Bohnet, 2016: 190) have important implications for innovation adoption, particularly since recent studies on the Great Barrier Reef note the importance of reducing waste entering waterways as one protection measure (Great Barrier Reef Marine Park Authority 2019: 183).

Other efforts to develop, incorporate, and systematize public engagement in Mexico’s Yaqui Valley, Arizona’s Upper San Pedro basin, Brazil’s Ceara state, and the Upper Ping River in Thailand have attempted to transform water governance systems from highly-centralized systems of management at national levels to more distributed, locally-based decision-making regimes that directly engage water users. Achieving this transformation is an arduous process, and leads to uneven results (Jacobs et al., 2016). For example, the Yaqui basin, like much of Sonora, has been traditionally dependent on groundwater. Since the early 1990s irrigation water management has been governed by a user group comprised of irrigators, with water rights administered by a special committee of the National Water Commission (Comisión Nacional

del Agua). Over time, several adaptive strategies have been embraced through this arrangement, including integrated ground- and surface water allocation, conservation, direct investment by water users in infrastructure planning, and greater reliance on local knowledge of drought repoused in respected local leaders (Jacobs et al., 2016: 4594).

While the Yaqui basin is not directly engaged in water innovation decision-making, a national study has identified a number of innovative strategies occurring or under consideration in arid parts of Mexico including the Yaqui basin. These efforts are especially relevant to irrigation management. Rainwater harvesting, effluent reuse, and irrigation practices are cited as promising *physical* responses to drought (Lutz Ley, 2017: 67). This national study also acknowledged the importance of basin councils as means “for promoting civil participation in addressing water issues that arise in . . . hydro-ecological regions..” Lastly, it conceded another issue relevant to water innovation governance: the limited role of decentralized decision-making in water governance due to the national government’s continued dominance over water rights allocations and infrastructure funding (Lutz Ley, 189).

In the Upper San Pedro basin, a voluntary partnership comprised of various federal, state, and local agencies and non-governmental organizations has worked together under federal tutelage to establish and enforce “sustainable yield” goals for the basin. Under the Defense Authorization Act of 2004 (Public Law 108-136), the Departments of Interior, Defense and Agriculture, in cooperation with the partnership, were required to prepare annual reports to Congress that describe water use management and conservation measures that have been implemented in order to restore and maintain the sustainable yield of the regional aquifer – so-called “321 Reports.” After this mandate expired in 2012, the partnership continued to track water use trends affecting the aquifer, riparian system, San Pedro River, and nearby springs via

a “spatial and temporal approach” managed by the partnership’s Technical Committee. The committee is responsible for coordinating identification, development and use of scientific and technical information to meet the region’s water needs (Upper San Pedro Partnership, 2017).

In addition to offering small-grants for conservation and end-use innovations (e.g., low-flow appliances) the partnership has benefitted from a decision-support tool developed by the University of Arizona under the sponsorship of the initiative’s Technical Committee. This demand-side management innovation employs actual data from monitoring stations throughout the basin to simulate various scenarios based on user input, provides multiple water management choices, and can even “game” outcomes based on decisions the user makes – (Upper San Pedro Partnership, 2017). For instance, users can simulate water level changes at the household through regional scale by taking into account data from groundwater models, evapotranspiration rates, and consumption trends (Figure 5.2). By simulating the benefits of wastewater reuse for groundwater recharge and other outcomes, the tool also incentivizes stakeholder participation in the partnership by enhancing opportunities for virtual decision-making.

Figure 5.2 about here

The Brazil (Ceara) and Thailand (Upper Ping basin) cases are intriguing examples of participatory arrangements in developing countries organized around the management of protracted drought in the former, and needs for integrated water management in the latter. In the Ceara region, a series of water-basin management councils advise the state water management company, COGERH, on reservoir releases and allocations. It also recommends new infrastructure projects. Staff scientists (técnicos) work with farmers to disseminate knowledge about drought and reservoir operations to improve local adaptation to climatic variability.

Information exchange has helped build trust between local stakeholders and federal and state officials. It has also resulted in a greater willingness among basin residents, including farmers, to share the risks of weather extremes and to adopt measures to avoid water shortages (Lemos & de Oliveira 2005).

While water infrastructure decisions are still made primarily at the federal level, the state government amply supports local stakeholders who generate social, climate-related, and economic knowledge that aid decisions. Adaptive management strategies have increasingly been embraced, and climate forecasts have been incorporated into basin planning (Jacobs et al., 2016: 4593). In 2019, the World Bank approved a \$139 million *Ceara Water Security and Governance project* whose aim is “to consolidate the water resources management capacity in the State, improve reliability of water services in selected municipalities, and increase operational efficiency . . . in the city of Fortaleza, the state’s capital” (World Bank, 2021).

Building on the initiative’s foundation of stakeholder engagement, this World Bank project explicitly targets strengthening of water governance in the State; improving service delivery and increasing accountability; and developing tools for evidence-based planning and decision-making. The project has directly resulted in a major demand-side innovation within the boundaries of Fortaleza: a set of District Metering Areas (DMAs) established in priority water distribution sectors of the city. DMAs help reduce water losses by controlling water pressure and providing the local water agency with detailed knowledge of losses and related problems, a revenue- and water-savings measure (World Bank, 2021). In short, World Bank funding has enhanced both engagement efforts and innovation adoption.

The Ping River is the largest of eight basins that together form the Chao Phraya river system and encompasses some 30 percent of Thailand’s land area. It is home to 40 percent of

the country's total population, and generates two-thirds of the nation's GDP. A major grain producing region, water needs for industry and cities have also grown in recent years (Jacobs et al., 2016: 4593; Thomas 2005: 3). Flooding, erosion – especially from deforestation, and loss of watershed protection are critical issues throughout the basin. In 2002, the central government, led by the Ministry of Agriculture and Cooperatives, established a series of river basin and sub-basin committees which, as depicted in Figure 5.3, feature a multi-level, multi-stakeholder process of engagement (Thomas, 2005 – Figure 5.3).

Figure 5.3 about here

While some accounts of this process characterize it as harboring the potential for local and expert knowledge exchange (Jacobs et al., 2016), others note that over-reliance on external consultants, frustration over the perceived slowness of implementation, and confusion expressed by some constituents have been common laments (Thomas, 2005: 33). One external evaluation of the river basin committee process concludes that participant approval of project plans is lacking, and that the RBC framework “perform(s) virtually no functions to fulfill its mandates such as a water resource management plan or water user priority or . . . allocation.” Furthermore, based on participant interviews, the RBC framework was found to be “an ineffective mechanism that is characterized by lack of collaboration, participation and outcomes which have impacts on water resource management in the river basin” (Kanjina, 2015: 158). An OECD assessment reached a similar conclusion in its plea for empowering local participants to co-determine water management priorities reflective of regional needs (OECD, 2019). In short, the Ping basin experience underscores the challenges in embracing a full-throated public engagement process committed to bottom-up decision-making in a context of top-down governance, dependence on external funding, and reliance on technocratic criteria for decisions.

Four conclusions may be drawn from this review of engagement efforts relevant to water innovation governance. First, expanded citizen engagement can facilitate social learning, transparency, equity, and knowledge sharing. However, in developing country contexts especially, involvement of numerous citizens and more diverse interests may also impose difficult-to-satisfy demands on the limited technical capacity of government agencies. They may also generate tensions over whether decisions should be based mostly on science or on public values and preferences (Jacobs et al., 2016: 4593-4). The Ping and Yaqui cases exemplify this challenge. These cases also suggest that agencies need to be more transparent at the outset of decision-making and they need to establish clear expectations regarding what they are able to do.

Second, tensions between top-down technocratic decision-making, centralized control of resource streams, and national or state-level control over water allocation and water rights are difficult to reconcile with local demands for a stronger voice in infrastructure and related plans – including plans to deploy various types of water innovations. In short, there is little reason to assume innovations would be governed in ways more democratic or inclusive than other infrastructure unless these tensions can first be resolved.

Third, in cases where engagement processes actually lead to investments in on-the-ground tools that promote the capacity of individuals and communities to monitor, measure, and rectify water use problems – and otherwise facilitate discussion on the advantages and benefits of innovations – higher levels of social acceptance of various innovations, both demand- and supply related, are likely. These on-the-ground tools, as in the Upper San Pedro and Ceara cases may also empower communities by enhancing local knowledge, spur funding of community-level improvements, and expand the range of water management alternatives considered.

Lastly, efforts to *institutionalize* participation remain elusive, and the concept itself warrants clearer definition. In some cases, it implies a transparent structure for engagement by various stakeholders – the Ping, Yaqui basin, Upper Pedro basins, Ceara region, Swedish RBDAs, and the Tully-Murray basin cases have all sought to establish this structure of engagement. To some researchers, however, institutionalization also means having a bona fide process for *exercising authority over decisions*, including the ability to formulate rules and partner with other groups having resources valuable to the process of decision-making (Gerlak, 2017). The capacity to conduct genuinely deliberative policy-making requires sound information, nominal control over resources, and a commitment to incorporating marginalized groups in deliberations. This is a high bar beyond the reach of many initiatives.

Other water policy domains face comparable challenges. Controversies over bottled water and hydraulic fracturing (fracking) exemplify the difficulty in fostering genuine public engagement over water-related choices. Bottled water has become a polarizing product. While convenient for consumers, it can impose adverse impacts on local communities where water is sourced, and generate enormous carbon and ecological footprints through production, bottling, and distribution (it is often bottled in polyethylene terephthalate, or PET, derived from petroleum, that ends up in landfills, streams, rivers, lakes, and the ocean). Many claim that it is brashly marketed to recent immigrants and other under-represented groups who are naturally distrustful of publicly-supplied water. This poses special risks to children who may be denied the benefits of fluoridation (Gorelick et al., 2011). From the standpoint of globalization, moreover, multi-national corporations such as Evian, Perrier-Nestle, Coca Cola, and PepsiCo have bought up local water rights in many countries. Despite concerted public opposition over threats to springs, headwater streams, and groundwater, local resistance has rarely been

successful in thwarting production.

In the U.S., when one corporation announced plans in 2013 to reopen an idled bottling plant near Mt. Shasta, California to produce bottled water and other beverages in a former logging community suffering from high unemployment, local officials supported the project, while some residents worried that the proposed plant had no cap on how much snowmelt generated groundwater it could pump, and how truck traffic and noise could diminish the area's quality of life. The California Environmental Quality Act requires an environmental assessment for large public-permitted projects. However, local officials claimed they had no legal authority to require a report because the plant's site was initially zoned for heavy industry, and because water bottling is a prior, permitted use (Romney, 2015). A lesson from this case, relevant to water innovations, is that differential authority between governance levels impedes effective engagement.

Hydraulic fracturing ("fracking") – the injection of water and toxic chemicals at high pressure into shale rock formations to extract gas and oil – illustrates another set of engagement problems. While potentially injurious to groundwater, it is an effective means of fossil energy mining – some 35% of U.S. gas and oil reserves are tapped through this method, and China may soon become the world's leader in its practice, despite environmental reservations by scientists (Biello, 2014). The European Union, which takes a precautionary approach to environmental risk, pursues a stringent approach to fracking regulation and tips the balance strongly toward protecting public health and the environment. In 2012 the EU adopted a risk-based framework to provide a "clear, predictable and coherent approach to regulating unconventional fossil fuels" (Feldman 2017). Because some of the water used in fracking is unrecoverable, adverse impacts to aquatic habitats and ecosystems may result, and member states are urged to impose stringent

safeguards against harm and to engage the public in setting standards.

Debates over fracking are contests over competing risks: protecting irreplaceable water supplies versus extracting needed energy. Viewed by its critics, and increasingly buttressed by biomedical research regarding fracking's use of endocrine-disrupting chemicals potentially injurious to peoples' health and the environment (e.g., Kassotis et al., 2016), its objectives are seen as better met by other means (e.g., renewable energy). In this respect, there is common ground between fracking and water innovation disputes. Critics of water innovations sometimes charge that additional supplies can be provided by other options (e.g., Monterey Bay, California in Chapter 1 and the UAE, in Chapter 3). Debate over the need for participatory governance for water innovations, as in fracking, thus entails both process and outcome considerations.

Sociodemographic, psychological, and institutional factors of acceptance

We have seen some of the ways in which demographic, social-psychological, and institutional factors facilitate or inhibit social acceptance of water innovations. A deeper dive suggests that three major *behavioral* factors are especially critical: *public confidence*, *public contact*, and *governance*. *Confidence* refers to the degree to which citizens believe that decision-makers charged with managing water innovations are competent and honest and that their actions are fair, reasonable, carefully considered, and trustworthy (Fielding et al, 2018; Adewumi et al., 2014). *Contact* has to do with intended end-uses for water and public perceptions of the risks associated with those uses. Finally, *governance* entails political and administrative factors that determine how an innovation is selected, the underlying attitudes that shape peoples' views toward an innovation's impacts, and the extent to which the public is involved in strategy development – what some political scientists refer to as *governmentalities* (Menegaki et al., 2007; also, Rogers et al., 2016).

Perceptual dimensions

Public confidence has perceptual and participatory dimensions. With respect to the first of these, studies have found that individuals' trust and confidence often revolve around messaging: or, how proponents of an innovation describe its advantages and benefits. A rhetorical question researchers often pose is: can advantages be expressed in language accessible to the general public and straightforward enough to engender credibility? As we saw in the case of Orange County's GWRS, project supporters were able to pinpoint – and articulate – tractable economic and community development advantages in an indirect potable reuse option. Likewise, OCWD willingly admitted previous failures in averting carcinogenic contaminants from entering treated wastewater. Positive messaging not only built confidence in the management of the GWRS, but reinforced the project's legitimacy (Harris-Lovett, 2015).

Messaging entails more than proponents' communication style. It entails reinforcing messaging by others, as well as actions that validate the message. In cases where water alternatives are widely accepted, such as Israel and Singapore, the competence displayed by technocratic leaders, coupled with the public's preoccupation with water security, helped validate the positive messaging conveyed by agencies responsible for innovation governance. As we saw in the case of Israel, however, messaging can break-down if decision-makers fail to make a compelling argument for a particular siting decision.

Messages conveyed by decision-makers regarding the safety and security of water innovations are more likely to influence public perceptions in a positive way *if* those messages are reinforced by family members, peers and colleagues who are deemed trustworthy, and whose knowledge or familiarity with certain technologies are viewed positively (Dolnicar, et al., 2011; Friedler et 2006). This is illustrated by the public engagement processes seen in

Orange County, California and in Melbourne, Australia during the Millennium drought. In the former case, reinforcing messages by community groups and public health as well as other local government agencies toward indirect potable reuse reinforced those issued by the Orange County Water District. In the latter case, citizen engagement processes such as *NextGen* enabled residents to deliberate, debate and discuss pros and cons of various innovations and their implementation, thereby generating their own unique community-relevant messaging.

Message reinforcement may also occur through perceived inter-group synergies. A study of wastewater reuse in Crete, for example, found that if one set of end users sees that another has confidence in an innovation's efficacy, then the result may lead to *social acquiescence*. In this instance, because local farmers were willing to use recycled water due to its economic advantages, consumers of the food they produced also found reuse acceptable and were likely to consume food irrigated with reused wastewater (Menegaki et al., 2007: 16). A comparable synergistic effect has been seen in Israel. Despite evidence of possible, albeit small, exposure risks to consumers from pharmaceuticals such as carbamazepine detected in fruits and vegetables grown in soils irrigated with reclaimed wastewater, neither farmers nor consumers appear to be highly concerned. The overall advantages of reuse have been reinforced by messaging regarding its economic, water saving, and environmental benefits (Friedler et al., 2006; Paltiel et al., 2016).

Addressing perceptual concerns is not a panacea. Critics argue that social psychological explanations for public support of water innovations too often assume that differences between expert and lay views of reclaimed water (or, for that matter, other innovations) are synonymous with “real versus perceived” or “objective versus subjective” points of view (Ormerod and Scott, 2012: 4). Adopting such distinctions lends support for well-meaning policy responses

intended to bring public opinion in-line with expert judgment through marketing and communication strategies. Such responses, however, according to one study of perceptions toward reuse among residents of Tucson, Arizona, may “reinforce hierarchical *technocratic* decision-making” (Ormerod and Scott, 2012: 4). They may also ignore the difference between confidence in a technology, and trust in the *process* that leads to a decision to adopt it. The latter is more often a critical factor in community opposition.

In communities where levels of trust toward elected officials is low, achieving public confidence in water innovations requires some degree of direct public engagement. In short, “finding innovative ways for the citizenry to truly participate in water policy decisions during the design and planning phases could engender confidence in the public engagement process” (Ormerod and Scott, 2012: 17). In the Tucson case, survey findings show that residents trusted messages emanating from the local water agency, but *not* from local elected officials, regarding wastewater reuse safety, especially for non-potable uses. Participation in adoption decisions was viewed as necessary in order to enhance the legitimacy of reuse projects, and to ensure that other viable alternatives were not overlooked (Ormerod and Scott, 2012: 18).

A similar conclusion was reached in a survey of residents of a community in southeast Queensland, Australia, undertaken just prior to a referendum on potable reuse. Researchers concluded that the more community members perceived that the local water authority used fair procedures in promoting potable reuse – by consulting with the community as well as providing accurate information on benefits, costs, and risks – the greater their support for reuse and for the agency. A “shared social identity” with the agency influenced citizen trust and reinforced the perception that it was competent “and (had) the community’s interest at heart” (Ross et al., 2014). These findings support claims that higher levels of trust in a public authority charged

with providing basic community services are associated with lower perceptions of risk. And, it also affirms the findings of studies suggesting that risks are *socially amplified* by distrust in institutions (Pidgeon and Henwood, 2010). In sum, to the degree that messaging and engagement on water innovations can be combined to enhance trust, the more likely concerns with potential risks can be alleviated and social acceptance enhanced.

As noted earlier, contact refers to the connection or proximity of end user to water source. End uses entailing direct means of contact such as ingestion, bathing, swimming or other bodily interaction with water can generate serious apprehensions when the water source is recycled effluent. Direct contact issues also arise for desalination and harvested storm-water but tend to be less serious. For recycled effluent, direct contact uses demand that “consumers are fully comfortable with the principle of wastewater recycling and fully confident in its safety in respect of their health . . . by demonstrating that the water is safe both in chemical and microbiological terms (Fawell et al., 2005: 56). On the other hand, end uses for recycled wastewater entailing *indirect* contact (e.g., landscape and crop irrigation) may also generate concerns, but are generally viewed as more publicly acceptable (Hurlimann & Dolnicar, 2010).

Studies of wastewater reuse, a water innovation domain where public concerns most often arise, also tend to dichotomize social acceptance factors into perceptual and participatory categories. Public apprehensions toward direct contact with treated wastewater tend to revolve around its purity and effects on health. Outright fears are often attributed to a lack of public knowledge and “misperceptions of what ‘reclaimed water’ is and how it may be used (Bio by Deloitte, 2015: 57).” However, studies also confirm that the presence of pathogens in reclaimed wastewater generate legitimate concerns, especially as reclaimed water use has increased. This points to the need for more rigorous risk assessment and stronger regulation in order to garner

public acceptance (Salgot and Huertas, 2006: 49).

Survey research in Europe and the U.S. suggests that social acceptance is impeded by the public's lack of awareness of how treated wastewater can provide an efficient solution to water scarcity and satisfy drinking water needs. Acceptance is also said to be impeded by a lack of understanding of the local water cycle. Making wastewater reuse more acceptable thus hinges on providing buffers between the treated wastewater and end users, which may take the form of injecting treated wastewater into groundwater basins or reservoirs – a measure that permits spatial and temporal distance between treatment and consumption (Bio by Deloitte, 2015: 82; Fawell et al., 2005).

Here again, critics charge that too much weight can be attributed to education and outreach as factors enabling social acceptance. Other studies suggest that some form of direct stakeholder involvement in the implementation of reuse is required to encourage its acceptance. A key to engagement is ensuring that those responsible for paying for wastewater reclamation are also its beneficiaries. A contingent valuation study of over 300 reclaimed water users in the Segura River Basin in Spain showed that reclaimed wastewater use for irrigated agriculture had significant non-market environmental benefits including reducing average treatment costs for water hat users felt justified its use (Alcon et al., 2010). Other cases suggest that when those paying for reclaimed wastewater do not directly benefit from it, acceptance is likely to be lower (Bio by Deloitte, 2015: 83).

While public contact issues have also arisen for desalination and storm-water/rainwater harvesting, intensity of concerns tend to be lower than for wastewater reuse. However, as with wastewater reuse, they also coalesce around human health impacts. Two explanations for the comparatively lower level of concern may be conjectured. First, the levels of contaminants

potentially present are closely regulated and monitored. Second, in the case of desalination, other public acceptance concerns such as ecological and aesthetic impacts may partially obscure relative levels of other concerns.

For desalination, product water can be adjusted to a quality target level fairly easily, and it is often blended with other sources to improve its quality and taste before distribution to customers (Voutchkov, 2013: 103). Nonetheless, as previously discussed, feedwater for desalination can introduce biological and chemical contaminants including viruses, protozoa, bacteria, and chemical contaminants ranging from xenobiotics (including endocrine disruptors, pharmaceuticals, and personal care products) to algal toxins (Cooley et al., 2005: 53).

The comparatively lower levels of concern over contact for storm-water may be attributable to the perception that it poses less direct risk to users. In most applications, storm-water undergoes treatment before both potable and non-potable use. Wetlands and bioretention systems which filter water through soil or sand-based media are able to remove sediment, nutrients, and heavy metals (Hatt et al., 2006; Grant et al., 2013). However, lack of data on human pathogens from roof runoff poses special challenges. In both instances, contact-related concerns are more often expressed by public health officials rather than by the general public.

In short, end uses, the perceptions that regulations suffice to protect the public, and incorporation of public participation in adoption all influence contact-related concerns. For its part, why wastewater reuse generates higher levels of concern has been succinctly hypothesized by one study which puts the matter thus: “facts and figures might inflame rather than convince. The acceptance of water recycling is a social factor with a high emotive content” (AQUAREC, 2006: 52). For all water innovations, and perhaps more especially for wastewater reuse, *governance* thus becomes an essential factor in hastening social acceptance since it

encompasses law, regulation, and stakeholder negotiation. More importantly, governance reflects existing power relationships in a polity, determines whose voices are represented in decision-making, and is responsible for addressing the issues that matter most to citizens.

Demographic Issues

To understand the role of governance, we must first recognize the demographic, historical, and institutional factors that underlie acceptance of innovations – the role of *political culture*. Demographically, investigators have found that higher levels of income and education are positively associated with acceptance of recycled water, for example. While people of color have lower levels of acceptance as do persons having lower income and education levels, some scholars charge that studies have been too localized and limited to definitively conclude if this is always the case (e.g., Fielding et al., 2019; Tortajada and Ong, 2016). While education can play a role in changing perceptions, some factors leading to resistance are more difficult to overcome. In places where residents are used to some form of recycling and/or fluoridation, reuse is less likely to be resisted. Conversely, in places that have traditionally relied on fresh water a higher resistance to recycled water, including rain- or storm water may arise (Goonetilleke et al., 2017). In addition, studies have also shown that the factor of “disgust” can play an important role in this issue. Disgust often is promoted by effective opposition campaigns labelled “Toilet to Tap” (Fielding et al., 2019).

Social acceptance of recycled water is also influenced by age (younger people are generally better educated and, thus, more accepting). Conversely, an individual’s degree of environmental concern, the degree to which s/he perceives that water is scarce, and the extent of personal knowledge about recycled water and how it is “manufactured” also affect perceived risk. Because individuals often lack interest, time, or knowledge to make informed decisions,

trust in authorities is key in public perception and acceptance (Ross et al., 2014; Fielding et al., 2019). Low trust in government officials to mediate potential risks can strongly impact acceptability of recycled water.

Historically, legacies of environmental injustice and mis-treatment suffered by some groups lends special credence to this issue, and is a governance challenge of inestimable importance. Mistreatment is strongly connected to the race, income and education levels of a community. Traditionally, low income communities are often bypassed when decisions to develop water and sewer infrastructure are made, or rate-payer decisions formulated. These are also the communities having the least leverage in decision-making regarding water innovations. Although laws now widely require that these groups must be consulted – and special measures undertaken to assure – that measures to retrofit water appliances and repair distribution systems are made, implementation challenges remain (Burch et al., 2005; Environmental Justice Coalition for Water, 2005; Sze, et al., 2009).

Disadvantaged communities remain disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, risk exposure, and environmental degradation. Because these communities have a large proportion of people of low income, high unemployment, low levels of home ownership, high rent burdens, sensitive health, and low levels of educational attainment, they also face distinct governance disadvantages from the very outset of decisions regarding innovation adoption. Their ability to attend public meetings or procedural hearings are low, as is their efficacy to bring compelling counter-arguments to bear when decisions to establish a desalination plant or wastewater reuse facility are being weighed. Studies of the role of under-represented communities in the context of air quality and greenhouse gas emissions reductions have documented this phenomenon, and

the findings resonate strongly with the historical experiences of groups contending with water quality issues as well, including the Flint, Michigan lead contamination crisis (Shonkoff et al., 2009; Izzeldin et al., 2017; Olson, 2016).

Providing environmental justice for under-represented groups with respect to water innovations ultimately entails ensuring procedural justice within governance processes – especially in decisions over resilience. A number of investigations have recognized the importance of this challenge in proposals to construct water infrastructure such as impoundments, diversion projects, and more recently, desalination plants or recycling facilities, particularly in developing societies (Spang et al., 2018). Often overlooked by decision-makers is the need to actively demonstrate the advantages of certain innovations to traditionally excluded or marginalized groups and to invite their engagement in project design. One study of rural people's inclination to adopt sustainable water management practices in Iran underscores the importance of this issue. This study showed that perceived benefits influenced rural people's intention. Villagers are interested in reducing adverse impacts to health and the environment. Furthermore, efforts to familiarize them with the benefits of sustainable water practices, and to instill them with knowledge and familiarity of how they operate, can influence their intention to adopt these practices (Aliabadi et al., 2020).

A final governance factor is the growing conflict between the quest for policies that “streamline” and expedite permitting, licensing, and/or approval of water infrastructure in order to incentivize their implementation on the one hand, and demands to carefully vet their environmental social, and health impacts on the other. Efforts to balance these goals have become increasingly pertinent in debates over the introduction of wastewater reuse, rainwater harvesting, and desalination, particularly in polities where traditional governance of water

innovations predominate (Farrelly and Brown 2011; Keremane et al. 2011). This requires an examination of the government's traditional role as protector of public welfare with respect to water.

The hydro-social contract – first, do no harm

Dominant perceptual factors dictating the inclination to consume water produced by innovations are healthfulness and safety: a theme encapsulated in the question “how safe is safe enough?” However, little appreciated is that this preoccupation is relatively recent by historical standards. It first arose in the late 19th Century as technologies able to remove hazardous contaminants began to emerge, and as public expectations regarding what constitutes a reasonable margin of safety began to be reflected in water regulations. These expectations gradually evolved into a widely-shared set of values termed the *hydro-social contract* or hydro-social cycle. This contract is now widely embraced by most industrialized nations and many developing ones and is predicated on the belief that a community's values dictate an informal yet binding agreement between the public, government, and business sectors regarding how water quality should be managed. This contract is expressed through engineered infrastructure, law, and regulation. Ideally, it seeks to avert disease and ensure the well-being of non-human as well as human life (Lundqvist et al., 2001; Linton and Budds, 2014).

The hydro-social contract was facilitated by the advent of large, centralized, hydraulically-engineered systems designed to provide dependable water supply through long-distance diversion projects – an innovation we might think of as a refinement of the Roman aqueduct. It was also characterized by an entirely new set of innovations: systems that were initially designed to shuttle waste (and wastewater) out of urban areas through sanitary and combined sewers that discharged waste to local water bodies. The latter were spurred by

epidemics of cholera, typhoid, yellow fever and other infectious diseases from human and animal wastes that collected in street gutters, cesspools, and streams in large cities including London, Paris, and New York (the latter suffered a cholera epidemic in 1832 causing the death of several thousand residents) (Koeppel, 2000).

Both sets of infrastructure were accompanied by governance innovations, mainly in the form of public and private investments in improvements to waste transport, increased public oversight of sewage systems, and jurisdictional consolidation of water services (often transforming ownership from private, investor-owned enterprises to public entities (Koeppel, 2000; Brown et al, 2009). Another key feature of the hydro-social contract was a widespread attitude change in mass society facilitated by the growth of chemical engineering, public health, and other fields of scientific endeavor: and, thus a conviction that sewage was not to merely be collected and transported away from population centers as in ancient societies, but actually treated to remove contaminants.

This latter innovation – first introduced in large metropolitan areas such as London – gave rise to a newer conception of risk: from a mechanistic conception of health and environmental impact measured through dose-response models used in epidemiology to a broader conception that embraces *public trust* in governance institutions charged with managing water and wastewater treatment systems, *confidence* in the ability of technologies to measurably improve sanitary conditions, and *concern* with stigma and other adverse impacts to quality of life stemming from living in unclean environments (Huitema, et al., 2009; Renn, 2017).

The hydro-social contract is important to social acceptance of water innovations because what various groups consider to be appropriate ways of managing water is – in part – determined by the social context and existing power relationships within a polity. In short, groups with

considerable power and influence are more likely to be satisfied by the efficacy of this hydro-social contract. They will likely believe that the management of infrastructure, and the enforcement of law and regulations is working according to well-regarded practices, because they trust expertise and have confidence in the authority of established institutions.

Conversely, those having less power and influence are likely to be less trusting in the efficacy of the hydro-social contract. They may view connections between infrastructure, law and regulations with suspicion unless they are convinced that the values they hold with respect to their welfare and well-being (i.e. health, safety and security) are working in their favor and are fervently embraced by government. They will not simply trust “experts” to have their interests at heart. They need to be reassured through actions. A study jointly undertaken by a consortium of European, Australian, and Israeli universities and research institutions states this case somewhat rhetorically but cogently. Charging that wastewater reuse adoption has been slow in many countries, some researchers claim that unwillingness by regulatory bodies to take responsibility for setting standards has been a significant impediment (AQUAREC 2006: 27). Proving that regulators and innovation proponents are committed to taking responsibility requires adopting specific actions to enhance an innovation’s legitimacy.

Legitimacy and social acceptance – what it means, why it matters

Legitimacy entails the connecting of efforts to adopt an innovation in the shared belief systems, moral standards, and cultural conventions of an entire polity (Harris-Lovett, et al., 2015: 7553). Ensuring that a technology’s adoption resonates with the dominant values of a polity requires more than altering public perceptions. It requires adopting actions ranging from demonstrating the efficacy of a technology to inviting citizens to co-engage in the planning, assessment, and implementing of innovations. A striking aspect of much of the literature on

public acceptance of water innovations, including research by the water innovation industry itself, is tacit acknowledgement that legitimacy is a key factor in building support.

Many discussions of legitimacy in the open literature tend to be prescriptive in tone and normative in substance, but sometimes weak in empirical evidence. Table 5.1 elucidates the activities often prescribed in the literature for our three major water innovations to achieve legitimacy. Table 5.1 also describes the activity's programmatic objective and how it is supposed to contribute to legitimacy. While the actions and their objectives are compelling, evidence for their actual effectiveness with respect to building legitimacy is too often limited to descriptions of "successful" cases alone.

Table 5.1 about here

Many reports that prescribe legitimacy-building measures acknowledge their limitations. For desalination and wastewater reuse, in particular, achievement of legitimacy poses special challenges due to their sometimes limited resonance with public values. In the case of desalination, three issues exemplify this problem. First, many of the concerns expressed by the public revolve around environmental impacts on the near ocean environments. Some environmental groups simply do not consider the mitigation measures proposed to alleviate these impacts as acceptable alternatives for averting intake impingement or entrainment, and these groups are frequently seen testifying before regulatory approval bodies in an effort to challenge the legality of proposed plans for power plant and desalter intakes.

In places such as Southern California, courts and regulatory agencies have usually found mitigation measures acceptable for seawater reverse osmosis (SWRO) projects "as long as (they are) applied along with the best technology available and (are) suitable for the site-specific project conditions" (Voutchkov, 2016: 142). Nevertheless, public opposition to these measures

may pose lengthy and thus expensive delays due to the need to alter plant design. This is a problem that will likely endure, especially as regulators adopt new and more stringent strategies as public involvement in desalination permitting issues increases.

Second, public acceptance of desalination depends on many factors that vary from place-to-place. For instance, the importance of desalination to a country's economic development plans and the magnitude of water scarcity, play important roles in shaping public opinion. Moreover, the public's general environmental awareness, how projects are funded, and the desired social function of coastal areas are other influences. In short, political culture is of critical importance in desalination's perceived legitimacy. In parts of the Middle East and North Africa that are severely impacted by freshwater scarcity, few major environmental concerns have been reported. From the standpoint of legitimacy and resonance with public values, in these regions desalinated water is already "an inherent part of many peoples' lives and that many countries are highly dependent on it" (Bleninger and Jirka, 2011: 61).

Third, as we previously noted with respect to Israel, high approval rates for seawater desalination do not automatically translate into support for *specific* projects. Even if opposition is confined to a minority of local residents, it is still are capable of substantially delaying projects. Again, it is incumbent on desalination proponents – and the industry as-a-whole– to dispel major environmental concerns, especially at the site-specific level when particular projects are under consideration (Bleninger and Jirka, 2011: 67, 69).

For wastewater reuse, similar legitimacy issues have arisen. While adoption experiences have shown that public support for potable reuse can be enhanced through proactive, appropriate, and consistent outreach, given the particular concerns various publics harbor, such outreach efforts require deft, highly-resourced, and well-targeted strategies to be effective.

Project proponents should communicate with agencies that have existing potable reuse projects to learn more about how to reach out to communities (we saw this strategy adopted for the GWRS in Orange County). In addition, appropriately-skilled and highly-trained staff should be assigned to this task, and tours of existing potable reuse demonstration facilities or visitor centers should be encouraged (Mosher and Vartanian 2015: 128).

Lastly, and consistent with our discussion of the hydro-social contract, not only must high-visibility and respected community partners be included to ensure successful adoption, but the public must be instilled with confidence that all those having a direct role in implementation of a project are transparent and competent, and willing to take ownership and responsibility for its operations and safety. The lead government agency in charge of the basin planning process must institute “a robust governance structure that allows stakeholders’ participation in the planning process” and clearly establishes their duties (Rodriguez et al., 2020).

A closing note regarding rainwater and storm-water harvesting is in order. Public support is often easier to obtain since these sources are usually of better quality than untreated sewage or industrial discharge, and they can readily be adopted to non-potable uses including landscape irrigation, agricultural or horticultural irrigation, or watering of lawns and gardens. In places where water supply is scarce or limited, reuse applications are generally better accepted by the community – as seen in Australia, for instance. In these and other instances, harvested storm-water and rainwater are often “mixed” with recycled wastewater for non-potable uses. An interesting question to explore is: what about areas that *do not* suffer from water shortages but face a surplus of precipitation resulting in local flooding? What innovations might be adopted, and what social acceptance challenges arise? We turn to one instructive example.

Like a sponge –cities, storm water innovations, and lessons in social acceptance

Large cities worldwide, especially those in rapidly developing countries, face a number of water problems made worse by climate variability and planned as well as unplanned growth. Proposed solutions to these problems face numerous, difficult to reconcile demands because they straddle the boundaries of flooding, water quality, and water supply management. These demands range from calls to become more environmentally sustainable by adopting “green” infrastructure to pleas to encompass water problems holistically through implementing remedies able to conjointly avert or reduce flooding, mitigate storm water pollution, and prevent groundwater depletion caused by impervious surface runoff: one cause of urban water shortage.

To tackle these problems comprehensively, a variety of so-called *low-impact* strategies have been prescribed that employ natural drainage processes including vegetated above ground features such as bioswales, storage ponds and rain gardens to reduce water-related risks and provide urban amenities. Different versions of these strategies have been adopted under the names Low Impact Development (US), Blue-Green cities (Europe), and Water-Sensitive Urban Design (Australia). One of the most ambitious efforts to date to reduce flood hazards while improving overall urban water management is China’s *Sponge City* initiative which began in 2013 with the involvement of 16 cities and has since been expanded to over thirty (30) (Fenner, 2017: 2; Zevenbergen et al., 2018; Nguyen, et al., 2019; Jing 2019).¹

Prompted by major flooding in Beijing in 2012, the overall objective of the *Sponge City* concept is to break the cycle of groundwater over-extraction, waterway degradation, and urban drainage problems caused by sprawling urban development and the use of impervious materials

¹ In December 2013, “Sponge City” was officially sanctioned by the central government and became a national policy when President Xi Jinping appealed for cities functioning “like sponges” during a high-ranking conference on Chinese urban development. See: Hongru Cai. 2017. *Decoding Sponge City in Shenzhen: Resilience Program or Growth Policy?* Thesis, Department of Urban Studies and Planning in partial fulfillment of the requirements for the degree of Master of City Planning, June. Cambridge, MIT, p. 15. <https://dspace.mit.edu/handle/1721.1/111261>.

for streetscapes and other surfaces. Sponge Cities employ permeable surfaces and green infrastructures; prioritize natural drainage systems; and make full use of green belts, roads, and river systems to absorb, maintain, and release water to mimic a city's predevelopment hydrological characteristics (Wang et al., 2017). Broader goals include improving urban resilience against torrential flooding, a threat to a large number of urban residents in China, and encouraging adoption of “green building” measures such as rain gardens, green roofs, and other bio-retention solutions including ponds and land basins. These measures help reduce run-off volumes, improve water quality, and provide resilient sources of storable supply for newly-built, flourishing cities (see Figure 5.4). As one Shanghai-based urban designer has stated:

Simply reducing the number of hard surfaces and increasing the amount of absorbent land, particularly green space, can make a significant difference in reducing the severity and frequency of flooding events. Supplementing this approach with efficient channeling and storage systems can help to counter the frequency of water shortages, which can be particularly acute in large cities (Xu, 2020).

Figure 5.4 about here

The Sponge City paradigm, perhaps unsurprisingly, fits neatly into the top-down, technocratic approach to city planning and environmental management characteristic of many rapidly developing polities such as China. Nevertheless, many of the basic tenets of the concept can be adapted to polities with more publicly-engaged traditions of urban planning. Taipei has adopted sponge-city type elements to help reduce the effect of urban heat islands, and sponge city principles are beginning to take hold in parts of the Caribbean and Kenya, as well as the cities of Berlin and even New York. The German capital has developed a partnership with the city of Copenhagen which, after a damaging rainy period, surrendered older design habits to

sponge city techniques in order to better manage run-off. Berlin's \$1.5 billion-plan includes expanding the city's sewer networks, replacing asphalt surfaces with grassy green roads, and creating temporary water retention zones serving multiple purposes (e.g., as below ground playgrounds) – an “absorbent network” to carry and reduce rainwater runoff velocity (VINCI group, 2019).

As with many centrally-planned initiatives in China, numerical milestones have been developed in support of Sponge City, one of which is ensuring that some 80% of urban land is capable of retaining and reusing 70% of storm water by 2030 (VINCI group, 2019). In 2014, shortly after the initiation of sponge city, the Ministry of Housing and Urban-Rural Development issued a set of detailed guidelines, *Technical Guidance on Sponge City Construction*, which prescribes explicit measures to ensure that sponge cities essentially follow the same principles as Low-impact Development. This guidance underscores the advantages of China's top-down governmental structure in facilitating relatively rapid implementation of ambitious built environment initiatives and innovations (Wang, et al., 2017: 12). Whether rapid implementation equates to social acceptance, however, remains an open question.

Inclusion and legitimacy challenges

Like all water innovations, *Sponge City* is predicated on social acceptance, especially acquiescence by segments of urban civil society. Since its implementation requires changes to the built environment, cooperation with urban designers, planners and architects is an important operational component for its efficacy. The Chinese government explicitly hoped for ready collaboration with property developers and builders in providing partial private sector funding for Sponge City initiatives as well as public-private partnerships in efforts to expand the concept to more cities. In addition, embedded into *Sponge City* is the belief that installation of

bioswales, rain-gardens, and other amenities can enhance the live-ability of the built environment, improve urban habitat and ecology, and thus “deliver multiple benefits to the general public by creating greater recreational space and improving the amenity value of a district or area” (Wang et al., 2017; Chan, et al., 2018: 773).

Despite these aspirations, as case studies of Wuhan and elsewhere indicate, thus far, “the government in China plays a significant role and . . . civil society is merely the recipient” of *Sponge City* innovations (Zevenbergen et al., 2018: 7). Engagement with civil society groups has been mostly unidirectional and emanates from the top downward. This pattern has often led to inadequate project supervision, knowledge gaps in the areas of project financing and maintenance costs, a lack of coordination across relevant agencies – especially in larger cities, an absence of monitoring and evaluation of projects’ effectiveness, and a lack of explicit public perception and support.

There is a larger irony underscored by these problems which would appear to reinforce the need for public engagement in implementing water innovations. In order for *Sponge City* implementation to be effective, public participation is required in project planning, implementing of specific practices, and raising capital for infrastructure. In addition, as officials acknowledge, public perceptions and behaviors directly affect *Sponge City* implementation. Many of its components, such as green roofs and rainwater collection systems, are “connected to peoples’ daily lives,” making dissemination of information and education important for fostering involvement and ensuring that these components operate as they were intended (Wang et al., 2018: 12, 19). Thus, despite the fact that the *Sponge City* paradigm has successfully exploited the presumed advantages of technocratic decision-making in being applied relatively quickly and expansively, some level of public engagement is necessary to reap the full measure

of benefits the paradigm promises.

Up to this point in time, *Sponge City* proponents have devoted greater attention to physical infrastructure considerations than to public engagement. This problem is manifested in two ways. First, while the overall object of *Sponge City* – to holistically address urban flooding, non-point pollution, and water supply regeneration – is clear, reasons for doing so are championed for different reasons. One narrative suggests that *Sponge City* is primarily designed to be a distributed resilience program modeled on Low Impact Development (LID) practices elsewhere, and whose objective is to restore, or maintain, cities in a condition mimicking natural conditions as closely as possible. A competing narrative views *Sponge City* as an urban growth management innovation justifying new investment in construction and public-private financial partnerships (Cai, 2017: 7).

While these divergent philosophies need not be seen as lying in opposition to one another, when coupled with the fact that many Chinese cities reportedly see themselves as engaged in inter-provincial competition as a means of enhancing their prestige, the result, as one observer notes, can take the form of ‘green-washing.’ What makes this an especially pervasive risk is the fact that there is little macro-scale environmental governance or accountability tied to ecologically-oriented urban development principles in China (Gill, 2020). Thus, while the *Sponge City* concept suggests an aspiration toward a comprehensive form of urban environmental planning, because governmental financing still predominates, the ability of – and incentive for – participating cities to bring together policy makers, real estate developers, urban planners, researchers, and the general public to enhance cities’ ability to minimize flood losses and achieve other water management objectives remain relatively low. (Cai, 2017: 35).

A second impediment to public engagement is the lack of incentives for private

stakeholder involvement in storm water management. Because there is no private land in China, the most relevant public participants in land-use, water management, and investment decision-making pertinent to *Sponge Cities* are mayors, vice mayors, and urban land use management agency officials (Qiao et al, 2019: 4, 6). Empirical studies of public perceptions of *Sponge City* efforts acknowledge that involvement of these officials is a positive – especially in order to ensure maintenance funding once projects are built. At the same time, however, general public awareness, “beneficial to construction and maintenance of *Sponge Cities*” remains low, and effective outreach is needed so that the public can better understand their role in implementing the paradigm. Notable exceptions to this lack of awareness are found in older residential districts such as the *Sponge City* pilot zone in Zhenjiang, where choices over retrofitting current green spaces into parking spaces and installation of rain gardens and bioswales directly was influenced by local residents (Qiao, et al., 2019: 6, 8).

Funding for participant cities also poses a further public engagement challenge – one directly hinging on legitimacy. While well-over US \$12 billion has been spent on all sponge city projects with the central government providing roughly 20% of total costs, with the remainder divided between local governments and the private sector, the recent municipal debt crisis in China has put a crimp in implementation. Increased borrower costs and declining bond ratings have combined to reduce private-sector interest in investments (Biswas and Hartley, 2017). Not helping matters is the fact that the cost effectiveness of *Sponge City* projects has not been adequately evaluated, further deterring private investment (Mei et al., 2018: 1397). Some observers contend that the lack of an incentive system driven by managerial expertise in *Sponge City* poses a kind of “moral hazard.” In effect, implementation relies mostly on technological prowess to compensate for the lack of management skill (Ma et al., 2018).

In sum, the *Sponge City* initiative exemplifies an important paradox in water resource policy. How can a society draw upon technocratic expertise to solve critical water resource problems affecting personal and property risk, public and ecological health, and water quality and supply while also finding ways to directly incorporate the opinions and needs of the intended beneficiaries? One pathway to reconciliation is recognizing the mutuality of interest between technocratic expertise for innovations and lay knowledge of the underlying problems they intend to solve. We contend that this reconciliation lies at the core of adaptive governance.

Conclusion – pragmatic engagement and social acceptance

Sponge City experiences affirm the importance of adaptive governance for water innovations. While China has pursued this low-impact development approach through technocratic, top-down governance, shortcomings experienced with respect to supportive private-sector funding, knowledgeable public buy-in, public support for development and maintenance, and striking an appropriate balance between urban development goals and liveability and ecological objectives are becoming widely recognized. How can polities reconcile the diverse objectives surrounding such innovations while also drawing on the benefits of adaptive governance?

Four lessons may be suggested based on this chapter's analysis. First, as we saw in our discussion of efforts to promote public engagement in developing societies that lean toward authoritarian governance, a natural if unfortunate inclination is to limit participation in order to expedite the fruition of plans. In reality, this approach merely delays – or obfuscates – reconciliation between technocratic objectives and public values. A more inclusive and deliberative policy-making process drawing upon local as well as expert information may slow down implementation of plans. However, it may also result in better decisions by providing a

means to discern financial, managerial, logistical and informational problems before they reach a critical and less easily soluble stage.

Second, governance issues are no less important in polities where trust and confidence in government is high, and where policy outcomes are tightly controlled by a political elite, than in more pluralistic polities. One study of Chinese urban attitudes toward *Sponge City* and its objectives found that gender, age and educational differences influence what people know about low-impact development and flooding, and what reforms they are most likely to support. The survey found that men were more likely to think urban flooding could occur in their city than women, and that the damage flooding would inflict was slightly greater than what women believed. Financing of *Sponge City* innovations also varies, with higher-income groups, perhaps not surprisingly, having a greater willingness-to-pay than lower income groups, and people with higher levels of education also more supportive of *Sponge City's* innovations. Lastly, government employees were most supportive of willingness-to-pay, underscoring differences in support for the role of the public sector in promoting and leading the program (Wang et al., 2017). In short, a more inclusive process of engagement leading to social acceptance can help reconcile these differing levels of knowledge and support in order to ensure optimal achievement of *Sponge City's* goals.

Third, legitimacy of decisions cannot be merely assumed by the absence of explicit or visible dissent. *Sponge City* has rarely sought to adopt the types of direct public engagement methods enumerated in Table 5.1 that aim to discern public values and preferences, identify private partners, or develop independent measures for assessing project performance. It remains an open question as to whether conscious efforts to incorporate activities such as those discussed in Table 5.1 would have made any real difference in how – and how well – *Sponge*

City objectives are achieved. It is not unreasonable to speculate, however, that such activities might at least have identified, and perhaps proposed ways to overcome the unforeseen challenges that have been encountered along the way.

Lastly, at the beginning of this chapter, we asserted that an engagement process leading to social acceptance of innovations requires a means to connect government and non-governmental actors in partnerships based on a free exchange of concerns – a “convergence ecosystem” (Roco et al., 2013) based on trust and confidence in the value of innovations. If private investment in *Sponge City* is any indication, such a convergence ecosystem remains to be developed. If it is any consolation, however, few real convergence ecosystems for water innovations exist anywhere. China is not alone in this respect. Very few polities have achieved the ideal level of engagement required to govern water innovations in ways that lead to water resilience – that is, technical soundness, economic sensitivity, low risk, and public acceptability. We return to this issue in our final chapter and suggest some lessons worthy of reflection.

CHAPTER 6 – FUTURE PROSPECTS – TOWARD A WATER RESILIENT FUTURE

The Social Construction of Water Resilience

Prior to adopting desalination, effluent reuse, rainwater harvesting or other freshwater innovations, policymakers must first acknowledge the *societal* elements comprising resilience if they hope for effective adoption. A water-resilient polity relies on multiple strategies to satisfy the criteria of technical feasibility, economic advantage, minimal risk, and public acceptability. The task of governance – the interactions between civil society and public authority – is to determine how, and how well, these criteria are met in light of climate change and other threats.

Our discussion of how water innovations are deployed, resilience assessed, and approaches employed to accommodate demands for greater public engagement in choosing innovations afford two essential lessons. First, all polities are implicitly bound by a *hydro-social contract* with their citizens. It is the state's responsibility to ensure water security through competent, trustworthy management resonant with a polity's values. Government does not fulfill this responsibility alone. It serves as a catalyst for bringing together those responsible for laws, regulations, and infrastructure aimed at ensuring that water is safely provided (Linton and Budds, 2014). Second, this contract varies across polities due to differences in political culture, public values, and attitudes toward governance. In short, water resilience is *socially constructed*.

The social construction of resilience shapes the way citizens view the causes and severity of water problems and, thus, what constitute appropriate remedies. While some view the water problems we have discussed in this book as purely natural; others contend they are largely, or at least partly, human-made. A third alternative, as some scholars have noted, is that citizens' collective aspirations toward the type of society they seek to bring about serve as a filter for how water needs, problems, and appropriate solutions are perceived (Buchs, 2010;

Aguilera-Klink et al., 2000; Kalof, 1997).

The social construction of resilience also constrains how decision-makers address water problems, as well as the remedies – both conventional (e.g., withdrawal and diversion of rivers, streams, lakes and groundwater basins) and innovative (i.e., based on technological advances) they choose to pursue. Decision-makers' perceptions of what constitutes an appropriate level of financial or other risk, and what comprises an acceptable solution is true not only for water resilience but has been observed in other environmental areas (Lukasiewicz et al., 2013; Liberatore, 1995). We conclude our analysis by examining how variations in water innovation governance – its structure, legitimacy, inclusion of affected groups, and adaptiveness – help us understand the governance challenges in meeting our planet's growing needs for freshwater.

Structure matters – decentralized versus centralized governance

The social construction of resilience is reflected in the structure of water governance. We have examined a number of cases where top-down, centralized and technocratic approaches prevail, and other cases where more decentralized, collaborative decision-making is being pursued. A key finding is that there are *tradeoffs* entailed in the structure of decision-making for innovations in *both types of systems* which impact water resilience.

Top-down, technocratic approaches to achieving water resilience have been the norm to varying degrees in Singapore, Israel, South Africa, China, much of the Middle East and even Ancient Rome. In the first two cases, socially conditioned aspirations toward water security and economic modernization drove choices regarding water innovations. An obvious benefit of this approach is that water innovations have been introduced in technically state-of-the-art ways, underscoring why these countries have also been extraordinarily effective in diffusing their expertise to other countries in commercially-valuable ways. Diffusion has generated economic

advantages for the companies and research institutes supported by these polities' efforts to transform water innovations into profitable enterprises. Health and environmental risks are rigorously protected, and public concerns with security and modernization have for the most part led to high-levels of public acceptance of innovations.

In those cases where a more adaptive, collaborative, and publicly-engaged process has prevailed at sub-national levels, such as in Australia, (Victoria) California, Arizona, much of the European Union, and to some degree Brazil, it is no coincidence that conflicts over water rights and responsibilities, including rights to participate in water allocation and/or innovation decision-making have been principal drivers of reform. In Australia, Brazil, and Arizona demands to engage indigenous populations have also arisen, with a direct bearing on innovation (i.e., wastewater reuse) policies (Lukasiewicz et al., 2013; Upper San Pedro Partnership, 2017).

In places where adaptive decision-making predominates, certain innovations tend to be more favored as *first* choices, probably because they are perceived as relatively low-in-impact, such as rainwater harvesting and demand-side management, and ecologically-sensitive. Wastewater reuse, especially for non-potable applications, is more favored than desalination. Some scholars have suggested that desalination, as an energy-intensive, costly, and largely privatized innovation is by nature more appropriate in polities with long-standing elite dominance of water and its allocation (William and Swyngedouw, 2018). True or not, many critics of desalination would probably agree with this claim.

Lastly, societies that have taken a hybrid approach to innovation governance: making concessions to public engagement while reposing responsibility for key investment decisions in an expert elite (e.g., Mexico, Thailand, Jordan, and the UAE) we find that the largest water use sector remains (the UAE being an exception) agriculture. Where water innovations have been

widely introduced, the public's most capacious domain of influence lies in *rejecting* options seen as out-of-sync with traditional cultural values (e.g., potable wastewater reuse). Looking to the future, while technologically-complex innovations have diffused across national borders, they have generally done so by being attractive to governments that can afford costly innovations and which embrace centralized, technocratic decision-making.

Legitimacy and resilience

To be acceptable, water innovations should resonate with the shared belief systems, ethical standards, and cultural norms of a polity. This is a tall order. It often requires state intervention through measures to engage, inform and educate the public and provide opportunities for their direct involvement in assessing a technology's appropriateness. Even the earliest "hydraulic societies" – Rome being exemplary – fostered widely shared utilitarian values toward water as a public good, and its citizens shared a common fear of hydraulic insecurity. Both attitudes enabled the state to furnish costly but effective water infrastructure to its citizens.

Legitimacy is especially important in pluralistic democracies where innovations encounter skepticism and sometimes overt opposition, and in places where public confidence and trust in government tends to be low. The Orange County potable reuse and Australia Millennium drought cases exemplify the lengths to which innovation proponents must go to build a case for legitimacy. In Orange County, targeting information to specific audiences, eliciting and responding to feedback from community leaders, and demonstrating trust through forthright admissions of past errors were all state-of-the art legitimization strategies adopted on behalf of indirect potable reuse (Harris-Lovett et al., 2015; Ormerod and Scott, 2012).

Legitimacy is also socially constructed. In Singapore, for instance, long-standing centralized control of virtually every aspect of water and wastewater by a single agency (PUB)

contributes to, benefits from, legitimized authority because PUB's operations and staff expertise have generated confidence in the agency's integrity and competence. Similar confidence is reposed in the Israel Water Authority. In this instance pressures for administrative reform were driven by a lack of confidence in the government's ability to respond effectively to a protracted drought due to allegations of governance inadequacies: i.e., fragmented, poorly coordinated water agencies and over-lapping, unclear responsibilities. Worthy of note is that criticism was *not* directed against water sector experts – only against the administration of water *policies*.

A final issue pertinent to legitimacy and resilience is the relationship between the water purveyor: the agency or other entity providing water through an innovation, and the end user. A distinct legitimacy challenge is the economic structure of the water industry. Whether the purveyor is a private corporation, a growing phenomenon in many countries, or a public agency, as in most of the USA, they face two intersecting challenges: the importance of water to life, and the public's over-riding concern with public health. Water purveyors are reticent to adopt new technologies that have not been carefully vetted, and the public is reluctant to accept innovations unless they have extensive and demonstrable performance records (Ajami et al., 2014: 2, 20, 34).

Despite higher costs entailed in their adoption, consumers may agree to pay a higher price for an innovation if they understand how a rate increase benefits the safety of water supplies. In addition to all the other steps a state can take to enhance legitimacy of innovations, sensible regulatory policies that promote innovation and allow financing mechanisms such as public benefit charges on water to raise the revenue needed to implement innovative solutions affordably can be a helpful policy innovation (Ajami et al., 2014: 20). These measures enhance legitimacy and suggest that public trust and confidence are *not* eroded by higher prices for water. The water innovation economies of Israel and Singapore demonstrate this.

Incorporating marginalized groups in decisions

Exclusion of under-represented groups from innovation decision-making is often tied to *discursive legitimacy* – the authority influential interests have in framing debates over water innovation adoption due to a general convergence between their views and the values held by most citizens. Claims regarding the technical advantages of innovations and the stewardship of their overseers are socially constructed and discount counter-arguments by minorities. Thus, when innovation advocates adopt one-way outreach, information dissemination, and education programs, they promote a: “if only we could make these people understand the benefits of this innovation, they would agree with us” attitude. This attitudes ignores or overlooks the fact that those who are less educated or well-off, yet who are directly affected by siting decisions or the costs or risks of innovations *also* have knowledge important for effective governance. Unless marginalized groups – farmers who understand drought if not the underlying causes of climate change, community groups lacking expertise about *reverse osmosis* but desirous of an accessible, attractive beach for their children’s recreation, and minorities lacking knowledge of drinking water treatment techniques but aware that their families are suffering from lead poisoning – are brought into decision-making, they will likely resist innovations that promise a one-size-fits all solution.

Moreover, advocates will more likely “lock” into large-scale, capital-heavy, path-dependent approaches that commit governments to outcomes that appear to be innovative strategies but might turn out to be impractical and expensive. This is one lesson of Victoria’s initial decision to pursue desalination during the Millennium drought. By contrast, in Iran, demonstrating the advantages of lower-impact innovations to traditionally marginalized groups, and inviting their engagement in project design encouraged community embrace of innovations

– and social learning (Aliabadi et al., 2020; Wonthaggi Desalination Plant, 2021).

Under-represented groups desire interactive exchanges of views regarding potential risks from any innovation and, assurances that they can monitor them. Interactivity includes actual engagement in key decisions and requires broader inclusion in decisions over water rights. Other examples, pertaining specifically to the social construction of environmental preferences underscore this claim. In Australia's Murray-Darling basin, the country's largest watershed and most agriculturally-important, efforts to clarify water rights and responsibilities among users often failed to account for how stakeholders attach socially constructed meaning to their views of water. While scientists and government officials responsible for resource management see the environment as the "passive recipient of human impacts," landholders (and others) using water tend to place greater emphasis on personal experience and local knowledge. Moreover, local knowledge varies considerably, with indigenous views often given less attention than those of dominant groups. Avoiding conflict and facilitating collaborative planning requires understanding and incorporating these divergent views (Lukasiewicz et al., 2013).

Moreover, a study of Tenerife, part of Spain's Canary Island territories, found that similar socially-constructed preferences among groups with divergent influence directly affected decision-making for desalination. Over time, an increasing concentration of authority for water distribution in the hands of landowners and resource developers, coupled with greater privatization of formerly communal groundwater led to its over-exploitation. It also resulted in path dependent reliance on technological panaceas (drilling and pumping and later desalination) (Aguilera-Klink et al., 2000: 234, 240, 242). In the long run, this not only resulted in greater reliance on an energy intensive water supply approach, but resulted in fewer sustainable water options being pursued, as well as diminishing embrace of equity.

Conclusions: Adaptation and Resilience – the same or different?

Every water supply innovation has distinct advantages and drawbacks, and any set of choices must meet a variety of objectives while permitting reasonable public oversight. Given that technical feasibility, economic benefit, perceived risk, and public acceptability are partly socially constructed, how can polities pursue resilient water supply strategies able to effectively meet the challenges of climate change, growing demands, and other threats? A simple suggestion is to embrace any and every innovation, while also ensuring that no single innovation predominates. However, this multi-option prescription ignores the political controversies that arise when one set of protagonists advocating for an approach they believe to be the “best” find themselves in competition with those advocating on behalf of a different strategy. We conclude this book by recommending an alternative approach – one that returns us to the hydro-social contract when it works most effectively.

A basic principle behind this contract is the paramount importance of protecting first-order values of public health and safety. The proper role of the state in enforcing these values is to ensure that law, regulation, engineering expertise, and those pursuing innovations for profit all work in concert to protect these values above everything else. These first-order values are non-negotiable principles that ensure water is treated as a *public good*. Even the Romans and Mesopotamians recognized this problem. A rule-of-thumb pertinent to all the innovations we have investigated in our study is that the more technologically-complex the innovation *and* larger-the-scale (i.e., size, volume of water produced, and economic cost), 1) the greater the economic and other risks the innovation potentially poses; and, 2) the more likely some sort of infrastructural or operational failure can occur. This is not an indictment of any particular technology. It is simply acknowledging a characteristic common to complex technologies – in

water resources management, energy, and other fields. Conventional engineered safeguards, while welcome precautions, may generate new managerial challenges with respect to training, personnel oversight, and decision-making that are difficult to foresee (Perrow, 1999).

Reverse osmosis (RO) desalination remains energy-intensive and costly. For all intents and purposes, however, it may also be the most suitable and appropriate option in certain locales – particularly those having few other alternatives likely to satisfy a polity’s water needs, as is the case, for example, in the Gulf states and other parts of the Middle East. Likewise wastewater reuse is also expensive and difficult to sell to those who insist that any risk from potable reuse, however small or remote, is morally unacceptable. Nevertheless, policy-makers would be foolish to ignore potable reuse if the only other tractable choices are to limit community growth or ration water, or to continue to divert water from other locales experiencing serious in-stream and groundwater depletion, as is true in California and much of the Southwestern U.S. Similarly, rainwater/storm water harvesting harbors health risks and urban-form challenges that may be difficult to surmount without a systematic re-design of the entire built environment of cities, and a rigorous “grading” of water sources for given end-uses, so-called *fit-for-purpose* water.

With respect to the hydro-social contract, the ultimate goal of the state in deciding among these various options and alternatives is to select those that will best ensure resilience: those that are technically feasible, economically advantageous, pose the fewest and most manageable risks, and are publicly acceptable. However, it should also be recalled that water resilience entails adaptability to changing conditions, a capacity to withstand adversity, and the ability to respond to unforeseen needs (Boltz et al., 2019). In short, resilience and adaptation are two sides of the same coin. To foster water resilience, polities should seek innovations that can best adapt to change, withstand threats, and respond to unanticipated problems – in other words, that afford

flexibility in the face of natural and societal uncertainties.

Achieving flexibility in the face of uncertainty requires a commitment to two major policy approaches to innovation adoption, I contend. First, the more incrementally innovations are adopted, the more likely it is that gross failures can be avoided and the greater the probability that adverse risks and consequences can be discerned early on. As we have seen, the advent of widely-available, practical small-scale, renewable energy-infused desalination remains, for the time being out-of-reach. Efforts to develop such approaches and to introduce them in ways appropriate to user markets should be pursued. In the meantime, to the extent that water innovations can be adopted in smaller-scales, and in specific applications, the greater the likelihood decision-makers can learn from experience how best to manage them before deploying them more widely. For desalination, the scale required to make the technology economically practical makes this a difficult bar to meet – we shall return to this problem shortly.

However, such an incremental strategy may be profitably applied to effluent reuse. When Orange County adopted *Water Factory 21* in 1976, as the first California project to purify sewer water to drinking water standards, the facility reflected the state-of-the art for the technology at the time. Its implementation also reflected an effort to adopt a supplemental water supply alternative incrementally. While this facility was the precursor to the *Groundwater Replenishment System (GWRS)*, this was less the result of conscious planning and more happenstance – continued population growth necessitated a new innovation. Nevertheless, the advantages of this prior effort are clear: officials were able to benefit from the lessons provided by a slow but steady learning curve, public confidence was gradually acquired, and experience in dealing with unforeseen challenges was facilitated. Effluent reuse adopted at appropriate scales

to satisfy a wide range of socially beneficial *non-potable* uses can also adhere to a similar incremental strategy. Such an approach not only builds public confidence, but it conserves precious potable supplies – such a strategy was largely pursued in Israel.

With regards to incrementalism, while large-scale applications of rainwater harvesting have been adopted in Singapore and China, with varying results as we have seen, polities less able or willing to adopt top-down land use and urban development approaches can tailor this innovation to smaller neighborhood-scale partnerships, as has been done successfully in Melbourne, Australia and Copenhagen, Denmark, for example. As we have seen, even in Singapore, considerable efforts have been made to infuse rainwater harvesting projects with public opportunities for recreation, public visioning regarding aesthetic improvements (e.g., the Green Plan for Environmental Protection and Improvement).

A second and final methodological lesson is more idealistic. *Process* – how decisions to adopt innovations are made – is in many respects as important to water innovation governance as *outcome*, the innovation ultimately selected. To the extent possible, polities should view water innovations through the four resilience criteria we discussed as a kind of “screening framework” for decision-making. While not always possible in practice, polities should aim for a kind of Hippocratic principle in making choices – “first do no harm.”

In confronting long-term freshwater challenges, we first need to ask: what are the lowest impact, least costly, most beneficial, and least risky option(s) we could pursue? The answer to this question may initially take us down the path of demand-side alternatives which, as we have seen, pose other political and ethical challenges. However, these challenges may be more readily soluble. Those options which pose a greater potential environmental risk, and that are more expensive – like desalination – may become the option selected *only* after all other alternatives,

less impactful and costly, and smaller-in-environmental footprint, are adopted. This is not a plea for “choosing winners and losers” in the quest for water innovations to quench our planet’s insatiable thirst. It is a petition for adopting a process of decision-making that considers the advantages and disadvantages of each and every water alternative on a level, equitable, and just playing field. Future generations deserve nothing less from us.

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Table 2.1 Assessing the Resilience of Water Alternatives

Criterion	Definition	Key stakeholders
Technical feasibility	Evidence that science and engineering assessments support the application of an alternative in a given location	Engineers, water resource planners
Economic cost	Determination of the relative affordability of an alternative relative to likely alternatives – further determination of who will pay these costs	Economists, engineers, water resource planners
Environmental and health impact & risk	Evaluation of the potential adverse impacts to public health and environmental resources the alternative might generate – further evaluation of whether these impacts be mitigated	Public health and bio-medical experts; environmental scientists
Public acceptability and engagement	Assessment of community perceptions regarding the efficacy of the option; public trust and confidence in its management; and the voice they have in its implementation	General public, civil society groups, elected decision-makers

Table 5.1 Prescribed legitimacy-building activities for social acceptance of desalination, wastewater reuse and rainwater harvesting

<i>Prescribed activity – desalination (1)</i>	<i>Principal objective</i>	<i>How strengthen legitimacy?</i>
Pilot testing facility technologies	Provide public outreach opportunity	Display advantages of desalination compared to other sources
Environmental assessment reports	Opportunity for public scoping meetings to identify key concerns & expectations	Will lead to partnership with community & develop trust
Invite community members to participate in planning, implementing, management	Assuage concerns regarding environmental impacts, effects on community growth	Conform the project to community aspirations and minimize environmental injustice
<i>Prescribed activity – wastewater reuse (2)</i>	<i>Principal objective</i>	<i>How strengthen legitimacy?</i>
Conduct planning and values-based decision-making at the community level	Involve all key stakeholders; facilitate dialog, participatory technology development, social learning	Reuse is situated into larger discussion of water supply & quality, and health concerns of community
Conduct opinion surveys of reuse and its sources of public support	Demonstrate underlying fears of drought & water shortages, public confidence in technology	Demonstrate economic, environmental, and household security advantages of reuse
Conduct dedicated public outreach program	If focused on direct potable reuse can build and increase confidence and support	Gain experience in developing and maintaining effective outreach throughout project life-span
<i>Prescribed activity – rainwater/storm-water harvesting (3)</i>	<i>Principal objective</i>	<i>How strengthen legitimacy?</i>
Carry out initial projects on small-scale	Demonstrate feasibility, provide public outreach opportunity	Demonstrating proper & appropriate application strengthens adoption for homes, agriculture, industry

(1) Sources: Voutchkov, 2013; WHO, 2007; Cooley et al., 2006

(2) Sources: Asano and Bahri, 2011; Mehan, 2019; Mosher and Vartanian, 2015

(3) Akram et al, 2014

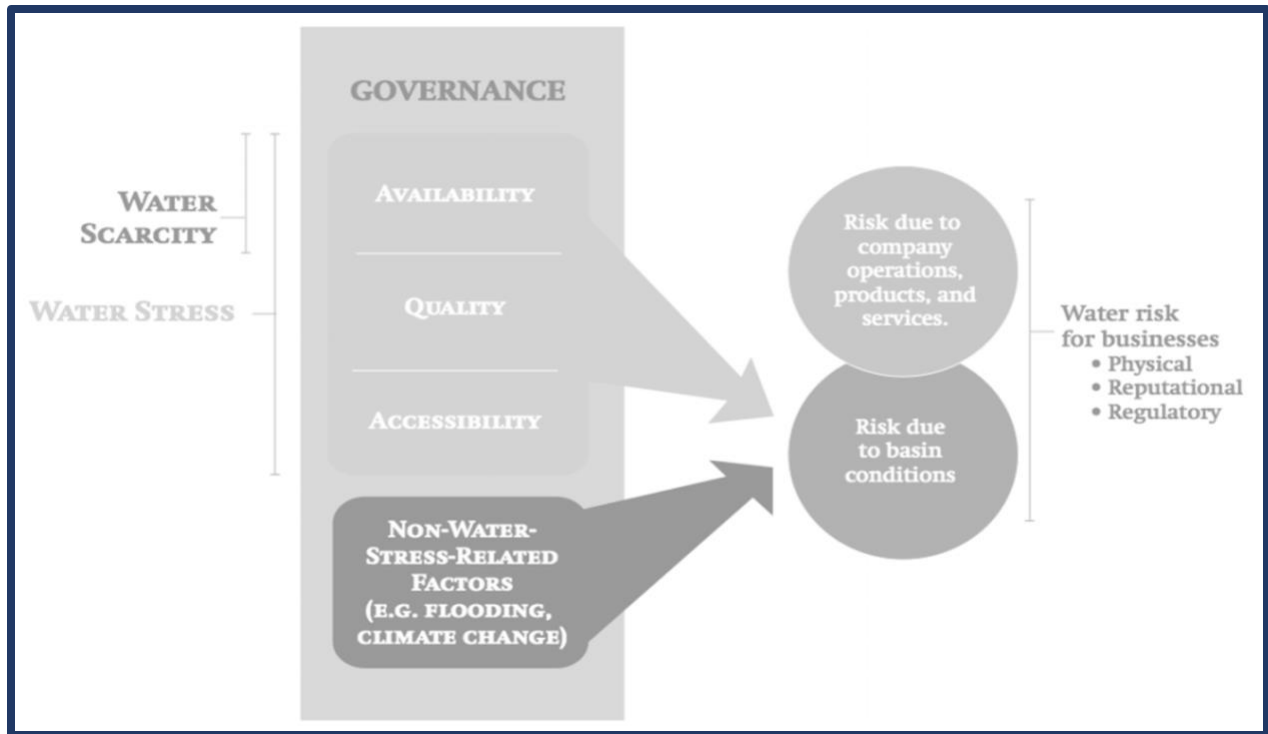


Figure 1.1 Connections between Water Stress, Scarcity and Governance

Source: UN Global Compact – CEO Water Mandate, 2017

<https://ceowatermandate.org/posts/water-scarcity-water-stress-water-risk-actually-mean/>

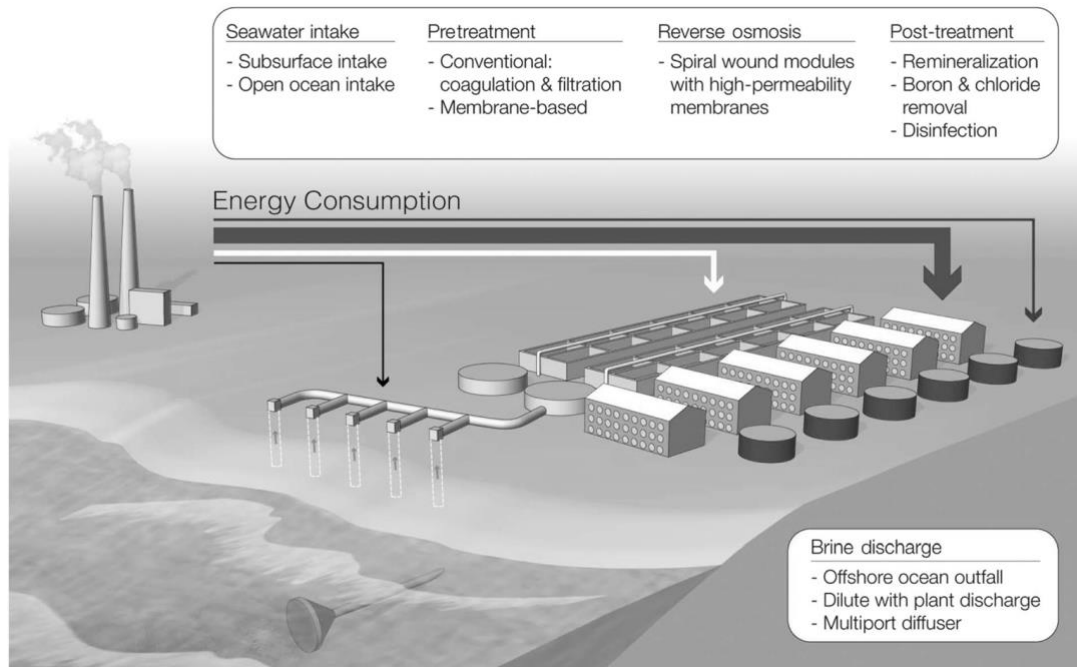


Figure 2.1 Conceptual drawing of an SWRO desalination plant

Source: reprinted from Elimelech and Phillip, 2011

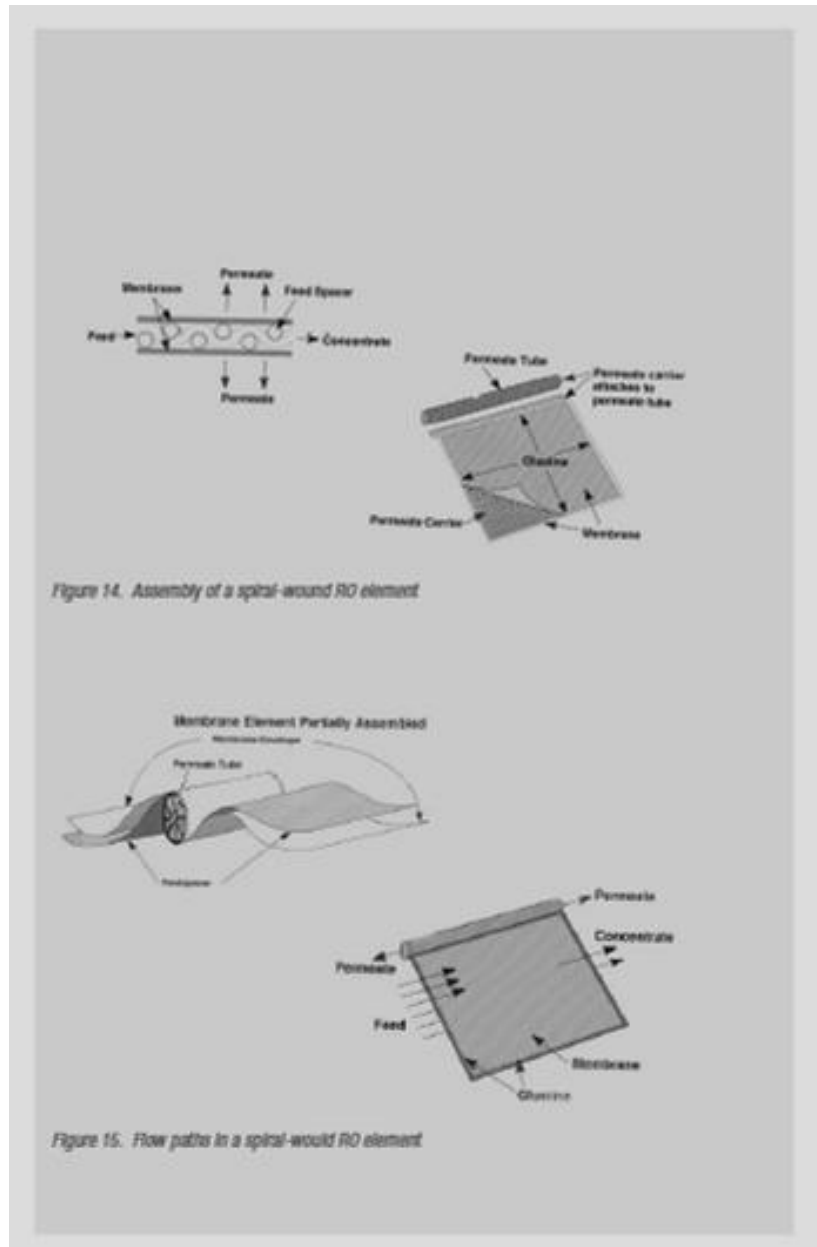


Figure 2.2 Spiral Wound Reverse Osmosis (RO) element used in Desalination

Source: Reprinted from – Birkett, 2011: 16

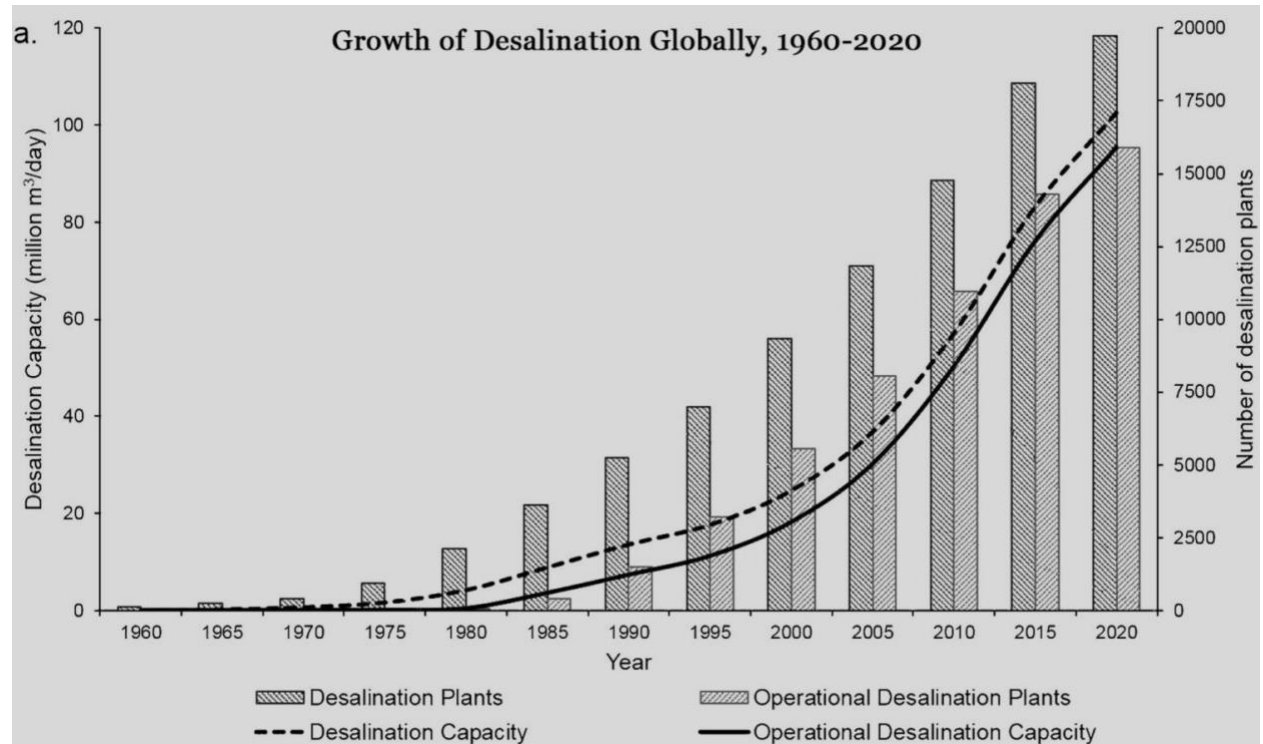


Figure 2.3 Global growth of desalination: 1960-2020

Source: Jones et al., 2019

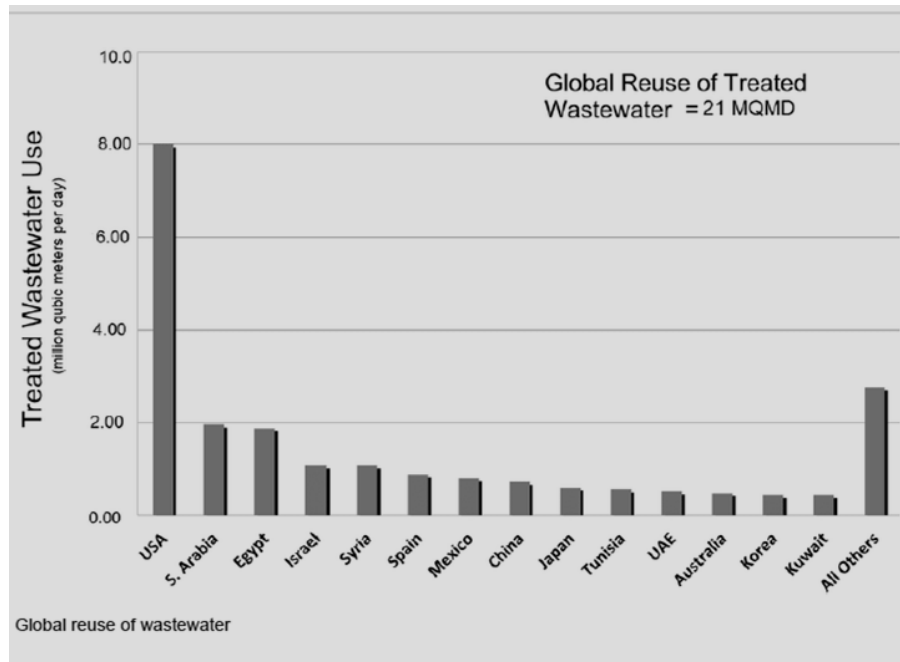


Figure 2.4 Global Wastewater reuse – 2018

Source: Galkina and Vayutina, 2018: 2

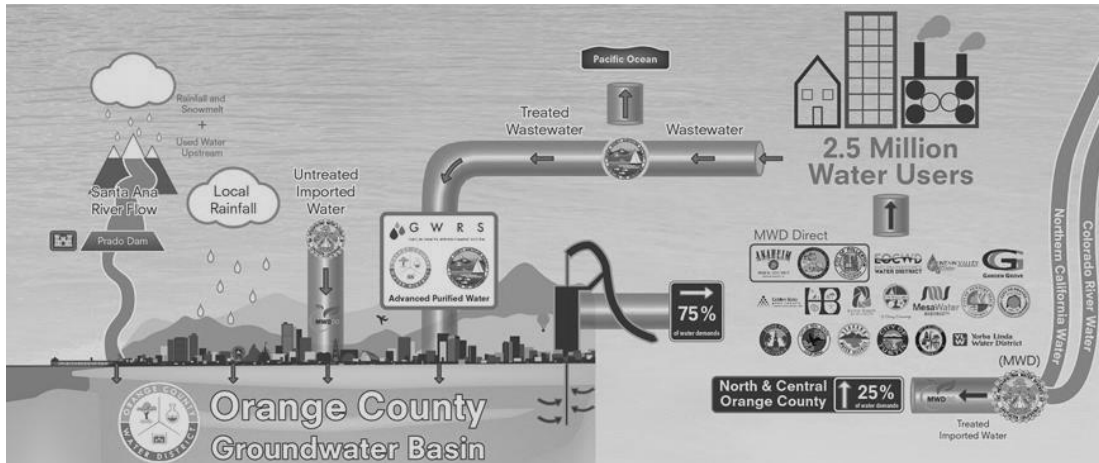


Figure 2.5 Orange County California Groundwater basin and wastewater reuse system

Source: Orange County Water District

<https://www.ocwd.com/learning-center/how-water-works-in-oc/>

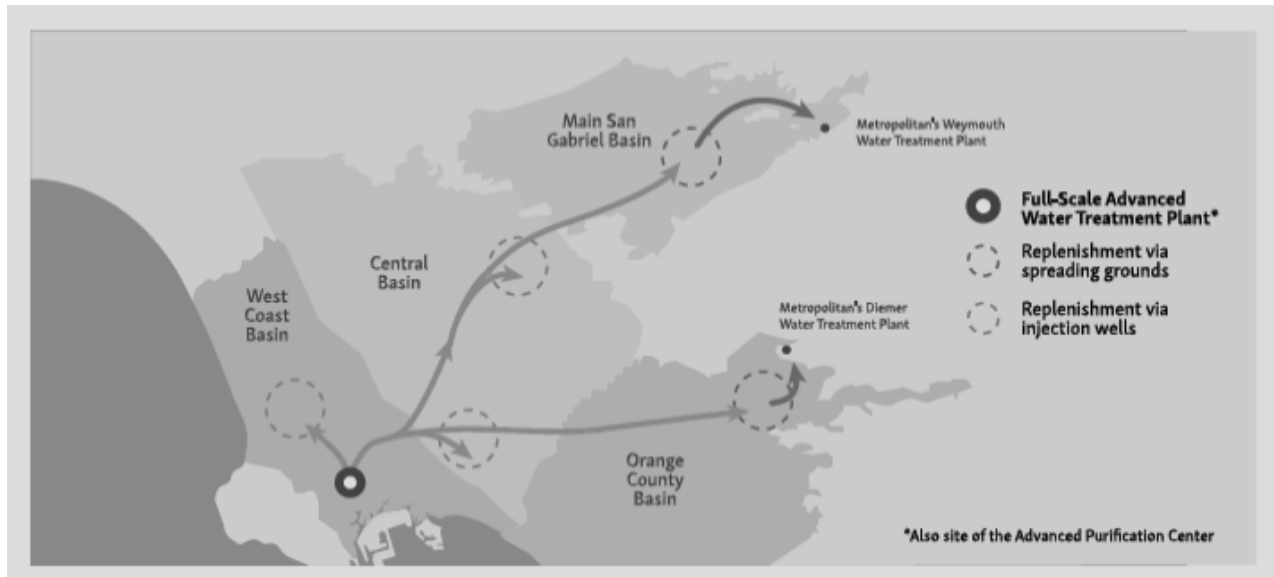


Figure 2.6 Schematic of proposed Advanced Purification Center

Source: MWD, 2021

<http://www.mwdh2o.com/DocSvcsPubs/rwp/index.html#how-it-works>

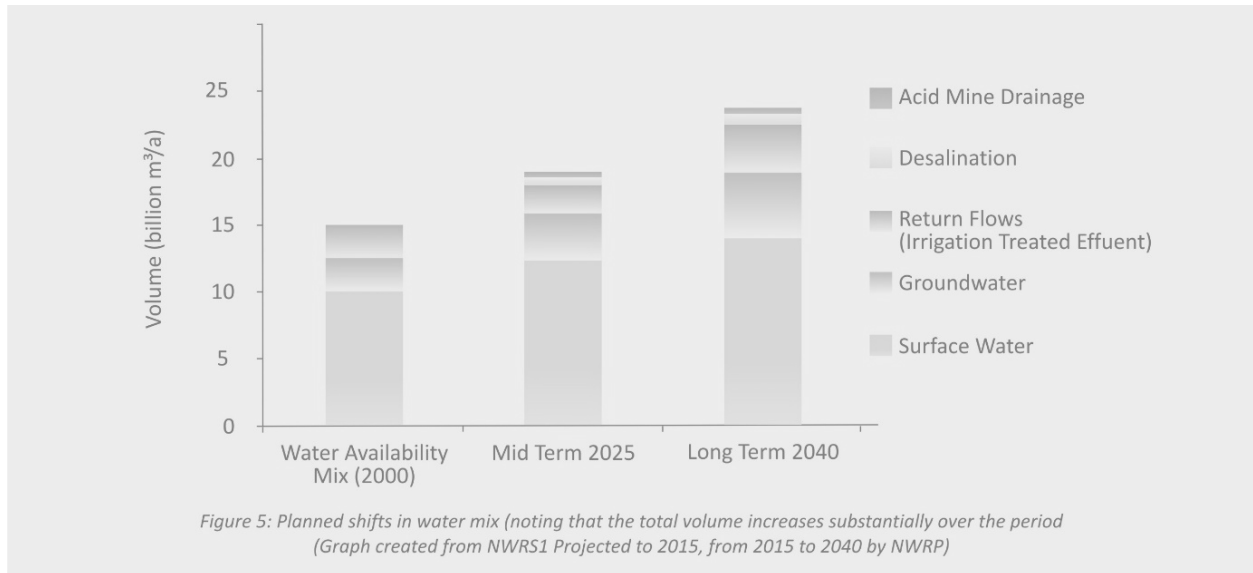


Figure 3.1 Proposed water supply options and shifts in supply in South Africa

Source: National Water and Sanitation Master Plan, 2018:10

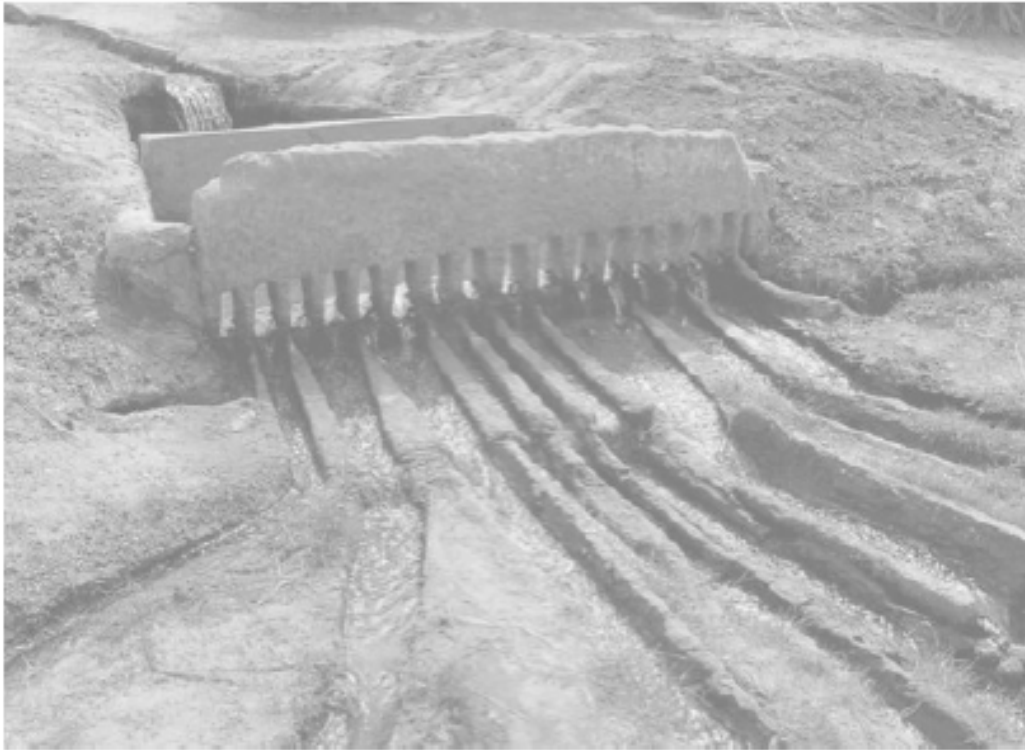


Figure 3.2 Irrigation Weir in Ancient Mesopotamia (reconstruction)

Source: Resources for history teachers (open source-undated)

<http://resourcesforhistoryteachers.pbworks.com/w/page/124512531/Growth%20of%20Mesopotamian%20Civilization>

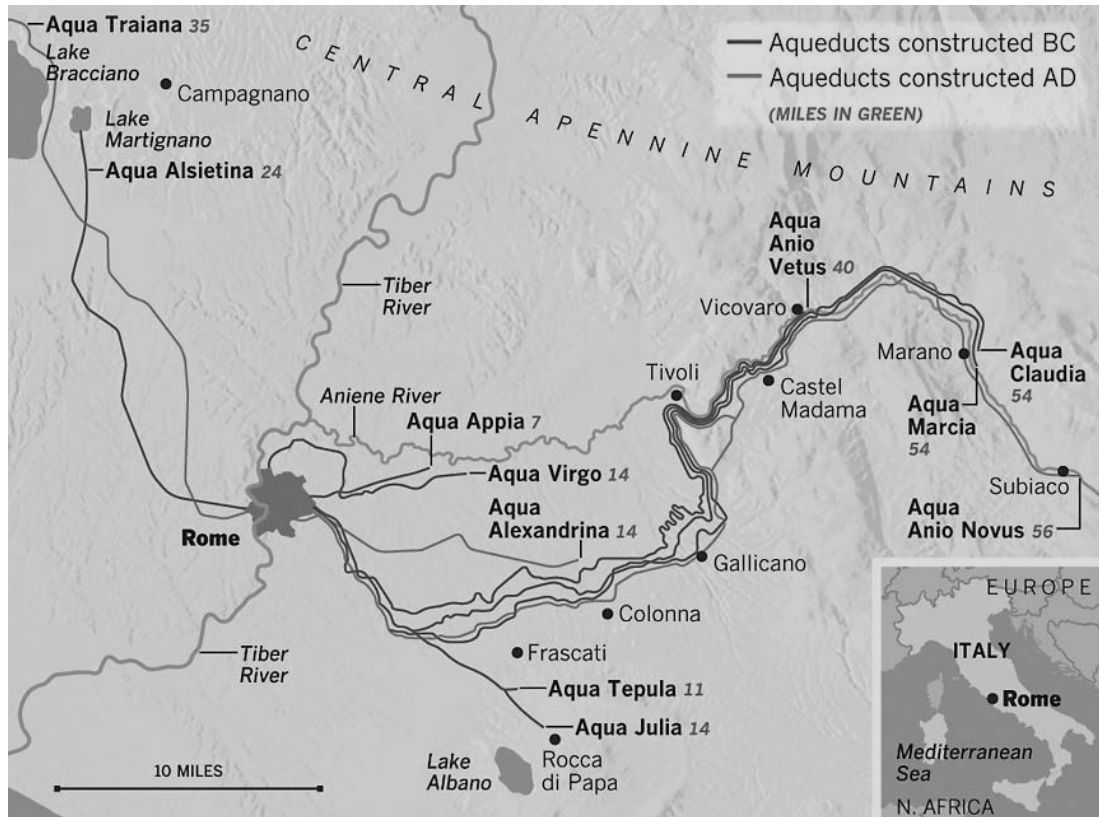


Figure 3.3 The Aqueducts of Rome

Source: Interactive Graphic – the Aqueducts of Rome, Los Angeles Times, 2021

<https://graphics.latimes.com/storyboard-la-fg-roman-aqueducts-g/>

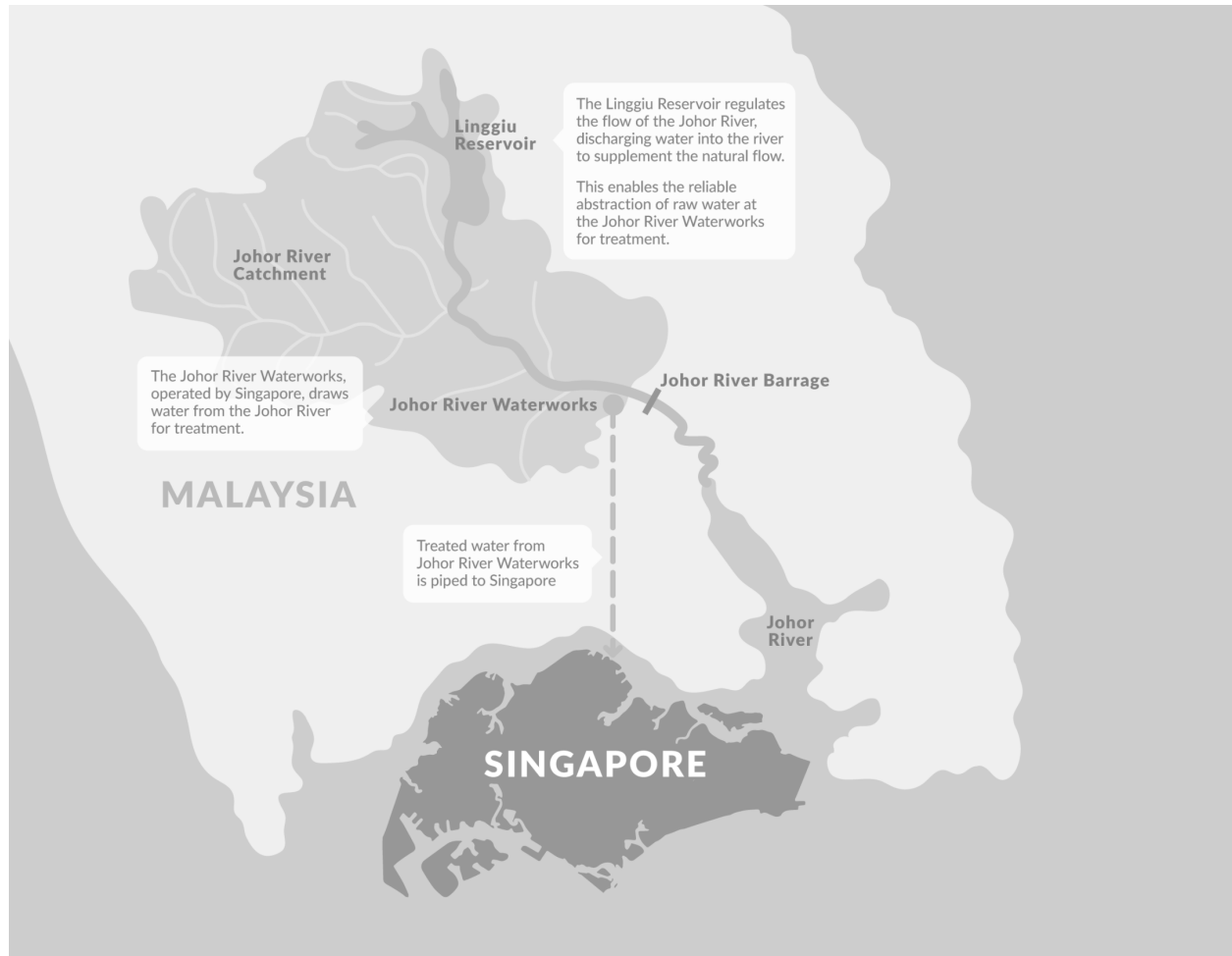


Figure 3.4 Area map of Singapore water sources

Source: Public Utilities Board of Singapore

<https://www.pub.gov.sg/watersupply/fournationaltaps/importedwate>

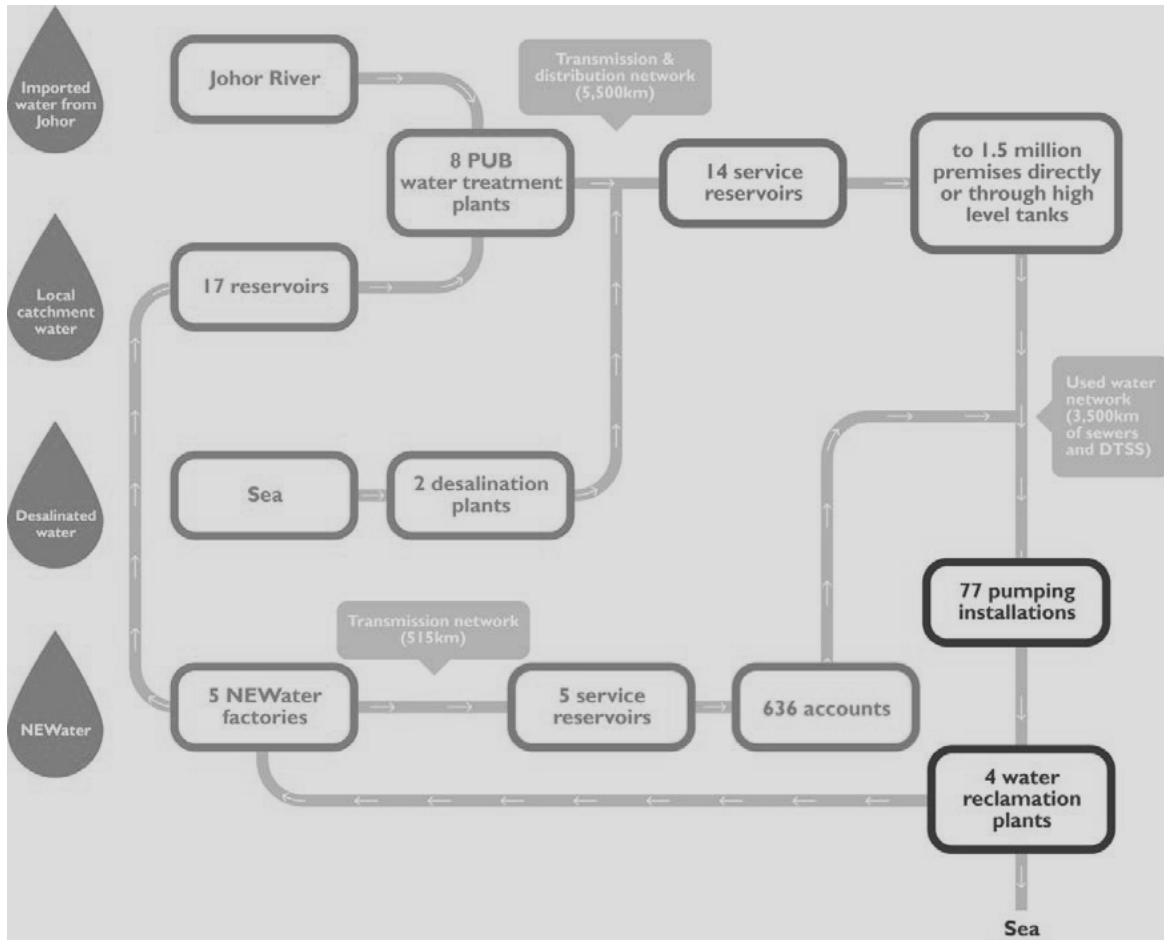


Figure 3.5 Schematic of Singapore's Water Supply

Source: Public Utilities Board of Singapore

<https://www.pub.gov.sg/watersupply/singaporewaterstory>

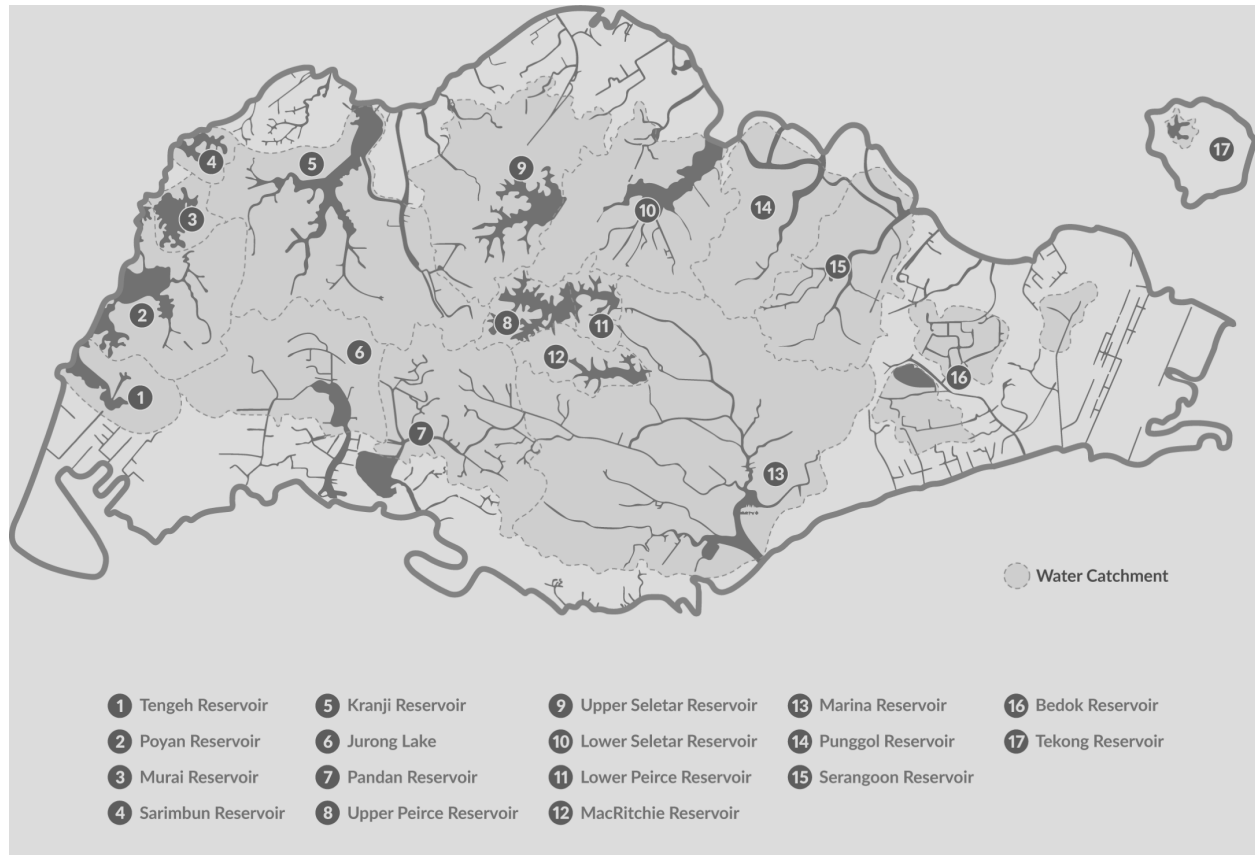


Figure 3.6 Singapore surface water reservoirs

Source: Public Utilities board of Singapore

<https://www.pub.gov.sg/watersupply/fournationaltaps/localcatchmentwater>



Figure 3.7 Major water supply infrastructure and sources of Israel

Source: Israel's Water Resources, Israel Ministry of Foreign Affairs

<https://mfa.gov.il/MFA/AboutIsrael/Maps/Pages/Israel-Water-Resources.aspx>

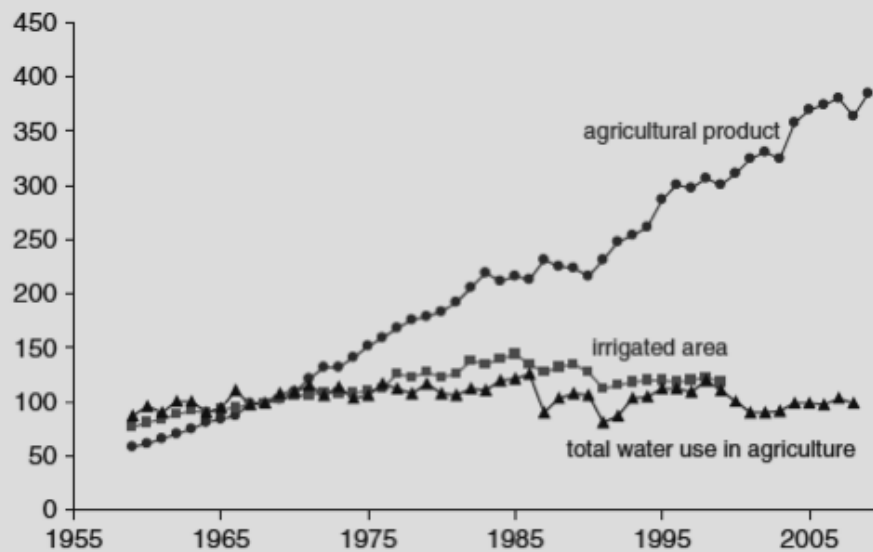


Fig. 2.2 Agricultural product, irrigated area,* and total water use in agriculture** in Israel 1959–2008 (index: 1968 = 100) [*Data on irrigated area was collected only until 1999. **Total water in agriculture includes freshwater, brackish water, and recycled wastewater] (Source: Central Bureau of Statistics, Annual Yearbooks)

Figure 3.8 Agriculture and water use in Israel: 1959-2008

Source: Eran Feitelson, 2013: 23



Figure 3.9 Proposed Red Sea – Dead Sea project

Source: “Sharing Water: Israel and Jordan Finalise Agreement for Red Sea-Dead Sea Pipeline,”
Future Directions International, March 25, 2015

<https://www.futuredirections.org.au/publication/sharing-water-israel-and-jordan-finalise-agreement-for-red-sea-dead-sea-pipeline/>

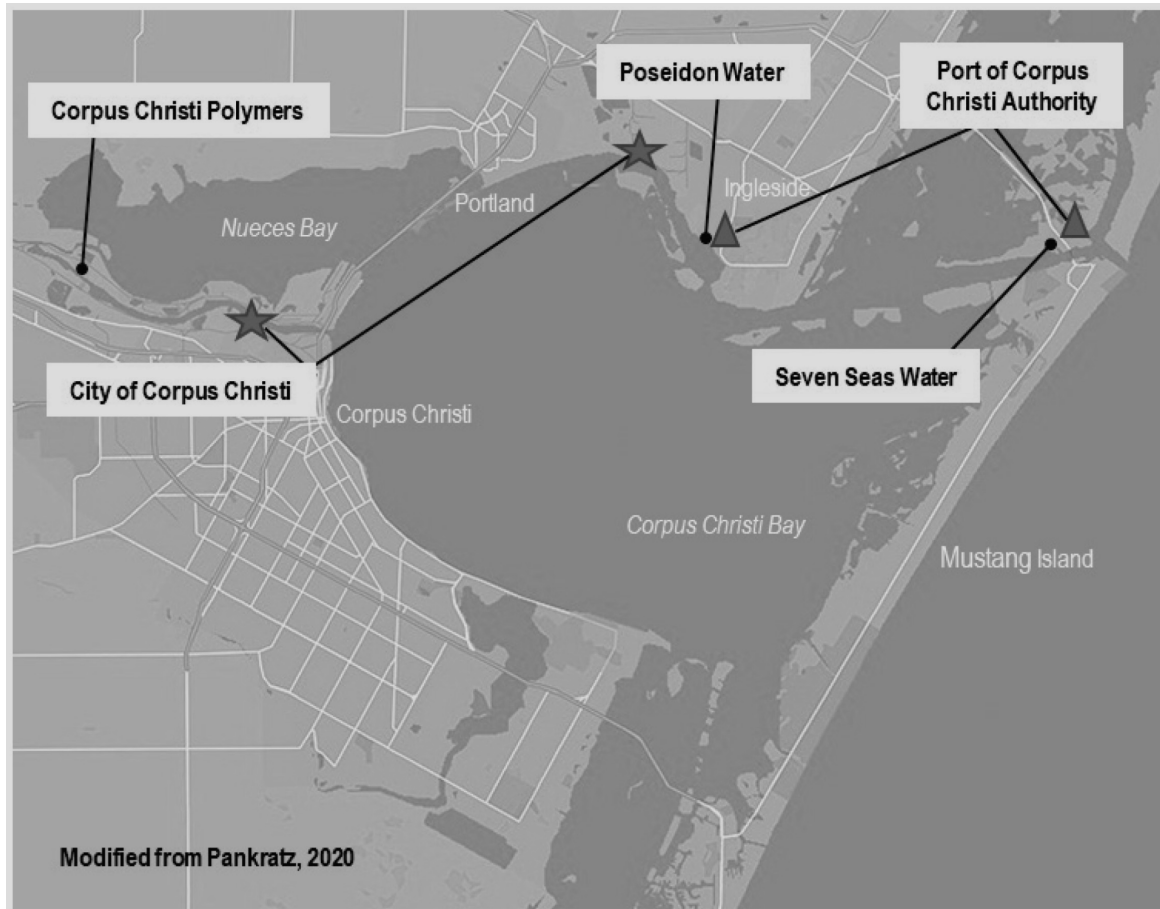


Figure 4.1 Seawater desalination Activities in the Corpus Christi, Texas region

Source: Texas Water Development Board. 2020. The Future of Desalination in Texas – 2020 Biennial Report on Seawater and Brackish Groundwater Desalination in Texas, 87th Texas Legislative Session. Austin, TX, December 1.

http://www.twdb.texas.gov/innovativewater/desal/doc/2020_TheFutureofDesalinationinTexas.pdf?d=1623.07000000000002, p. 15.

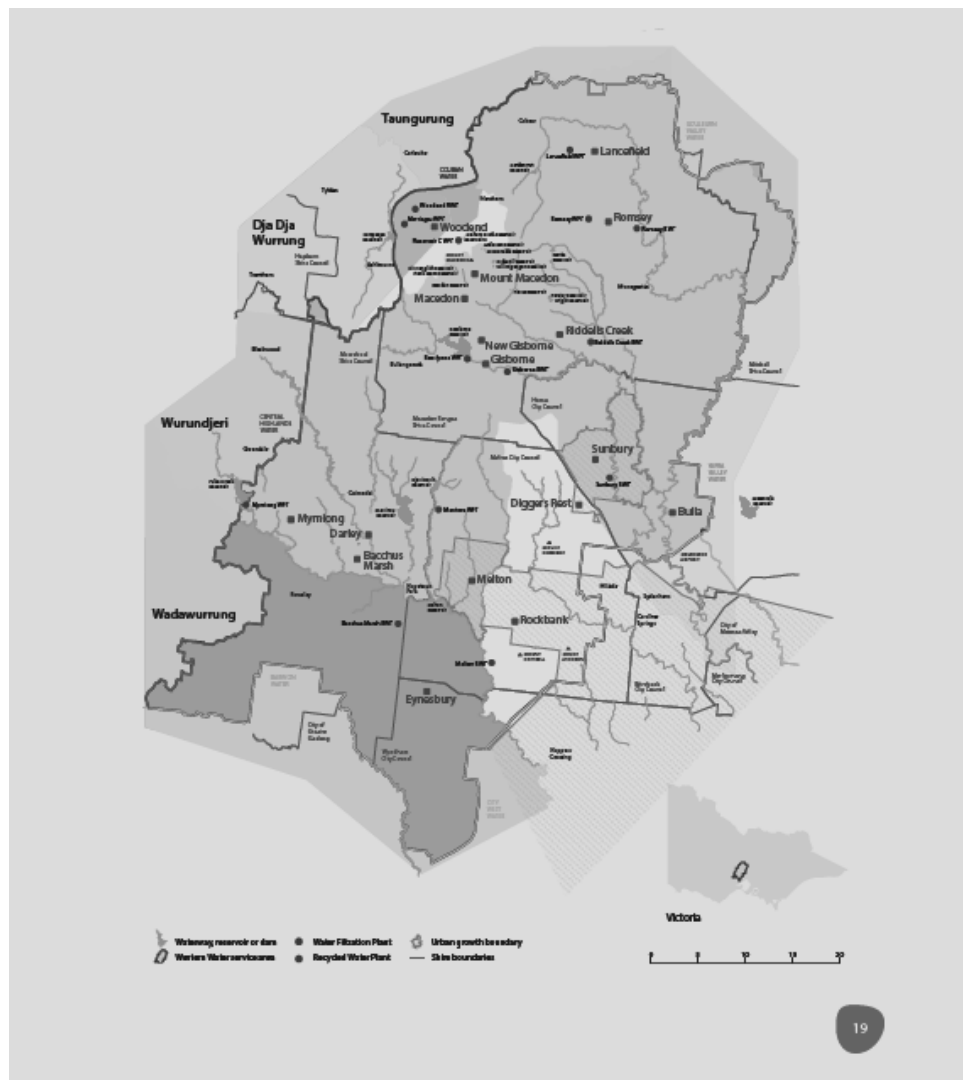


Figure 4.2 Western Water Service area – Victoria, Australia

Source: Western Water Annual Report, 2019/2020. Sunbury, Victoria, p. 19.

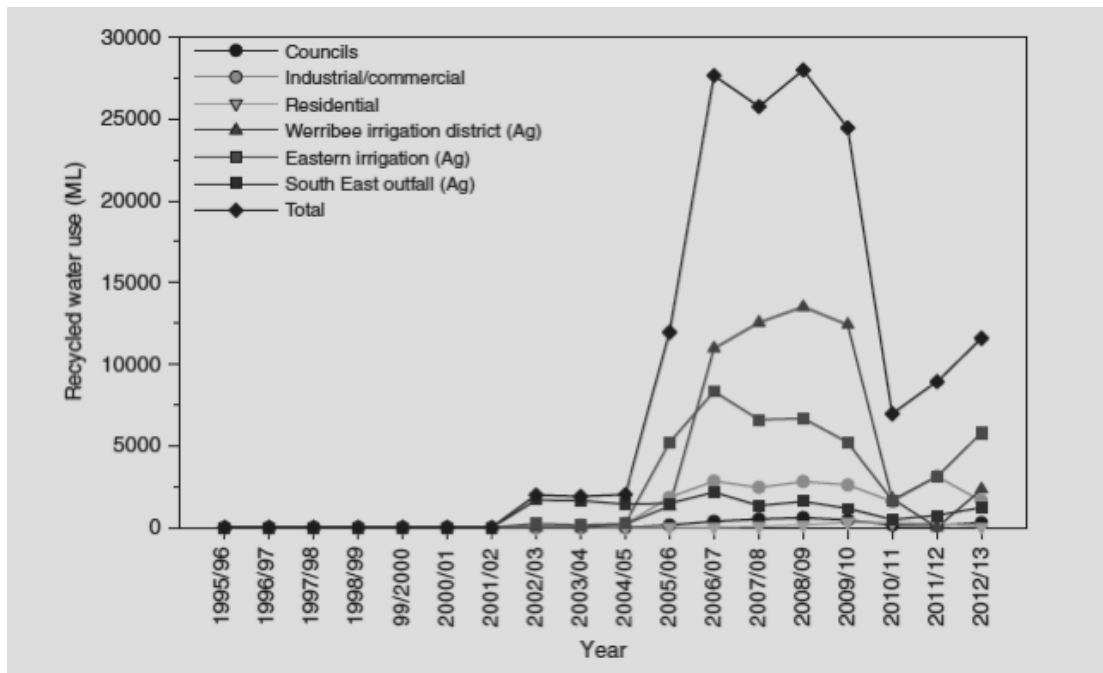


Figure 4.3 Recycled water demand in Melbourne region by various local councils as well as agriculture sector during and after the Millennium Drought

Source: Low, Kathleen G., D.L. Feldman, Stanley B. Grant, Andrew J. Hamilton, Kein Gan, Jean-Daniel Saphores, Meenakshi Arora. 2015. "Fighting Drought with Innovation: Melbourne's Response to the Millennium Drought in Southeast Australia," WIREs Water. doi: 10.1002/wat2.1087.



Figure 5.1 Tully-Murray (Australia) basin map

Source: Spatial Data Centre, Great Barrier Reef Marine Park Authority, Commonwealth of Australia (GBRMPA) 2014 (reproduced in: Bohnet, Iris C. 2015. "Lessons Learned from Public Participation in Water Quality Improvement Planning: A Study from Australia," *Society & Natural Resources* 28 (2):

180-196 <https://doi.org/10.1080/08941920.2014.941446>, p. 186

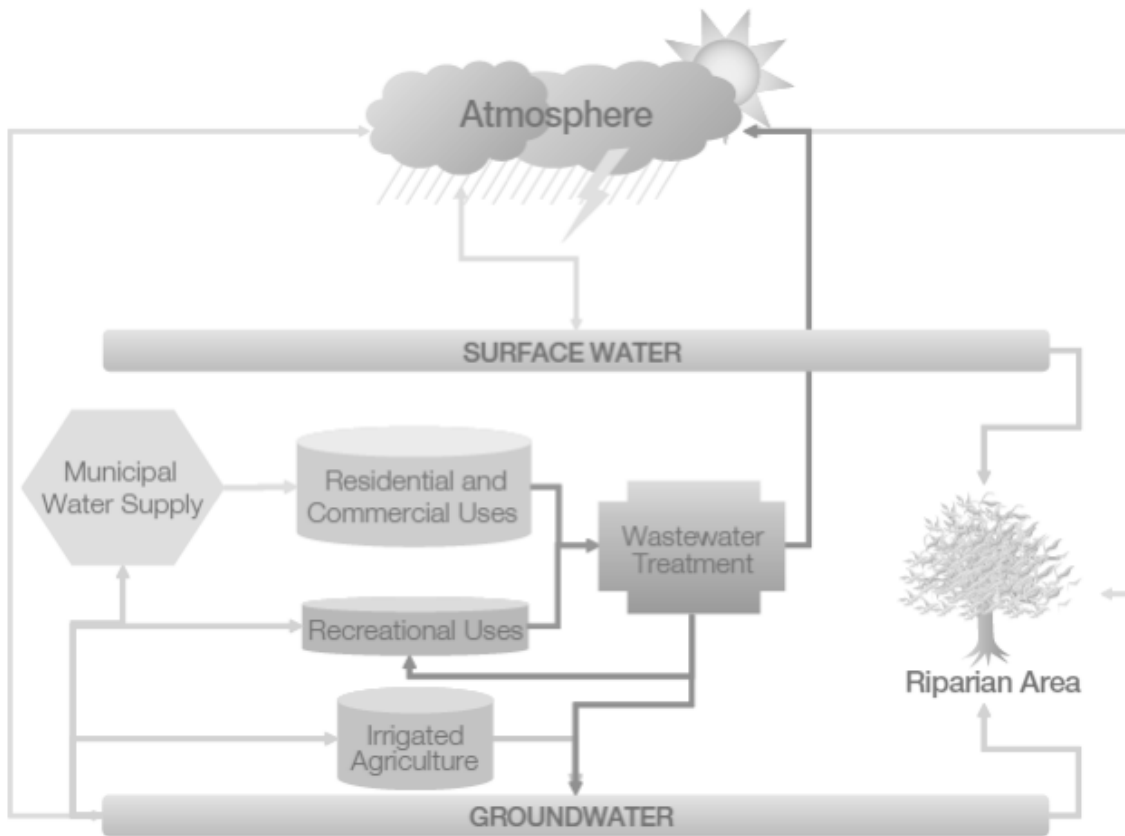


Figure 5.2 Schematic of Upper San Pedro Partnership 21st Century Decision-support

Source: <http://uppersanpedropartnership.org/wp-content/uploads/2017/10/21stCenturyDecisionMaking.pdf>

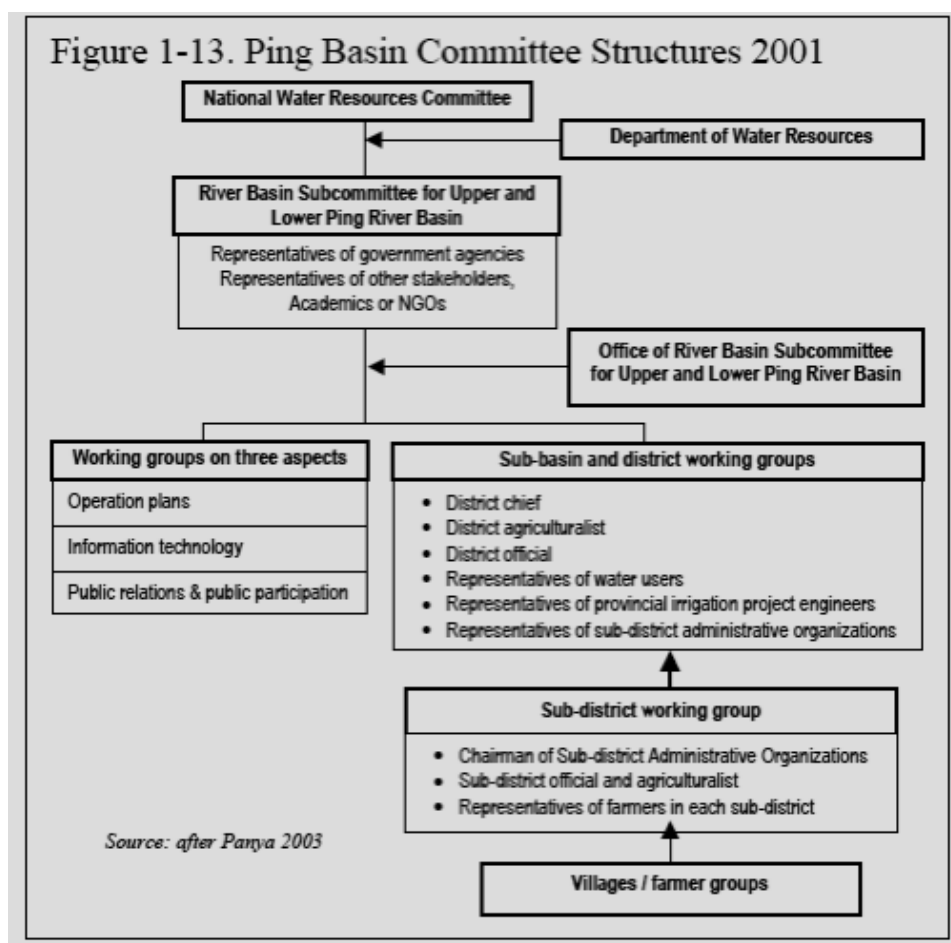


Figure 5.3 Ping Basin Public Engagement Process – schematic

Source: Thomas, David E. 2005. *Developing Watershed Management Organizations in Pilot Sub-Basins of the Ping River Basin – Final Report to ONEP under the Participatory Watershed Management Consultancy*. Office of Natural Resources and Environmental Policy and Planning Ministry of Natural Resources and Environment, December, p. 22

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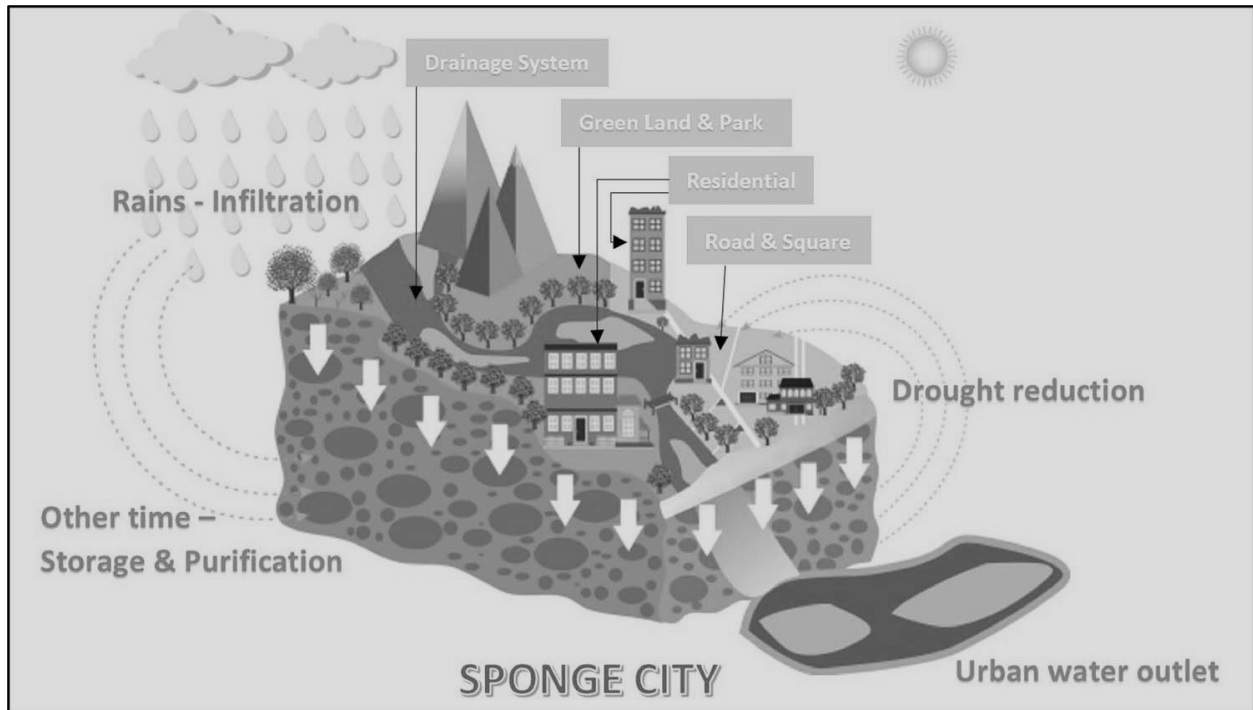


Figure 5.4 Schematic of the Sponge City Concept

Source: Chan, Faith Ka Yu, Shun Chan, James A. Griffiths, David Higgitt, Shuyang Xu, Fangfang Zhu, Yu-Ting Tang, Yuyao Xu, Colin R. Thorne. 2018. "Sponge City" in China—A breakthrough of planning and flood risk management in the urban context," *Land Use Policy* 76: 772-778, <https://doi.org/10.1016/j.landusepol.2018.03.005>.