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Evaluating the Role of Public-Private Partnerships in Bolstering Sustainability and Resilience in California’s Water Sector: A Comparative Case Analysis

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Evaluating the Role of Public-Private Partnerships in Bolstering Sustainability and Resilience in California's Water Sector: A Comparative Case Analysis

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Social Ecology

by

Evgenia Nizkorodov

Dissertation Committee:
Professor Richard Matthew, Chair
Professor David Feldman
Associate Professor Walter Nicholls
Assistant Professor Nicola Ulibarri

2020

DEDICATION

To my beautiful family

Whose love and encouragement
Push me to be the best version of myself
Every single day.

May the days always be full
of baby giggles
and the pitter patter of little feet.

TABLE of CONTENTS

LIST of FIGURES

LIST of TABLES

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VITA

EDUCATION

PhD in Social Ecology (in progress) 2020
University of California, Irvine, Irvine, CA

MA in Social Ecology 2017
University of California, Irvine, Irvine, CA

Bachelor of Arts 2013
International Relations (Economics) and Environmental Studies
Wellesley College, Wellesley, MA

HONORS, AWARDS, and CERTIFICATES

UCI Fletcher Jones Foundation Fellowship *awarded to "an outstanding doctoral student who demonstrates the potential to become a leader in academia, industry, government or public service"*	2019
Social Ecology Dean's Quarterly Fellowship	Fall, 2019
Don Owen Water Science and Technology Fellowship	Spring, 2019
Social Ecology Doctoral Progress Fellowship	Winter, 2018
Certification of Completion: Mentoring Excellence Program	Spring, 2015
Graduate Student Mentoring Award	Spring, 2015
Newkirk Award	Winter, 2015
School of Social Ecology Merit Fellowship	Fall, 2014
Certificate of Completion: Madeleine Korbel Albright Institute for Global Affairs	2012
Schools First Federal Credit Union Scholarship	2009, 2010, 2011
Schools First Federal Credit Union Recognized Honor Student	2009, 2010, 2011
Presidential Volunteer and Service Award: *national recognition for community service*	2009

PUBLICATIONS

Books

Matthew, R., **Nizkorodov, E.**, Goodrich, K., Hooper, A., Maharramli B., Purcell, M., Wagle, P. & Murphy, C. (Eds.). (Forthcoming, 2020). *The Routledge Handbook of Environmental Security*. New York, NY: Routledge

Matthew, R., Goodrich, K., Harron, K., Maharramli B., & **Nizkorodov, E**. (Eds.). (2016). *Continuity and Change in Global Environmental Politics: The Social Ecology of the Anthropocene.* The WSPC Reference Set on Natural Resources and Environmental Policy in the Era of Global Change. Singapore: World Scientific Publishing Co.

Books Chapters

Matthew, R., **Nizkorodov, E**., & Goodrich, K. (Forthcoming, 2020). Introduction. In Matthew, R., Nizkorodov, E., Goodrich, K., Hooper, A., Maharramli B., Purcell, M., Wagle, P. &

Murphy, C. (Eds.). *The Routledge Handbook of Environmental Security*. New York, NY: Routledge

Nizkorodov, E. & Wagle, P. (Forthcoming, 2020). Population Displacement and the Environment. In Matthew, R., Nizkorodov, E., Goodrich, K., Hooper, A., Maharramli B., Purcell, M., Wagle, P. & Murphy, C. (Eds.). *The Routledge Handbook of Environmental Security*. New York, NY: Routledge

Orbinski, J., Reazi, S., & **Nizkorodov, E**. (Forthcoming, 2020). Conflict, Climate Change, and Public Health. In Matthew, R., Nizkorodov, E., Goodrich, K., Hooper, A., Maharramli B., Purcell, M., Wagle, P. & Murphy, C. (Eds.). (Forthcoming, 2020). *The Routledge Handbook of Environmental Security*. New York, NY: Routledge

Upreti, B.R. & **Nizkorodov, E**. (Forthcoming, 2020). Environmental Security in Nepal: A Perspective from the South. In Matthew, R., Nizkorodov, E., Goodrich, K., Hooper, A., Maharramli B., Purcell, M., Wagle, P. & Murphy, C. (Eds.). (Forthcoming, 2020). *The Routledge Handbook of Environmental Security*. New York, NY: Routledge

Goodrich, K. & **Nizkorodov, E**. (2016). The Science of the Anthropocene. In Matthew, R., Goodrich, K., Harron, K., Maharramli B., & Nizkorodov, E (Eds.), *Continuity and Change in Global Environmental Politics: The Social Ecology of the Anthropocene.* The WSPC Reference Set on Natural Resources and Environmental Policy in the Era of Global Change. pp. 3-32. Singapore: World Scientific Publishing Co.

Matthew, R., Goodrich, K., Harron, K., Maharramli B., & **Nizkorodov, E**. (2016). Introduction. In Matthew, R., Goodrich, K., Harron, K., Maharramli B., & Nizkorodov, E (Eds.), *Continuity and Change in Global Environmental Politics: The Social Ecology of the Anthropocene.* pp. i – xxvi. Singapore: World Scientific Publishing Co.

Matthew, R., Goodrich, K., Harron, K., Maharramli B., and **Nizkorodov, E**. (2016). Conclusion. In Matthew, R., Goodrich, K., Harron, K., Maharramli B., & Nizkorodov, E (Eds.), *Continuity and Change in Global Environmental Politics: The Social Ecology of the Anthropocene.* pp. 483 – 491. Singapore: World Scientific Publishing Co.

Academic Articles

Nizkorodov, E. (Revise & Resubmit). Evaluating Risk Sharing and Project Impacts of Sustainability-Oriented Water Public-Private Partnerships in Southern California: A Comparative Case Analysis. *World Development.*

Reports and White Papers

Matthew, R., **Nizkorodov, E**., & Reazi, S. (2018). *Global G.L.O.W.: Assessment and Program Recommendations*. Santa Ana, CA: Global GLOW.

Nizkorodov, E. & Feldman. D. (2018). Water UCI/TAU Workshop: Grand Challenges Facing the Future of Freshwater. White Paper

Matthew, R. & **Nizkorodov, E**. (2017). *Stand #withMalala Campaign Impact Report*. New York, NY: Malala Fund.

Conference Papers

Shambaugh, G., Mathew, R., & **Nizkorodov, E**. (April 2018). Inequality, Club Goods, and Public-Private Partnerships. Conference paper presented at Annual ISA Convention. San Francisco, CA.

CONFERENCE PANELS and PRESENTATIONS

Nizkorodov, E. (March 2020). Evaluating sustainability-oriented water sector public-private partnerships: An exploratory analysis of success and failure in developed and developing economies. Panel presentation at the ISA 2020 Annual Convention. Honolulu, HI

Nizkorodov, E. (Oct. 2019). Meeting sustainability objectives through water sector public-private partnerships: A comparative analysis of four southern California projects. Panel presentation at the Sustainability and Development Conference. Ann Arbor, MI.

Nizkorodov, E. (Sept. 2019). Conflict, climate change, and environmental security discourse in Nepal. Panel presentation at the ISA West Annual Conference 2019. Pasadena, CA.

Nizkorodov, E. (Sept. 2018). Mitigating the Environmental Impacts of Forced Displacement. Panel presentation at the ISA West 2018. Pasadena, CA.

Craig Welti, J. & **Nizkorodov, E**. (April 2018). Addressing Graduate Student Wellness through Climate Committees**.** Conference presentation at UCGPC Campus Climate Conference. Irvine, CA.

Craig Welti, J., Castro, I., **Nizkorodov, E.**, & Simmons, C. (Feb. 2018). Addressing Graduate Student Wellness through Climate Committees**.** Conference presentation at NASPA 2018 Conference. Philadelphia, PA.

Nizkorodov, E. (Oct. 2017). Critical Success Factors of Water Public-Private Partnerships in Low-Income Regions: A Comparative Analysis of Water Distribution Projects in Ghana, India, and the Republic of Congo. Panel presentation at the ISA South Annual Convention, Orlando, FL.

Harron, C., **Nizkorodov, E**., Maharramli, B., Goodrich, K., & Gellers, J. (April 2016). The Social Ecology of the Anthropocene. Panel presentation at the XXIst International Conference of the Society for Human Ecology (SHE), Santa Ana, CA.

ES300 Environmental Decision-making. (April 2013). Food is Not Trash: Redefining Wellesley's Waste Culture by Composting. Presentation at the Ruhlman Conference, Wellesley, MA.

Nizkorodov, E., Moses, A., Mirounciuc, E. Wucherpfennig, J., & Zhang, L. (Jan. 2011). Addressing Climate Change and the Need for Mitigation and Adaptation. Presentation for the Madeleine Korbel Albright Institute for Global Affairs Symposium, Wellesley, MA.

POSTERS and RESEARCH SYMPOSIUMS

Nizkorodov, E., Goodrich, K., Harron, C., Maharramli, B. (March 2016). The Social Ecology of the Anthropocene. Poster presented at the 2016 Social Ecology Poster Session, Irvine, CA

Nizkorodov, E., Shchapov, K.S., Shakhtanova, N. & Moore, M.V. (July 2011). Testing the Transparency Regulator Hypothesis: The Effect of Ultraviolet Radiation on the Diel Vertical Migration of Zooplankton in Transparent Lakes. Poster and Presentation in the Science Center Summer Research Program, Wellesley, MA.

Nizkorodov, E., Tsitsenko, M., Axenov-Gribanov, D., & Moore, M.V. (Aug 2010). Consumption of Fish Carrion by Benthic Macro-scavengers in Oligotrophic Lakes. Poster and Presentation in the Science Center Summer Research Program, Wellesley, MA.

ABSTRACT of the DISSERTATION

Evaluating the Role of Public-Private Partnerships in Bolstering Sustainability and Resilience in California's Water Sector: A Comparative Case Analysis

By

Evgenia Nizkorodov
Doctor of Philosophy in Social Ecology
University of California, Irvine, 2020
Professor Richard Matthew, Chair

California faces a number of pressing threats to water supply and quality, including ageing infrastructure, climate volatility, and demographic pressure. Public-private partnerships (PPPs) may be uniquely positioned to address these challenges through the private partner's ability to mobilize resources, provide technical expertise, and share project risks. However, the best practices and impacts of PPPs are not well understood. This research clarifies the role of the private sector in bolstering sustainability and social-ecological resilience in California's water sector through a qualitative comparative case analysis of seven infrastructure and three data-oriented water PPPs. Semi-structured interviews, observations, shadowing, and document analysis are utilized to examine (1) the endogenous and exogenous drivers of PPPs, (2) socio-economic, environmental, and political impacts of projects, (3) challenges faced throughout the project lifetime, and (4) lessons learned. Three theoretical frameworks (social-ecological resilience, holistic sustainability, and new institutionalism) guide the analysis of impacts and illuminate the opportunities and constraints facing PPP project participants.

The cases suggest that when carefully managed, PPPs can result in environmentally beneficial projects that diversify local water resources and improve efficiency of water utility operations. Moreover, through risk sharing and pooling of resources, PPPs provide a “unique opportunity” for the traditionally risk-averse water sector to pursue innovative technologies that minimize risks to ratepayers in the early stages of a project. However, PPPs face a tension between economic efficiency and equity. Public sector respondents stressed the challenge of “getting the best deal” for the public in the face of diverging priorities between public and private actors, information asymmetries, and limited experience in negotiating PPP contracts. A complex permitting process and evolving environmental regulations exacerbate this tradeoff through cost overruns and project delays. Distributional impacts to ratepayers can be reduced through mutual agreement of project goals and benefits, a robust contract structure that quantifies performance standards and provides opportunities for adaptive learning, and the inclusion of end-users and affected stakeholders early on in the project life-cycle.

Evaluation of PPP impacts also suggests that gains in short-term resilience can occur at the expense of distributional impacts to low-income water users or to ecosystems. The cases reveal that considerations of ecological well-being requires significant intervention on behalf of regulatory agencies. NGOs may play a critical role in future PPPs by increasing environmental sensitivity of projects, monitoring adverse environmental impacts, and serving as “bridges” between regulatory agencies and water utilities.

This dissertation fills a critical policy and research gap. The research examines the first water PPP projects in California. This study, thus, is a unique opportunity to examine institutional innovation in an organizational domain that has high socio-technical and regulatory constraints. This study also introduces a new role for PPPs in the water sector: data collaboratives can aid water districts in effective and science-based decision-making and provide alternatives to a “hard infrastructure” approach to water management. Finally, this is one of the first studies to evaluate PPP projects across all three dimensions of sustainability, paying careful attention to the distributional impacts of these partnerships. Ultimately, the research assists water districts in providing much-needed water system upgrades in a way that ensures that projects are economically efficient, environmentally sound, and do not disproportionately impact low-income populations.

1.0 INTRODUCTION and PROBLEM STATEMENT

California faces a number of pressing threats to water supply and quality. The state has the highest infrastructure investment needs out of any state in the US, requiring $51.03 billion in investment over the next twenty years (EPA, 2018) to cope with ageing infrastructure, demographic pressure, and climate change impacts. California's water supply and treatment infrastructure has been ranked with a C grade (ASCE, 2019). The water system also faces the risk of interruption due to natural disasters such as earthquakes, droughts, and floods (Davis & Shamma, 2019; Diffenbaugh et al., 2015; Mount et al., 2018).

These large-scale stressors to the water system highlight the importance of implementing flexible and resilient water infrastructure and management systems. That is, infrastructure systems (the facilities equipment, managing organizations, types of services provided, and beneficiaries of the services) must be able to reduce the magnitude and/or duration of disruptive events through anticipation, absorption of impacts, adaption, and rapid recovery to perturbations (EPA, 2015b; NIAC, 2009). It is imperative to implement technologies that conserve, re-use, and diversify water management strategies; decrease overall energy use; and coordinate with other sectors to minimize water contamination and over-use (Hanak et al., 2014). These changes require not only a high degree of technical expertise and capital investment, but also careful consideration of the distributional effects of funding demands.

Decentralization of water management has created variation in the ability of water districts to adapt to water quality and quantity threats (Hanak et al., 2011; Pincetl et al., 2019; Shukla et al., 2015). Local water districts, particularly rural ones, lack the financial and technical resources to adopt capital-heavy technologies. To provide these system upgrades, water managers are proposing the adoption of public-private partnerships (PPPs), or collaborations between public and private actors to co-provide or co-manage goods and services by sharing risks and pooling resources and skills (Adjarian, 2017; Ajami, 2018; EPA, 2015). The approach has been heralded as a way to promote innovation, maximize technical and economic efficiency, and bolster water security resilience while reducing public budgetary strain of capital investment (Douglass & Sykes, 2013; EPA, 2015; Pessoa, 2010). PPPs have even been enshrined in the Millennium (2000) and Sustainable Development Goals (2015): SDG Goal 17 strives to "encourage and promote effective public, public-private, and civil society partnerships" in order to "share knowledge, expertise, technology, and financial resources" (UN, 2016). As a result of the exogenous push by international organizations, the approach has been adopted globally. To date, 7,095 PPP projects (a total of $1,654 billion in investment) have been undertaken in low- and middle-income countries (PPI, 2020). In the US, PPPs gained traction in the transportation sector, and were integrated into the Obama and Trump infrastructure development plans (Bryan, 2016; Mann & Hughes, 2017). PPPs have also been featured heavily in the G20 discussions regarding "boosting investment" in critical infrastructure provision (Romero, 2015; Leighland, 2018). The G20 has launched a PPP Contract Management online resource tool to assist public officials in achieving value for money and stipulated contract objectives (Global Infrastructure Hub, 2019)

Yet, PPPs have not proven to be the panacea initially anticipated by development agencies. Empirical-driven criticism for PPPs has risen in the last two decades (Hodge & Greve, 2017; Leighland, 2018). Assessments reveal that PPPs have been unable to close the infrastructure gap in developing countries (Leighland, 2018; Nizkorodov, 2017) and may contribute to uneven economic development (Siemiatycki, 2011) and marginalization of low-income populations (Patil et al., 2016; Pusok, 2016). Moreover, project failures are costly, accounting for roughly 26% of total investment in water sector PPPs (PPI, 2020). These costs are often borne by public agencies and ratepayers (Pessoa, 2010).

Ultimately, best practices and impacts of PPPs are not well understood. Therefore, the primary focus of this research is to ***clarify the role of the private sector in bolstering resilience and sustainability of California's water sector***. This study utilized semi-structured interviews, observations, shadowing, and document analysis to examine the impacts and processes of seven infrastructure-based and three data-oriented water sector PPPs in California. This research includes five sub-questions:

(1) What are the endogenous and exogenous drivers of water sector PPPs within the state of California?

(2) What are the economic, political, social, and environmental impacts of public-private partnerships? How do these impacts contribute to or detract from social-ecological system resilience and holistic sustainability?

(3) How are risks allocated between public and private actors throughout the project lifetime? How does this allocation impact project outputs and outcomes?

(4) What challenges did public and private actors face throughout the project lifetime?

(5) What are the best practices of water sector PPPs in California?

Overview of Methods

Case selection was purposive. Projects included in the study are publicly recognized as public-private partnerships, focus on the management of water and water-related resources, and have publicly included commitments to meeting sustainability or resilience goals. The Lake Mission Viejo project, for example, highlights the partners' efforts to convert the lake to a "drought-proof, safe, and sustainable new water source" (Lake Mission Viejo CA n.d.). All but the Rialto project have received local- or national-level awards for their innovative and sustainable project design and resource management. The cases control for institutional frameworks (state- or country-level legislation regarding PPP development) and large-scale exogenous stressors (climate change, macro-economic conditions). However, public water agencies included in the study vary in size, district culture, financial, technical, and institutional capacity, and availability of local water supplies. Capturing diverse temporal and spatial scales of projects allowed for a more complete understanding of project barriers and the contributions of PPPs to social and ecological systems.

Fieldwork and document analysis focused on capturing a complete narrative of each project, beginning from the early stages of partnership formation until the present day. Interview respondents recruited for the study were those that directly participated in either one or several stages of the PPP project lifetime. Interview data was triangulated with shadowing, observation, and document analysis. Fieldwork provided opportunities to observe early stages of partnership formation, mutual goal-setting, and the day-to-day operations of projects. Fieldwork also provided opportunities to observe how best practices and impacts of PPPs are communicated to other key water stakeholders. Document analysis supplemented fieldwork data: examination of grant reports, internal memos, PPP contracts, op-eds, and independent evaluations of projects provided a more holistic understanding of community-buy in, perceived risks associated with projects, and potential impacts.

Theoretical Frameworks

This research draws on three theoretical frameworks – holistic sustainability, social-ecological system resilience, and new institutionalism – to examine the processes and impacts of the ten projects. The frameworks are instrumental in understanding the socio-technical constraints and challenges facing the project participants, as well as the tradeoffs or opportunity costs that may emerge from picking a particular water management pathway.

Previous studies that have examined PPPs within a sustainability framework have utilized a reductionist approach, and have assumed that an improvement in one dimension of sustainability (economic, social, or ecological) will improve sustainability overall (Pinz et al., 2017). This study, however, acknowledges that the three dimensions are interdependent, and thus considers the tradeoffs and tensions that can emerge between economic, environmental, and social outputs and outcomes throughout the project lifecycle. Under a holistic definition of sustainability, PPP projects are economically efficient (are able to ensure a rate of return to cover capital and O&M costs) and maximize ecological well-being and social welfare without placing disproportionate burden on marginalized populations (Koppenjan & Enserink 2009; Pinz et al., 2017). To do so, public managers are transparent, accountable, and responsive to consumers and constituents (Silvius & Schipper 2016), particularly those most heavily affected by negative impacts of critical infrastructure provision. Table 1.1 summarizes the data collected for each of the three dimensions of sustainability.

Economic Dimension	• Project costs (cost overruns and agreed-upon changes to project costs throughout project lifetime)
Social Dimension	• Changes to monthly water rates • Opportunities for civil society participation and “voice” throughout project lifetime
Ecological Dimension	• Net changes to ecosystem and hydrological function (e.g. changes to biodiversity, aquifer water levels) • Net changes to efficiency of water- and water-related resources (e.g. demand management, water-energy nexus considerations)

Table 1.1 Data collected to evaluate project impacts for each dimension of sustainability

Social-ecological system (SES) resilience is the system’s ability 1) to withstand stressors or 2) to adapt, and – most importantly – transform in response to untenable conditions (Folke, 2006; Folke et al., 2010). SES water resilient systems are flexible systems that are adaptive to a variety of hydrological futures (Eriksson et al., 2014; Hayes et al., 2019; Krueger et al., 2020; Rodina, 2019). Thus, this study considers projects to contribute to social-ecological resilience when they diversify water supplies, create tailored solutions that forge connections across geographic or political boundaries, and ensure environmental impacts are reversible.

Projects are considered maladaptive when they 1) create irreversible environmental impacts or do not align with a community's ability to pay for water supplies, or 2) when they cannot be sustained during the contract period or after the private partner exits the contract.

Practical and Theoretical Contributions

This research fills a pressing research and policy gap. In California, public-private partnerships in the water sector are a recent phenomenon (Douglas & Sykes, 2013; Hewes & Randolph, 2018). This research examines the impacts and processes of some of the first water PPPs attempted in the state, and can thus illuminate barriers to successful project design and implementation. The research also presents a unique opportunity to examine institutional innovation in an organizational domain that has high socio-technical and regulatory constraints (see Baehler & Bidden, 2018; Farrelly & Brown, 2011, Lach et al., 2005). New institutionalism posits that water managers are constrained by past policy and infrastructure decisions as well as public expectations of affordability, safety, and reliability. These constraints result in high risk-aversion in and incremental change in the water sector: technologies are adopted only after extensive pilot testing and evaluation. By examining the exogenous factors and internal motivations that led to the adoption of PPPs in California water sector, this research contributes to the growing body of literature innovation uptake and institutional change.

Moreover, improving sustainability and resilience of water systems is a state-wide concern (EPA, 2011). There is limited work focused on how governments can simultaneously advance economic, social, and environmental policy goals (Berrone et al., 2019; Pinz et al., 2017; Spraul & Thaler, 2019). Most analysis is focused on the economic dimension of PPPs such as achieving value for money and minimizing transaction costs (Berrone et al., 2019). Studies that move beyond economic dimensions often focus on mean-ranking of critical success factors (see Ameyaw & Chan, 2014; Cheung et al., 2012; Osei-Kyei & Chan, 2015) or single case studies (see Ameyaw & Chan, 2013). While literature on sustainability-oriented PPPs is rising, there is low consensus on whether the mechanism contributes to or detracts from sustainability. Moreover, studies have emphasized the contribution of PPPs to infrastructure resilience (the ability to "bounce back" and maintain the status quo in the face of shocks such as climate change and natural disasters) rather than system-wide resilience. This research, therefore, addresses a literature gap in regards to not only organizational-level, but also system-level impacts of PPPs in the water sector.

While a number of studies have examined best practices and impacts of infrastructure public-private partnerships, very little research has been done specifically in the water sector (Ameyaw & Chan 2016). PPPs in the water sector have a higher rate of failure than other sectors (PPI, 2020). Public acceptance to privatization of a traditionally public good is low (Hall et al., 2005), and costs of service delivery to rural areas is high, resulting in a high risk of non-payments or the exclusion of low-income water users (Bond, 2010; Dellas, 2012; Koppenjan & Enserink, 2009). Despite a stable demand, the sector usually has a low profit margin (Albalate et al., 2013; Ameyaw & Chan, 2013, 2015). Most profits are the result of labor cost reductions and increased government subsidies, rather than technology-based cost-saving measures (Loxley, 2013). Moreover, high degrees of political interference, with various government regimes shifting attitudes towards private sector participation, create a high degree of regulatory risk for private partners (Iossa & Martimort 2015; Pessoa, 2010). Finally, the sector requires a high degree of collaboration between various government agencies – water, health, environmental protection, lands, natural resource use, and procurement management– that creates the high possibility of inefficiency and conflicting project goals (Ameyaw & Chan 2014). Thus, due to its unique economic, political, and social challenges, the sector is in need of greater scrutiny PPP scholars.

The water challenges in the state of California are similar to the infrastructure and management issues faced by local water districts in the United States and around the world. America's water infrastructure system received a D grade in 2017 (ASCE, 2017). The country's ageing system lacks both the capacity to adapt to the growing population and the ability to safely and efficiently treat and distribute water. Daily, nearly six billion gallons (14 to 18% of daily treated water) are lost due to leaking pipes (ASCE, 2017). The system also loses two trillion gallons of water per year due to water main breaks. Despite this high water waste, the replacement rate of pipes is 0.5% per year; at this rate, the estimated time to replace the full water system is 200 years, a time-scale that is double the lifespan of our current water infrastructure. Funding poses as a critical challenge to infrastructure system maintenance and expansion. An investment of $250 (AWWA, 2017) to $472 (EPA, 2018) for infrastructure maintenance and expansion is necessary to meet the country's growing population demands, increase district cost-effectiveness, and improve overall system resilience. Roughly $52 billion of investment needs have been funded, leaving a $198 to 420 billion infrastructure gap (ASCE, 2016). Failure to close this gap by will result in a $5,907 billion loss in business sales due to interrupted provision of services and rising costs of production. These costs are passed directly onto the public through rising prices of goods, reduced employment opportunities, and lower wages of employees. Ultimately, the research assists water districts in California and in the US in providing much-needed water system upgrades in a way that ensures that projects are economically efficient, environmentally sound, and do not disproportionately impact low-income populations.

Generalizability of Findings

The cases reveal that PPPs can provide multi-benefits projects that increase and diversify local water supplies and/or promote efficiency of water management. However, ensuring PPP projects maximize environmental benefits requires significant intervention on behalf of regulatory agencies. Moreover, cases face a tradeoff between equity and economic efficiency. When PPP contracts “lock in” communities to long-term increases in water rates, projects can disproportionally impact low-income water users. It is important to that these PPPs adopted were implemented by water utilities with high financial and technical capacity (e.g. AAA credit ratings, experiencing in operating complex technology). Only one case, the Rialto infrastructure upgrades, represents an application of a PPP to a low-income region with a high proportion of traditionally marginalized populations.

A path dependency approach suggests PPP outcomes and processes will not be the same in each country due to differences in socio-technical, economic, and regulatory contexts across regions. (Matos-Castaño et al., 2014; Mu et al., 2011; Skelcher, 2010). California’s water system is a complex, multi-layered, highly technical system that has evolved over the span of 170 years (Hanak et al., 2011; Hundley, 2001; Pinter et al., 2019). California also has developed strictest environmental regulation in the United States (Ulibarri et al., 2017). Middle-income to upper-middle income countries and regions with developed regulatory frameworks, water systems, and utility operations will be the ones most likely to replicate similar gains in sustainability and resilience.

This research reveals three lessons learned that can be applied broadly to public-private partnerships across sectors and regions. First, introducing and adopting PPPs requires a “perfect storm” of conditions, including appropriate project selection and available technology, broader political will and PPP-enabling regulations, and discourse that signals the need for additional infrastructure provision and legitimizes the private sector participation in resource management. Second, the research highlights the importance of tailoring PPP projects to local conditions and the needs and capacity of communities (see Mert & Dellas, 2012). Public partners and regulatory agencies must carefully weigh economic, environmental, and social impacts of projects. Projects that provide short-term gains in resilience at the expense of long-term sustainability (environmental degradation, disproportionate impacts to low-income water users) are maladaptive and will increase vulnerabilities of communities to future shocks and stressors. Finally, this research demonstrates that adaptive management of PPPs requires significant dedication of time and resources to developing relational and contractual governance mechanisms and including diverse stakeholders throughout the project lifetime.

Roadmap

This dissertation is structured as follows: Chapter 2 establishes the theoretical foundation for the dissertation. It defines public-private partnerships and presents the three frameworks utilized in the study: holistic sustainability, SES resilience, and new institutionalism. The chapter demonstrates how institutions and path dependence can constrain opportunities for project participants in the water sector and can lead to variations in PPP success around the globe. Chapter 3 provides a detailed overview of the methodology for collecting and analyzing data. Chapter 4 summarizes current water challenges, identifies factors that limit adaptive capacity of water managers, and highlights difference and similarities in how regulators and water utilities interpret sustainability and resilience. Meanwhile, Chapter 5 presents the current national- and state-level PPP enabling legislation and examines the endogenous and exogenous drivers of PPP adoption. While Chapter 6 focuses specifically on the impacts and processes of data oriented partnerships, Chapter 7 summarizes the economic, environmental institutional outputs and outcomes of all 10 PPP projects within the context of SES resilience and holistic sustainability. Chapter 8 identifies allocation of risks between partners and key challenges encountered throughout the project lifetime. Chapter 9 presents lessons learned by project participants. The chapter then proposes a framework for the development and adaptive management of PPP projects that contribute to sustainability and SES resilience. Finally, Chapter 10 summarizes key findings, provides policy recommendations, and avenues for future research.

2.0 THEORETICAL FRAMEWORKS and BROADER PPP BACKGROUND

This chapter overviews the three theoretical frameworks utilized to provide a robust evaluation of PPPs in California's water sector: holistic sustainability, social-ecological resilience, and new institutionalism. These frameworks are essential in understanding not only the potential outcomes of PPPs, but also the broader formal and informal institutional constraints that public and private partners in the water sector may face when developing and implementing a PPP project. The chapter begins with an overview of new institutionalism and demonstrates how public expectations and infrastructure create inertia and risk-aversion in the water sector. Next, the chapter defines PPPs and examines the role of institutions and path dependence in the variations in PPP outcomes between countries. Finally, the chapter defines holistic sustainability and social-ecological resilience in the context of water management.

2.1 New Institutionalism, Path Dependence, and Adaptive Management

The first theoretical framework utilized within this dissertation is new institutionalism. The framework is critical in understanding the broader formal and informal constraints for PPP participants in the water sector. The framework evolved from old institutionalism, which was a normative examination of the role of institutions in governing individual behavior (Peters, 2019). Old institutionalism prioritized the analysis of formal government structures and their historical patterns of political development, but provided little room for the examination of informal relationships within institutions (Bell, 1994). New institutionalism represents a second wave of research on institutions, and emphasizes both formal political structures as well as social behaviors, preferences, and power distributions of actors (Bell, 1994; Powell & DiMaggio, 1991). Since the 1980s, several types of new institutionalism theory have been developed, including rational choice institutionalism, historical institutionalism, sociological institutionalism, discursive institutionalism, and new institutional economics[1] (North 1990; Schmidt, 2008, 2009, 2010). This dissertation will draw on elements from all new institutionalism theories, as a holistic approach can yield a more complete understanding of exogenous and endogenous factors that constrain actors within a particular organizational field (Peters, 2019).

Institutions are socially constructed frameworks that constrain human actions and enable predictable, patterned behaviors (Matos-Castano et al., 2014; North, 1990; Peters, 2019). These constraints include formal regulatory mechanisms such as public policy, procedures, and laws as well as informal ones such as individual norms and values, institution-level belief systems, and cultural frames. The institutional environment, thus, shapes political processes and the rules within them (Peters, 2019). Institutions are typically analyzed at the level of organization fields, or collections of organizations with similar and vested interests such as suppliers, consumers,

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[1] Scholars has written extensively on various types of new institutionalism (see Schmidt 2008, 2009, 2010; Powell & DiMaggio, 1991). A summary of each theoretical framework is provided below:

1. **Rational choice institutionalism** posits that actors within institutions organizations are rational, and make calculated choice to maximize their preferences (Schmidt, 2009). Institutions serve as incentive structures that reduce uncertainties that arise from individuals preferences of multiple actors. In the absence of institutions, actors will encounter collective action problems (see Hardin, 1982; Ostrom, 1990).
2. **Historical Institutionalism** examines institutions in a historical context, and argues that institutions are sets of practices and formal rules that structure actions and outcomes (Schmidt, 2009, 2010). Change of institutions is believed to exogenous through critical junctures (see Mahoney, 2000) or punctuated equilibrium (see Krasner, 1988).
3. **Sociological institutionalism** formed as a direct criticism and response to rational choice institutionalism, and views institutions in light of culturally-specific practices and historical contexts (Schmidt, 2009). Institutions are viewed as norms and cognitive frames that create a shared system of meaning and guide human action through a "logic of appropriateness" (see March & Olsen, 1989; Powell & DiMaggio, 1991)
4. **Discursive institutionalism** focuses on the preferences, strategies, and normative orientations of actors and how discursive processes (construction and deliberation of ideas) in an institutional context can enable the creation of new institutions and maintain them. Schmidt (2008, 2009, 2010) argues that DI differs from other new institutionalism frameworks by viewing institutions as dynamic structures that can change as actors communicate critically about them.
5. **New institutional economics** posits that political and economic institutions, through their influence on human behavior, underlie economic growth and development (Klein, 1998; Schoemaker, 2014). The dominant role of institutions is to reduce transaction costs between actors by internalizing them or by establishing rules of action (contracts, resource or property rights, etc.) (Hira & Hira, 2000). Institutions will not be created or maintained if the costs of maintaining institutions outweighs their benefits (Powell & DiMaggio, 1991).

regulatory agencies (DiMaggio & Powell, 1983). These fields are dynamics “fields of struggles” where organizations will strive to alter institutions, and will also be shaped by the institutions in which they operate (Mahalingam & Delhi, 2012, cited in Matos-Castano et al., 2014; see also DiMaggio & Powell, 1983).

Formal and informal institutional constraints can result in path dependence: due to entrenched, vested interests of dominant actors or organizations, the long-term nature of infrastructure (particular at economies of scale), and high costs of developing and implementing new policy, policy actors will privilege the continuation of existing agreements and practices, even when the status quo approach becomes increasing maladaptive (Barnett et al., 2015; Cox, 2016; Heinmiller, 2009; North, 1990; Marshall & Alexandra, 2016). In other words, institutional decisions in the present may affect future policy options by limiting what is politically possible, as each step along a particular path will increase the benefits of this path relative to the alternatives that were originally available (Sorensen, 2013). The longer an institution exists, the more difficult it is to undertake large-scale institutional change.

Institutions can be influenced and changed through the interaction between rules, resources, and agency of actors (Fuenfschilling & Truffer, 2016; Sorensen, 2013). At an exogenous level, institutions can be shaped by new regulations imposed by powerful agents such as national and state governments (Scott, 2014) or through critical junctures such as crises (Mahoney, 2000; Sorensen, 2013). Exogenous shocks can disrupt mechanisms that reproduce behavior and provide alternative choices. The loss of legitimacy of existing institutions creates an opportunity for actors to introduce institutional change (Sorensen, 2013). The choices made by policy-makers during these 'critical junctures' can trigger subsequent events and result in new recurring and self-reinforcing institutional choices (Mahoney, 2000). Critical junctures, thus, can have long-lasting legacies in shaping distributions of power, values, and capacity of actors (Sorensen, 2013).

Institutional change can also be endogenous. New patterns of behavior can be introduced into organizations by entrepreneurs or can be diffused through sharing of best practices (Fuenfschilling & Truffer, 2016; Jooste, Levitt, & Scott, 2011; Lawrence, Hardy, & Phillips, 2002). Actors within organizations can shape institutional contexts by mobilizing resources (political will, money, knowledge, and social capital) and shifting discourse narratives surrounding norms and practices (Lawrence & Suddaby, 2006). This "institutional work" can be dramatic or it can be invisible day-to-day adjustments, adaptations, and compromises. Over time, these introduced behavioral patterns or discourses within organizations can become a new norm (DiMaggio & Powell, 1983), which individuals will begin to view as "*the way we do these things*" (Scott, 2014, p. 68). The capacity to introduce change into institutions will vary based on an entrepreneur's skills, access to resources, and the effectiveness of their relationships and networks (Jooste et al., 2011; Lawrence et al., 2002). Organizations with a high number of networks and connections are more likely to promote the widespread adoption of new practices, technologies, or rules (Lawrence et al., 2002). Thus, as innovation diffuses across the organization field, homogenization of organizations occurs, as actors and organizations will adopt these innovations to gain legitimacy (DiMaggio & Powell, 1983).

Inertia in the Present-Day Water Sector: Institutional Constraints and Opportunities

New institutionalism is a useful theoretical lens for examining the present-day inertia and risk aversion in California's water sector. Water management is complex due to volatility and uncertainty of hydrological conditions as well as shifting demands in built spaces (Lach, Ingram, & Rayner, 2005). Water agencies have developed norms, infrastructure, agreements, and relationships that manage the irregularity of water availability and quality (Barnett et al., 2015; Hundley, 2001; Lach et al., 2005). The focus is on supply provision (Ajami, Thompson, & Victor, 2014; Barnett et al., 2015; Lach et al., 2005). Droughts and other extreme events are used as a baseline for planning, designing, and operating the system. The goal is to "smooth out fluctuations in the system" by ensuring adequate capacity for all system functions, including storage, adequate water quality, energy demands (Lach et al., 2005). As a result, the created water system is often redundant and highly controlled. As water system infrastructure has a life-span of 50 to 100 years, the system is also difficult to change once the infrastructure is in place. Thus, decisions made within a particular investment cycle can result in institutional and technological lock-in (Marlow, Moglia, Cook, & Beale, 2013) or "entrapment" (Brown et al., 2011).

Decisions of water utilities and alternative pathways for the adoption of sustainable and resilient strategies are also shaped by public expectations of affordable, reliable, and safe (e.g. high quality) water provision and management (Lach et al., 2005). Failure to meet these expectations will result in public dissatisfaction and political backlash. Even short-term reductions in these three values for long-term improvements are often met with criticism (Lach et al., 2005). Thus, while water managers recognize that change is necessary, they are not prepared to risk destabilizing the conventional model of urban water management (Baehler & Biddle, 2018; Brown et al., 2011; Kiparsky et al., 2016). Public expectations are "binding constraints" (Rayner et al., 2005), which have resulted in a highly conservative approach to risk and decision-making (Baehler & Biddle, 2018; Barnett et al., 2015; Brown, Ashley, & Farrelly, 2011; Kiparskyet al., 2013; Lach et al., 2005). Implementation of technology requires extensive preparatory work, bench-testing, and pilot testing (Baehler & Biddle, 2018; Lach et al., 2005). A survey (N=63) of wastewater managers suggests that 65% of managers require a demonstration to consider a technology, and 25% will only consider adopting new technologies if they are already the industry standard (Kiparsky, Thompson, Binz, Sedlak, Tummers, & Truffer, 2016). Unfortunately, most utilities in the United States are small, and often lack the resources and capacity to test new technologies on their own (Ajami et al., 2014). Fragmentation limits the dissemination of best practices and outcomes of pilot testing, further reducing uptake of innovative practices. Regulatory practices can also reduce incentives to innovation (Ajami et al., 2014) by creating risks of overspending by amending designs/re-building according to new specifications (Sherman et al., 2020). In a survey (N=275), uncertainty about future regulation and regulatory standards was identified as barrier to innovation by 73% of wastewater utility managers (Sherman et al., 2020).

Constrained by the built environment, expectations of the public, and the broader regulatory regime, water utilities develop an ingrained culture of "the way things are done" (Lach et al., 2005). This culture is often perpetuated as younger employees become entrenched in institutional norms as they develop the necessary "craft skills" and knowledge to manage and operate an agency's infrastructural system[2]. As a result, younger employees may lock in practices that they do not believe are the optimal approach, but will pursue these strategies because they align with the dominant interests of the utility (Brown et al., 2011). Typically, low to middle-level employees only have opportunities to promote change through small-scale

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[2] Lach et al. (2005)'s qualitative analysis of public water utilities in the U.S. revealed that water utilities view operation and maintenance of water systems as a craft skill. The unique physical conditions (soil chemistry, precipitation patterns, etc.) result in nuanced differences between local infrastructural systems, which are learned and understood by employees over prolonged periods of time. Training staff attuned to all these elements may require three to ten years.

experimentation; these experiments can become institutionalized through repeated activity, but are limited to incremental changes within organizations (Lach et al., 2005).

Thus, to promote large-scale change, innovation must often be compatible with the skills and the values of senior/experienced operators (Brown et al., 2011; Lach et al., 2005). There is high demand among water managers for innovative technologies and governance mechanisms that promote local-level, drought-resistant supply or demand management (Ajami et al., 2014). Yet, investment in innovation remains low relative to other sectors such as the energy sector (Ajami et al., 2014). Most utilities in California do not have formal policies or norms in place to promote experimentation and innovation[3] (Kiparsky et al., 2016). Water managers often believe that their organizations are more innovative than they truly are (Baehler & Biddle, 2018; Kiparsky et al., 2016), and thus may provide low incentives to employees to seek out alternative solutions. Water managers themselves spend only a small proportion of their time (10 to 20%) on innovative projects, citing cost, risk aversion, and regulatory compliance as key barriers to developing innovative practices (Kiparsky et al. 2016).

Overcoming Inertia in the Water Sector

Path dependency in water institutions has resulted in command-and-control systems that prioritize an engineering resilience approach. Decision-making is centralized and is focused on the harnessing of technical expertise, rather than stakeholder inclusion (Lach et al., 2005; Schoeman et al., 2014), ultimately limiting adaptive capacity of the system (Barnett et al., 2015). The current form of urban water management is highly unsuited for addressing challenges with high complexity and uncertainty (Wong & Brown 2009).

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[3] Only 10% of water managers in California's wastewater sector (N=63) reported that their organization have explicit policies related to R&D (Kiparsky et al., 2016)

Integrated Regional Water Management (IWRM) and adaptive management (AM) have been proposed overcome path dependency and inertia in water governance (Engle, Johns, Lemos, & Belson, 2011; Schoeman, Allan, & Finlayson, 2014; Varady et al., 2017). IWRM promotes collaboration and water, land, and their related resources at a watershed scale (Schoeman et al., 2014). The goal is to balance environmental well-being and resource protection with socio-economic development (Medema, McIntosh, & Jeffrey, 2008). Adaptive management builds on IRWM (Schoeman et al., 2014). It is predominantly a "learning by doing approach" – a cyclical process of decision-making, monitoring, and evaluation allows managers to overcome uncertainty, increase policy effectiveness, increase scientific knowledge, and reduce tension amongst stakeholders (Allen & Gunderson, 2011; Medema et al., 2008; NRC, 2004; Schoeman et al., 2014). At its core, adaptive management promotes flexible decision-making. Decisions can be adjusted or reversed as impacts from management choices and actions are better understood (Pahl-Wostl, 2008; NRC, 2004). The ability to respond to emerging policy impacts requires the establishment of a robust monitoring system as well as institutional practices that allow actors to integrate new findings into decision-making. Adaptive management, thus, is a cyclical learning process rather than a form of "trial and error" experimentation (NRC, 2004; Varady et al., 2017). Social learning is a crucial component of adaptive management, as iterative and inclusive participation can lead to co-production of knowledge and the development of user-responsive policies and objectives (NRC, 2004; Pahl-Wostl et al., 2007; Varady et al., 2017). While time consuming and costly, the involvement of scientists and the public in policy dialogues is critical to developing a holistic understanding of potential impacts and outcomes of policy decisions.

Presently, the use of adaptive management and IRWM in water resource governance is limited (Allen & Gunderson, 2011; NRC, 2004; Schoeman et al., 2014; Varady et al., 2017).

Previous models of management – either command-and-control or IWRM - may constrain opportunities for effective implementation of adaptive management (Engle et al., 2011). The US Army Corps of Engineers, for example, began employing adaptive management approaches in the early 1990s, but is still working to reconcile the approach's focus on flexibility with the Corp's engineering resilience approach. Like IRWM, adaptive management has been criticized for its nebulousness (Varady et al., 2017; Schoeman et al., 2014). Water managers struggle to set clear goals and quantify outcomes. Coordination across stakeholder groups and agencies can result in large-scale, centralized, and unwieldy forms of governance which are slow to respond to new information (Allen & Gunderson, 2011). Moreover, the high resource and time costs of participatory input and robust monitoring may lead to "box-ticking rather than learning" (Schoeman et al., 2014, p. 383). The approach may be "more of an ideal than a reality," as competing interests between stakeholders, ingrained institutional norms, high risk aversion, and constraints of the built environment limit flexibility and experimentation of water management solutions (Schoeman et al., 2014, p. 382; see also Medema et al., 2008; NRC, 2004).

Due the complexity of social-ecological systems and the high socio-technical constraints facing institutions, the transition to sustainability will not be a linear process (Sullivan et al., 2017). Cities and water providers can take steps forward or backward depending on available technology, the values and interests of key influencers, and the institutional context (Marshall & Alexandra, 2016; Sullivan et al., 2017). New policy does not replace existing policy, but is often integrated with old hydrological approaches (Miejerenk & Huitema, 2010,) resulting in constrained water governance alternatives.

2.2 Defining Public-Private Partnerships and Examining Past PPP Outcomes

Throughout history, public and private sectors have come together in various ways to provide critical infrastructure services (Wettenhall, 2010).The private sector has participated to a certain degree in almost all infrastructure projects, blurring the lines between privatization[4], design-build practices[5], and public-private partnerships (Delmon, 2010). Over 25 terms have been used to describe models with various degrees of involvement. The earliest recorded practices of contracting out, partnership building, and marketization dates back to the Imperial, China, and Rome roughly 2,500 years ago, with private tax and toll road collection (Forrer et al., 2010). Within California's water sector, private ventures of water management date back as early as the Spanish colonialism era (Hundley, 2001). Private participation in water management was further strengthened in the early stages of water management under an American government system, with a laissez-faire federal government enabling the rise of agricultural and water retailer monopolies (Hundley, 2001). Similarly, between the sixteenth and the nineteenth centuries, expansions of transportation, water supply, sewerage, and energy sectors in Europe were primarily driven by private entrepreneurs through concession contracts (PPIAF, 2009).

While models similar to PPP arrangements date back to the era of mercantilism (Wettenhall, 2010), the term "public-private partnership" can be formally traced back to urban development and downtown renewal projects in the US during the 1960s (Bovaird, 2010). Since then, the concept has shifted and "taken on several lives of its own" to describe a vast array of activities (Hodge et al., 2018, p. 1105). Presently, there is no core PPP concept or global PPP

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[4] The definitions of privatization ranges from the inclusion of private actors (NGOs and firms) in governance systems (Bruhl, 2001) to a direct transfer of enterprise ownership – in whole or in part – from state to private hands (Savas, 2000). For this research, privatization will refer to the full transfer of state-owned enterprises to a private company.

[5] Design-build is a project delivery process in which the state contracts a team of private entities (a consortium) to provide design and construction services. The relationship of the state and the design-build team is one of a principal-agent one (Design-Build Institute of America, n.d.)

model (Hodge et al., 2018). As a result, there is a lack of consistent and common terminology on PPP among businesses, academia, and government (Greve & Hodge 2013; Hodge & Greve, 2007; Miraftab, 2004). Definitions of public-private partnerships can vary by research framework (Hodge & Greve, 2013), agenda, project structure (Weihe, 2008), and the national institutional context (Hodge & Greve, 2007), leading to three distinct definition groups in the literature: practitioner-driven, technical, and public policy oriented[6] (see Nizkorodov 2017).

Even within the United States there is no uniform definition of PPPs (AGC, 2020; Debevoise & Plimpton, 2019). Both the Build America Bureau[7] (2019) and the Associated General Contractors of America (2020) utilize the broad definition provided by the Government Accountability Office: PPPs are "contractual agreements between a public agency and a private entity that allow for greater private participation in the delivery of projects." The EPA (2008) and the National Council for Public-Private Partnerships[8] expand on this definition to include the sharing of risks and the pooling of skills and assets of public and private actors to deliver infrastructure or service to the general public (AGC, 2020). The EPA (2008) also includes the

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[6] The variation in research frameworks, research goals, project types, and national attitudes has led to the emergence of three definition groupings in the literature (see Nizkorodov, 2017):

1) *Practitioner-Driven:* Practitioner-driven definition of PPPs that strategically frames the management structure as a method for promoting infrastructural development. The language surrounding the definition of PPPs can rely on "conflict-avoiding jargon" that may obscure the high levels of economic, political, and social conflict that accompanies water privatization efforts (Swyngedouw, 2013, p. 826). Scholars have referred to this re-branding as a "language game" (Hodge & Greve, 2010; Wettenhall, 2003, 2007), as the primary role of these definitions is to promote neoliberal development strategies under the guides of "partnership" (Hodge & Greve 2007).
2) *Technical:* Typically utilized in management, economics, and engineering literature, technical definitions focus on project product (Liu, Love, Smith, & Davis 2014) emphasizing project output, elements of risk sharing, efficiency, and cost. These definitions typically apply to complex infrastructural projects and may not carry over to grassroots PPP projects.
3) *Public Policy:* While public policy definitions are frequently tailored to the selected cases and research scope, definitions emphasize partnership management, political process, and partnership impact on the affected community.

[7] The Build America Bureau is the federal unit responsible for transportation infrastructure investment

[8] NCPPP is a non-profit, non-partisan organization that supports the development of PPPs at the local, state, and federal level by providing education and training resources to governments.

stipulation that it is the public partners' "ultimate responsibility" to insure that social needs and objectives of a PPP project are met (p. iv).

This research distinguishes PPPs from other procurement methods by the partnership structure: unlike the principal-agent relationship in a traditional public procurement (e.g. a Design-Build structure), the relationship between partners in PPPs strives to be a principal-principal one. While a truly-balanced relationship between stakeholders is difficult due to unequal power distributions and resources between partners (Parrado & Reynaers, 2018; Shi, Chong, Liu, & Ye 2016), the public and the private entity strive to be horizontal partners, working *jointly* to provide a good or service (Bovaird, 2004; Forrer et al., 2010; Miraftab, 2004; Weihe, 2008). PPPs, thus, are distinct from other methods of procurement by the presence of mechanisms for joint decision-making, sharing of risks, and the pooling of resources and skills (Forrer, Kee, Newcomer, & Boyer, 2010; Hodge & Greve, 2007; Schaferhoff, Campe, & Kaan, 2009).

Along with ambiguity in the definition of public-private partnerships, there is also imprecision in the typology of PPP structures. Scholars have classified various projects based on the degree of interaction between private and public entities (Loxley 2013); the degree of infrastructure ownership by the private entity (Jeffares, Sullivan, & Bovaird 2009); the degree of risk and task transfer (Koppenjan & Enserink, 2009); project purpose (McQuaid & Scherrer, 2010); the policy objectives (Bovaird, 2004); the partnership structure (Bovaird, 2004); and the degree of transaction costs (Stoker 1998). To ensure typology aligns with the majority of peer-reviewed literature on infrastructure PPPs, this research will utilize the World Bank classification of projects for greenfields, divestitures, concessions, and management and lease contracts (See Appendix Table A1 for definition of each PPP type and subtype).

Understanding PPP Experiences and Impacts around the World: the Role of Institutions and Path Dependency

Public entities are motivated to enter into PPP arrangements to overcome budget constraints, transfer project risks, gain access to private sector knowledge or skills, and accelerate infrastructure provision (Ameyaw & Chan, 2013; Beevers, 2016; Chou & Pramudawardhani, 2015; Liu & Wilkinson, 2011). The promise of quality, innovation and efficiency had led to a rise in popularity in PPPs as a mechanism for infrastructure and service delivery (Leighland, 2018; Tetteh, Teye, Abosi, & Chong, 2019): according to the Private Participation in Infrastructure database (2020), 7,095 PPP projects ($1,654 billion in investment) have been enacted across 137 low- and middle-income countries between 1990 and 2020. PPP adoption is also market drive. Through unsolicited proposals, private companies can persuade local governments to partner and to enact PPP enabling policies (Wang, Chen, Xiong, Yang, & Zhu, 2019). In entering partnerships, firms seek not only financial returns on investment, but also access to previously closed markets and public knowledge sources, reputational gains, and opportunities for future contracts (Kivleniece & Quenlin, 2012; Shambaugh & Matthew, 2016).

Comparative case studies suggest that PPPs have improved water quality, coverage, and service around the world (Marin, 2009; Porchet & Saussier, 2018), yet have also failed to make the promised technical efficiency gains (Porchet & Saussier, 2018; Tetteh et al., 2019). Innovation is only pursued in cases where there is explicit social and economic value (Parado & Reynaers, 2018). Moreover, international experiences with PPPs suggest projects encounter numerous challenges throughout their life-cycle (Leighland, 2018). For example, an analysis of 3,700 PPP infrastructure projects revealed that more than half of PPP contracts were renegotiated within the first 11 years of the project lifetime (Baird, 2018). Moreover, distressed or cancelled projects represent roughly 5.4% of total investment in low- and middle-income countries (PPI, 2020). Rates of failure are highest in the water sector: while water PPPs account for 14% of all projects in the PPI database, water and sewerage PPPs represent 21% of cancelled and distressed projects (roughly $20 billion in investment).

New institutionalism serves as a useful framework for understanding the variations of PPP project success around the world. Institutions play a critical role in PPP outcomes by providing legal frameworks, establishing practices for procurement and negotiation contracts, developing mechanisms of deterrence, creating an environment conducive to investment, and monitoring social-ecological system impacts (Beevers, 2016; Matos-Castano et al., 2014; Mu et al., 2011; Schoemaker, 2014; Skelcher, 2010). In countries with low institutional capacity, regulatory risk (the government's failure to honor contracts), discourages potential investors or may "lock in" public partners in unsustainable contract structures[9] (Pessoa 2010). Moreover, in cases of limited local authority and weak institutions, private partners will demand favorable market conditions and will shift commercial risks to public partners, taxpayers, or users (Koppenjan & Enserink, 2009), ultimately increasing the risk of project failure (Ameyaw & Chan, 2014). Water PPPs may be particularly at risk at increasing inequality and leading to partnership arrangements with high moral hazard and corruption (Shambaugh & Matthew 2016). The public partner may tolerate low quality service in a PPP arrangement, rather than risk disrupting water provision during re-negotiation of the contract or re-nationalization of the water system. Contract termination is often a last resort option (Ho & Tsui, 2009). The direct link between water and human health may force public managers to bail out infrastructure projects or to re-negotiate contracts on unfavorable terms, increasing transaction costs throughout the

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[9] For example, between 1989 and 2000, in five Latin American Countries, government agencies renegotiated 79% of the 307 transport and water projects after an election (Iossa & Martimort 2015)

project lifetime (Iossa & Martimort, 2015). Thus, the provision of water may be “too important to fail” (see Ho & Tsui, 2009) and highly path dependent.

Studies suggest that PPPs are successful when policy expresses clear and stable political support for PPP projects, public partners have the regulatory capacity to monitor project quality, and parties have the skills and technical capacity to develop a robust contract structure (Ameyaw & Chan, 2014; Chen & Doloi, 2008; Jamali, 2004, Li et al., 2005, Pinz et al., 2017; Zhang 2005). Yet, creating PPP enabling institutions and the expertise to manage PPP projects can be challenging (Matos-Castano et al., 2014), as it may require the introduction of new policies that conflict with existing rules and practices (Matos-Castaño et al., 2014; Mu et al., 2011). Due to the high cost of developing and implementing new policy, actors will privilege the continuation of existing agreements and practices, resulting in incomplete PPP institutional frameworks (Dormois et al., 2005). In France, for example, collaboration between public and private actors in urban renewal PPPs is “almost illusory” (Dormois et al., 2005, p. 246). Despite policy discourse emphasizing the need for horizontal partnerships and integrated approaches to urban renewal, standardization of technical and legislative practices policy leaders’ focus on short-term outcomes have restricted public-private partnership interactions. While the public actors define partner roles and flush out project goals, the contribution of private actors is limited to provision of resources. The emphasis is on minimizing economic and legal risks rather than innovative, integrated partnership development.

The adoption of PPPs and their outputs depend not only on the regulatory context, but also on the norms and values of actors driving the reforms (Dormois, Pinson, & Reignier, 2005; Jooste et al., 20011; Matos-Castaño et al., 2014; Wang et al., 2019). PPPs, thus, will have their own individual path-dependent trajectories in each country. In other words, despite the concept of PPPs propagating globally through an international network of experts and organizations (see Hodge & Greve, 2018; Jooste et al., 2011; Nizkorodov, 2017), PPP outcomes and processes will not be the same in each country (Jooste et al., 2011; Matos-Castaño et al., 2014; Mu et al., 2011; Skelcher, 2010; Tetteh et al., 2019). "There is no one-size-fits-all institutional framework that is universally applicable for the pursuit of PPPs" (Matos-Castaño et al., 2014, p. 48; see also Jooste et al., 2011). Even when PPPs are implemented in similar regions, political contexts and institutional entrepreneurs will ultimately shift the development trajectory of PPP-enabling fields.

Mu, De Jong, and Koppenjan (2011), for example, argue that transposing the PPP from the UK to China's transportation sector was unsuccessful due to the incongruence of the institutional frameworks in the two countries. Prior to adoption of PPPs, the main form of infrastructure provision in China was a top-down approach, where public sector agencies produced projects in-house. Demand for private sector participation began to grow through a global push of PPP adoption and rising criticism of the inefficiency and poor accountability of public agencies. However, due to the historically state-centric approach to infrastructure provision, there was limited experience in China's government in tendering and negotiating contracts. New legislation, inspired by international examples such as the UK's PFI best practices, was enacted to promote private participation in financing and infrastructure delivery. Public agencies soon discovered that PPPs had unexpectedly high transaction costs due to the costs of tendering, evaluating bids, and providing long-term monitoring to minimize opportunism. Projects failed to meet expectations due to the private sector's collusive behavior, the public sector's poor tendering process, and the public sector's continued provision of alternatives that minimized demand for PPP-provided infrastructure. The bankruptcy of many private enterprises during the 2008 Global Financial Crisis resulted in a high rate of government takeovers of PPP projects. The government responded to the wave of failed PPPs with new selection criteria and regulations that required contractors to provide 5% of total project investment up front, creating barriers to market entry for small and medium sized private enterprises. Thus, failed expectations of past PPPs and the reduced opportunities for private sector investment led to a shift to infrastructure provision through Public-Public Partnerships through State-Owned Enterprises. The rise (1993-2007) and rapid fall (2007 – 2010) of PPPs in China ultimately highlights the challenges of adopting best practices and international policy mechanisms without consideration of local socio-economic and institutional conditions.

Incongruence between institutional frameworks and exogenous policy approaches can be overcome by implementing a long-term, reflexive orientation towards institutional development (Matos-Castaño et al., 2014; Wang et al., 2019). Matos-Castaño and colleagues (2014) examined development of PPP enabling institutions by comparing the long-term evolution of PPPs in Tamil Nadu (India) and the Netherlands. In both countries, the first wave of PPPs failed to meet performance expectations due to limited institutional support and public sector experience with the policy mechanism. The Dutch government viewed PPPs as a means of service delivery, treating these earlier experiences as a learning process and adjusting institutions and policy to strengthen technical and regulatory capacity of public agencies. Political stability (low rates of government turn-over) and a long-term commitment to developing a PPP program enabled steady and effective policy interventions. This reflexive approach allowed the government to build trust, legitimacy, and capacity, and to develop a successful PPP program that was well-received by the public. As a result, PPPs are now viewed in Netherland as “acceptable, well understood way of delivering infrastructure services” (Matos-Castaño et al., 2014; p. 62).

Conversely, the government of Tamil Nadu approached PPPs as a form of asset creation. High rates of government turnover led to a focus on short-term outcomes, limiting opportunities for reflection and institutional change. Moreover, few steps have been taken to create trust and legitimacy surrounding PPPs, resulting in low public acceptability of the mechanism and the gradual abandonment of the method as a form of infrastructure delivery in Tamil Nadu.

This section illustrated how formal and informal institutions as well as project participant motivations can impact PPP outcomes around the world. Understanding impacts, thus, requires process tracing PPPs from the earliest stages of partnership formation to the end of project lifetime. Two theoretical frameworks, holistic sustainability and social-ecological resilience will be utilized to evaluate PPP impacts within California. The remainder of the chapter situates these frameworks within the context of PPPs and California's water sector.

2.3 Defining Sustainability: Reductionist vs. Holistic Perspectives

Sustainable development was first introduced by the Brundtland Commission (1987), which defined the concept as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (p.8). Since then, a number of alternative definitions have been proposed, leading to the establishment of various indicators, metrics, and research frameworks in academia and practice (Gladwing, Kennelly, & Krause, 1995; Vos, 2007). Definitions range from narrow interpretations of maintaining the status quo to a broader emphasis on human and ecological well-being (Lew, Ng, Ni, & Wu, 2015). As a result of this flexibility, the study of sustainability - like the study of PPPs – runs the risk of remaining ambiguous, imprecise, and ideologically controversial (Gladwing et al., 1995), limiting the overall effectiveness of decision-makers in promoting sustainable practices (Hueskes, Verhoest, & Block 2017).

Among definitions, it is possible to find common ground: sustainability embraces the protection of environmental and human systems for both the present and the future, acknowledges the interconnectedness of global resource and welfare, and promotes the equitable distribution of environmental and social benefits while minimizing the concentration of harms to marginalized populations (Hueskes et al., 2017). This research builds on these common elements to define sustainability within the context of project management and infrastructure procurement. Projects are financially viable throughout the infrastructure lifetime while maximizing ecological well-being and social welfare. If poorly managed, the high capital cost and low profit margin of water infrastructure can create an additional tax burden on current and future generations. To ensure that profitability is not achieved at the expense of high environmental degradation or distributional impacts (i.e. the exclusion of low-income water users), project managers must be accountable, transparent, and responsive to affected individuals (Silvius & Schipper, 2016). Thus, within the context of PPPs, this research defines the three dimensions as follows:

- The ***Economic Dimension*** refers to economic efficiency and traditionally takes the form of maximizing project profitability. PPP's will meet the economic dimension if they retain financial viability while also maximizing service and infrastructure quality.
- The ***Social Dimension*** in public-private partnerships contains two components. The first is the democratization of the decision-making process through citizen inclusion in project design and implementation. The second element is minimizing distributional impacts (i.e. ensuring that those worst-off in society are not bearing the burden of hazards and are provided equal opportunity for benefits). For water sector PPPs, the social dimension will primarily entail the dissemination of knowledge surrounding the partnership structure, citizen participation in infrastructure and watershed management, and affordability of water rates and local taxes for both current and future generations.
- The ***Ecologic Dimension*** refers to the impact of service delivery of public infrastructure on the environment (Koppenjan & Enserink, 2009). For the water sector, environmental sustainability requires consideration of the full watershed – water quality, downstream impacts, groundwater replenishment, ecosystem function – as well as consideration of additional resource inputs such as energy use.

Drawing on these three dimensions, research on sustainable PPPs has utilized two perspectives –reductionist and holistic (Pinz et al., 2017). A reductionist perspective evaluates sustainability in respect to the three dimensions independently. In this perspective, as long as stability of one dimension is improved, the management structure increases overall sustainability. A holistic approach, on the other hand, emphasizes the interdependencies and tradeoffs between the three dimensions. Sustainability is achieved when all three dimensions are fulfilled. This research utilizes a holistic perspective to examine impacts and processes of water sector public-private partnerships. Consideration of all three dimensions of sustainability – as well as the tensions and feedbacks between them –in the development, implementation, and operation of public-private partnerships can assist policy-makers in understanding the circumstances under which a PPP will present a long-term optimal outcome to public well-being.

2.4 Defining Social-Ecological System (SES) Resilience

The concept of resilience was first introduced in the 1970s to refer to an ecosystem's ability to recover from disturbance and to return to equilibrium or to an alternative steady state (see Holling, 1973). Since then, the definition has expanded across disciplines and has been adopted widely in policy rhetoric and academic literature (Meerow, Newel, & Stults, 2016; Xu, Marinova, & Guo, 2015). Yet, there is low consensus on the term's definition or application to infrastructure and service provision (Brand & Jax, 2007; Meerow et al., 2016; Norris et al., 2007; Smith, 2012; Wardekker, 2018). Like sustainability and PPPs, the term has "joined the long list of intuitively appealing yet stubbornly intangible concepts" (Smith, 2012, p. 193). California's 2020 *Water Resilience Portfolio*, for example, provides an overview of present and future socio-ecological water challenges and presents collaborative and individual strategies state regulatory agencies will undertake to "adapt and retool the water management system" to address pressing stressors (CNRA et al., 2020, p. 6). However, neither the *Resilience Por*tfolio nor the Executive Order that led to its creation provide a concrete definition of resilience. On the one hand, the concept's malleability allows it to bridge disciplines as a paradigm for analyzing social-ecological systems (Brand & Jax, 2007). This ambiguity, however, can lead to miscommunications and misconceptions among decision-makers and can hinder scientific progress (Brand & Jax, 2007; Lew et al., 2015; Marchese et al., 2018).

Across academic disciplines, there are three broad conceptualizations of resilience: engineering, ecological, and socio-ecological (Folke, 2006; Davoudi, 2012). Engineering resilience promotes predictability and stability of one system equilibrium. Success is measured by the ability of a system the speed from which it returns to equilibrium (Boltz et al., 2019; Folke, 2006; Holling, 1986). For instance, the EPA's water and wastewater toolkits[10] broadly describe resilience as being able to "respond to and recover from disasters" such as deliberate attacks, accidents, or naturally occurring threats or incidents (EPA, n.d.-a). Ecological resilience acknowledges that more than one possible equilibrium can exist (Holling, 1996) and focuses on the ability of a system to persist at its current equilibrium or adapt to a new one (Folke, 2006; Davoudi, 2012).

Social-ecological system resilience refers to a system's ability 1) to "bounce back" to its original steady state, 2) to adapt in order to sustain its present function, or 3) to transform, taking on a new identity and function (Boltz et al., 2019; Bruce et al., 2019; Hall et al., 2019). This emphasis on change is critical, as alternative pathways of system transformation can improve the status quo or can lead to a new steady state that decreases overall public welfare (Boltz et al.,

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[10] The Creating Resilient Water Utilities toolkit provides video training sessions and checklists to assist water utilities in conducting risk assessments, planning for and responding to emergencies, and implementing long-term water quality monitoring systems (EPA, n.d.-a).

2019; Johannessen & Wamsler, 2017). For water supply and quality management, the type of alternative pathways will depend on the socio-technical constraints of the system. Another crucial element of social-ecological resilience is the recognition that social and ecological systems are interconnected: impacts to one system will create vulnerabilities in the other (Eriksson et al., 2014). Given the complex and interrelated interactions between human and ecological systems in water management (Falkenmar, Wang-Erlandsson, & Rockstrom, 2019), this research will focus on social-ecological resilience.

While there is an abundance of empirical and theoretical literature that focuses on resilience, the concept has only been recently introduce in policy discourse in the United States. The Obama Administration first formally introduced the concept in the context of national security (Roostaie et al., 2019). The National Security Strategy (2010) defined resilience as "the ability to adapt to changing conditions and prepare for, withstand, and rapidly recover from disruption" such as terrorism, natural disasters, large-scale cyber-attacks, and pandemics (p. 18). The NSS also included an explicit role for PPPs in improving resilience: public and private sectors must collaborate to design structures and systems that can withstand disruptions by decentralizing critical operations, investing in improvements and maintenance of existing infrastructure, and testing system continuity and preparedness (p. 19). Similar definitions have been issued in the context of climate change impacts (Executive Order 136563, 2013), National Preparedness (Presidential Policy Directive 8, 2011), and Infrastructure Security and Resilience (Presidential Policy Directive 21, 2013). PPD-8 has resulted in the country's first National Disaster Preparedness goal (Roostaie et al., 2019), which identifies strategies to "prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk" to communities at a national scale (FEMA, 2018, para.2)

Despite this recent rise in federal discourse and legislation, there is limited application of social-ecological resilience thinking in metropolitan planning and resource provision (Davidson, Nguyen, Beuilin, & Briggs, 2019). Water scarce regions have historically relied upon engineering resilience solutions, an approach that is rooted in the belief that complex systems can be managed (Le Maitre & O'Farrell, 2008). To support urban growth, cities altered natural hydrological systems, channelizing rivers and diverting water sources, sometimes across hundreds of miles (Brown et al., 2008; Feldman, 2017). During the Hydraulic Era, elite technocratic decision-makers prioritized the development of large-scale, centralized water systems, with little consideration afforded to the environmental impacts of water management strategies (Feldman, 2018; Hundley, 2001). The focus of engineering resilience approaches is on fail-safe design that produces efficiency, consistency, and predictability (Folke, 2006; Holling, 1996). Yet, policies that focus on maintaining a constant yield will result in a loss of system resilience over time (Holling, 1986): as systems evolve to become more uniform and less functionally diverse, they become more sensitive to disturbances (Holling, 1996; Le Maitre & O'Farrell, 2008). In engineering resilience, there is ultimately a divergence between the scales and functions between human and ecological systems, with environmental degradation and uniformity creating additional vulnerabilities for socio-economic systems (Holling, 1996; Le Maitre & O'Farrell, 2008). Unfortunately, the traditional response to addressing this divergence and subsequent vulnerability is to engineer additional controls on ecological systems, thus creating a cycle of decreasing resilience (Le Maitre & O'Farrell, 2008).

Resilience can be influenced through adaptive capacity (Walker, Holling, Carpenter, & Kinzig, 2004), or the ability of actors to respond to and adapt to environmental and socio-economic changes (Varady et al., 2017). Adaptive capacity includes the social, institutional, and technical skills, resources, and strategies available within a community. Increasing adaptive capacity allows communities to better manage shocks and risks, ultimately increasing overall resilience (Hill & Engle, 2013).

Effective water management will play a fundamental role in providing social-ecological resilience in the Anthropocene (Falkenmar et al., 2019). In the water sector, shocks and stresses can be technical (system operation and maintenance), institutional (failure of governance system or changes in regulation), natural (drought or flooding), economic (financial crisis or changes price or availability of interrelated resources such as electricity), or social (public support or opposition). It is important to note that disturbances are not always abrupt in nature – long-term disturbances (also known as chronic stressors) such unsustainable resource extraction can also destabilize systems and disrupt resource provision (Johannessen & Wamsler, 2017).

Perceptions of what enables urban systems to cope with shocks and stresses or to build adaptive capacity will vary across cities and regions (Bruce et al., 2019). Qualitative investigations of resilience discourse suggest that practitioners in the urban water sector refer to many various types of disturbances in one umbrella definition of resilience (Johannessen & Wamsler, 2017). However, they will often prioritize strategies that address immediate technical disruptions rather than those decrease broader social-ecological system vulnerability. The most common principles of resilience adopted by practitioners are the diversification of resource provision and creation of redundancy in infrastructure systems (Boltz et al., 2019). Thus, despite the rise in rhetoric, planners and water managers have been unable to achieve large-scale governance shifts to promote resilience and sustainability (Albers & Deppisch, 2012; Bruce et al., 2019; Smith, 2012).

Understanding the Link between Sustainability and Resilience

Both sustainability and resilience are used as descriptors of systems and often utilize similar methods to examine system vulnerability (Marchese et al., 2018). However, the two concepts have unique characteristics. Resilience focuses on processes that maintain or change system functionality while sustainability is focused on outcomes of human quality of life, social equity, and environmental well-being (Park et al., 2013, Redman, 2014; cited in Marchese et al., 2018). In other words, sustainability focuses on long-term longevity and is measured on changes to the social, economic, or ecological dimensions of human-ecological systems relative to the status quo (Roostaie, Nawari, & Kibert, 2019). Meanwhile, resilience focuses on the steps necessary or the speed at which systems “bounce back” to equilibrium, adapt, or transform. Thus, in a community development context, sustainability initiatives focus on conservation of resources, maintaining environmental knowledge and livelihoods, preserving cultural traditions, while resilience prioritizes building the capacity for change through innovative application of environmental knowledge and social collaboration (Lew et al., 2016). The concepts also operate at different time-scales. Sustainability efforts are often understood to be a long-term endeavor whereas resilience is frequently understood to respond to more immediate temporal scales (Marchese et al., 2018; Meerow et al., 2015).

A challenge in the research and application of resilience is that scholars have linked resilience with sustainability in diverging ways (Lew et al., 2015; Marchese et al., 2018; Roostaie et al., 2019). Academic literature on sustainability and resilience can be grouped into three categories: 1) resilience as a critical component in achieving sustainability, 2) sustainability as a factor that contributes to system resilience, 3) sustainability and resilience as separate objectives that can complement or compete with each other (Marchese et al., 2018). This research views sustainability and resilience as two separate concepts: policy objectives in one domain can reinforce or weaken the other. In some cases, decisions to promote sustainability can result in long-term destabilization of existing systems (Fiksel, Goodman, & Hecht, 2014). Conversely, elements that promote infrastructure resilience – particularly to hazard disruptions such as flooding – can reduce environmental, economic, or social sustainability (Johannessen & Wamsler, 2017; Roostaie et al., 2019).

2.5 Chapter Summary

This chapter established the three broader theoretical frameworks of this dissertation. Holistic sustainability and social-ecological resilience allow for an evaluation of PPPs at the organizational and the system-level. Holistic sustainability conditions are met when projects are financially viable, contribute to ecological well-being, (either through increased resource efficiency or through direct ecosystem benefits), and minimize social injustice (provide opportunities for voice and minimize distributional impacts) (Pinz et al., 2017). Meanwhile, SES resilience requires consideration of the linkages between social and ecological systems and focuses on the ability of systems to withstand, adapt or transform in the face of shocks and stressors (Holling, 1996; Folke, 2006, Folke et al., 2010; Erikkson et al., 2014; Rodina, 2019). Building SES resilience requires flexible, adaptive, and experimental management strategies that promote joint production of knowledge and responsiveness to critical ecosystem functions.

The third framework, new institutionalism, is critical in understanding how the past choices of actors in the water sector have constrained alternative water solutions to pressing water challenges. Current applications of SES resilience and holistic sustainability are limited in the water sector. California has a long history of pursuing engineering resilience solutions to address water management: water organizations have strived to overcome climate volatility and variability by creating redundant infrastructure systems, securing multiple sources of water supply, and developing technocratic institutions that prioritize engineering, economic, and legal solutions to water management (Hanak et al., 2011; Hundley, 2001; Mitchell et al., 2017; Pincetl et al., 2019; Pincetl & Hogue, 2015; Zetland, 2009). Priority was placed on supply reliability, with low attention paid to environmental impacts for projects (Hundley, 2001; Hughes & Mullin, 2015). The supply-oriented institutions and infrastructure have led to the development of a system that is poorly suited for present day water challenges (Hanak et al., 2011, Zetland, 2009).

A new institutionalism framework suggest that opportunities can be influenced by exogenous and endogenous factors. However, opportunities for reform are constrained or "locked in" by existing institutional arrangements and the past decisions of policy actors (North, 1990). In the water sector, large sunk costs of designing, building, expanding large-scale systems, the historical emphasis on technical and output-driven solutions, and the need to ensure reliability and safeguard public health creates inertia and slow adoption of innovative practices (Baehler & Biddle, 2018; Brown et al., 2011; Farrelly & Brown, 2011; Heinmiller, 2009; Lach et al., 2005; Marlow et al., 2013). Change is incremental. These self-reinforcing decision-making regimes can lead to sub-optimal policy outcomes and reduce resilience of human and ecological systems (Brown, Ashley, & Farrelly, 2011).

Practitioners and scholars have proposed PPPs as mechanisms to bolster sustainability and resilience due to the private sector's ability to share risks, develop flexible and resilient and innovative technologies, and to free up government budgets in order to address other critical needs (Hewes & Randolph, 2018; Koppenjan, 2015). However, the success of PPPs has been mixed (Leighland, 2018). PPP outputs and outcomes around the world are influenced by the past political and socio-economic regimes of countries (Jooste et al., 2011; Matos-Castano et al., 2014; Mu et al., 2011; Skelcher, 2010). Path dependence suggest that PPPs cannot be simply transplanted from one location to another. Instead, institutions and practices that enable PPP adoption and success must be developed over time through a long-term reflexive approach: lessons learned must be used to update PPP policies (Matos-Castano et al., 2014). To aid practitioners, this research, thus provides a thorough examination of some of the first water sector PPPs in California. Exploration of PPP impacts, project challenges, and lessons learned can reduce barriers of adoption and transaction costs of future PPP initiatives within the state. The next chapter presents the methodology for data collection and analysis.

3.0 METHODS

The primary purpose of this research is to examine the role of PPPs in bolstering resilience and sustainability in California's water sector. PPPs are a recent phenomenon in California's water sector (Douglas & Sykes, 2013). Previous empirical work on California's water PPPs has focused on individual cases (see Douglas & Sykes, 2013; Hewes & Randolph, 2018; Ocasio, 2015). This qualitative study compares 10 water sector public-private partnerships to explore factors that enabled partnership formation and PPP development, project impacts, allocation of risks between partners, challenges encountered by partners throughout the project life-time, and best practices of PPPs. The study utilizes a modified grounded theory approach. While a literature review guided the development of an interview guide, coding was inductive. This approach allowed the researcher to identify common themes across cases that may be unique to California's regulatory and socio-technical environment, as well as to situate these findings in the past international experience of water PPPs.

This research draws on three broader theoretical frameworks to contextualize the findings. Exogenous and endogenous pressures and challenges of adopting PPPs are situated within a broad framework of new institutionalism. To ensure that the evaluation of PPP impacts is theoretically-oriented and robust (Jeffares, Sullivan, Bovaird, 2009; Skelcher & Sullivan, 2008), this research will examine both outputs[11] and outcomes[12] of PPP projects in relation to social-ecological resilience (see Eriksson, et al., 2014; Folk, 2006; Rodina, 2019) and holistic sustainability (see Berrone et al., 2019; Pinz et al., 2017). Figure 3.1 shows the similarities and

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[11] Outputs are the direct quantifiable project goals (Jeffares, Sullivan, & Bovaird 2009) agreed upon by both public and private partners (Meng et al. 2011). An output-based evaluation of success for PPPs will typically emphasize whether the project is completed within agreed-upon scope, time, cost, quality, resource, and risk constraints, with most evaluation encompassing economic outputs of the project (Silvius & Schipper 2012).

[12] Outcomes are factors – qualitative or quantitative – that indirectly emerge as a result of the project (Jeffares et al., 2009). These factors may include greater citizen participation in future projects, increased governance capacity, or institutionalization of sustainability objectives within future decision-making processes.

differences between the two theoretical concepts, as identified in an extensive literature review of water governance and management literature. Holistic sustainability is achieved when projects meet all three pillars of sustainability: economic efficiency, ecological well-being, and social justice (public inclusion and minimizing distributional impacts). Holistic sustainability evaluations also account for tradeoffs that can emerge between the three dimensions (Pinz et al., 2017). Under an SES resilience framework, the research examines how PPP projects (1) impact the adaptive capacity of the water stakeholders and (2) the social-ecological system's ability to withstand shocks, anticipate stressors, and to adapt or transform in the face of changing conditions.

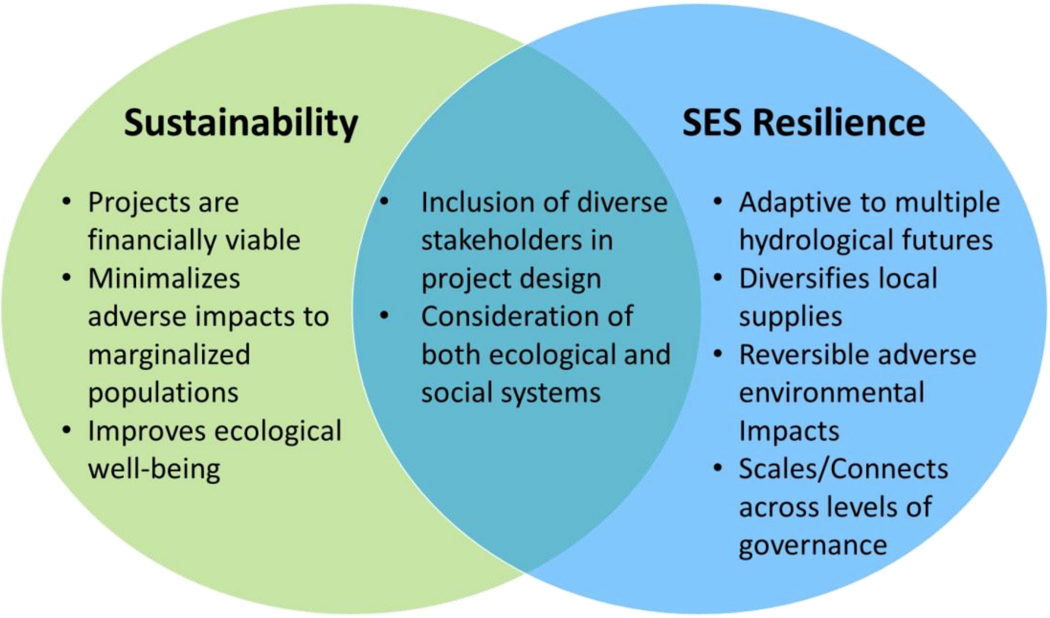

Figure 3.1 Similarities and differences between holistic sustainability and SES resilience in the water sector

Understanding mechanisms that might lead to tradeoffs between the three dimensions of sustainability as well as best practices of PPPs required tracing the process of project design, contract negotiation, implementation, and operation and management. Process tracing accounted for both endogenous and exogenous project factors. Infrastructure projects are highly complex

(Gerrits & Verweij, 2018): each project faces unique combinations of socio-physical constraints such as hydrological conditions, stakeholder preferences, institutional structures, available technologies (Gerrits & Verweij, 2018; Spraul & Thaler, 2019) and is embedded in networks of internal and external actors (De Schepper et al., 2014, cited in Gerrits & Verweij, 2018). This research, therefore, accounted for the legal, hydrological, geological, economic context of the project as well as the diverse values, interests and goals of actors and affected stakeholders (Gerrits & Verweij, 2018).

To evaluate the impact of PPPs on SES resilience and holistic sustainability, this study collected qualitative and quantitative data (when available) for the following indicators:

- Cost overruns or agreed upon changes to original project cost (in millions $)
- Changes to average monthly water rates (in $ and as a % change)
- Changes to ecological system function and its reversibility (e.g. health and function of habitats, biodiversity changes, aquifer water levels; stormwater & run-off management; water quality)
- Opportunities for civil society participation and “voice” throughout the project lifetime, including legal action enacted against projects
- Changes to resource efficiency (e.g. water reclamation and re-use, reduction of water loss; energy efficiency)
- Development of new local supplies (in Acre Feet/Year)

Projects were considered failed – and maladaptive - projects when they 1) result in irreversible environmental impacts that create additional vulnerabilities to human systems, 2) do not align with a community’s ability to pay for water supplies and will not achieve a return on investment without significant public sector intervention, 3) when the agreement is terminated prior to the end of the contract period, or 4) when the community lacks the technical or financial capacity to sustain operate and maintain the facility after the private partner exits the contract. It is important to note that the PPPs featured in this study are still in the early contract phases. Therefore, the success/failure of the project will not be fully known until the end of contract lifetime. However, presently, none of the 10 cases (see Table 3.1 below) featured in this research meet the criteria for failed projects.

3.1 Case Selection

Case selection was purposive and included three considerations:

1. Mechanisms that determine project success can vary based on the resource or service provided (Phua, 2004). Therefore, all cases must be related to the management or the provision of water.
2. Partners must be publicly recognized as PPPs and must include sustainability or resilience of water systems project or organization goals. Sustainability or resilience goals can include improving resource efficiency (e.g. reduction of water loss, reclamation and re-use of water, and targeting linkages in the water-energy-climate nexus), improving water quality; or strengthening the water system's ability to withstand natural or anthropogenic stressors.
3. Cases should control for as many exogenous factors as possible: case sites must be located within the same regulatory context (at the state and federal level) and are exposed to similar climate conditions.

Utilizing these criteria, seven infrastructure PPPs and three data-focused across Southern California were selected (see Table 3.1 for an overview of project partners, description, start date, and year in which commercial operation begins). Data-focused PPPs are projects that utilize private partners to develop algorithms and models that assist districts in water management or decision-making. As PPPs can be formal or informal collaborations (Lebeck, 2018), an omission of data-focused PPP arrangements would yield an incomplete picture of the types of roles PPP can play in future water management.

Table 3.1 Descriptions of Case Sites. Partners in green are public agencies, organizations in blue are private companies, and partners listed in purple are non-governmental organization.

Project Name	**Project Partners**	**Project Start**	**Year Operational**	**Project Description**
Gobernadora Multi-Purpose Basin (GMB)	(1) Santa Margarita Water District (SMWD) (2) County of Orange (3) Rancho Mission Viejo	1999	2015	A joint use project that includes a storm detention basin, a natural treatment system, an open wetland habitat restoration project, and a groundwater recovery and recharge system. A side weir with two inflatable rubber dams allows for automatic stream flow management and the capture of dry weather runoff. Ownership of the GMB is split between SMWD and the County of Orange.
Lake Mission Viejo Advanced Water Treatment Facility (LMV AWTF)	(1) SMWD (2) Lake Mission Viejo Association (3) City of Mission Viejo	2015	2016	Construction and operation of a reverse-osmosis water treatment facility that provides 600 AFY of water to Lake Mission Viejo and 300 AFY to the city of Mission Viejo for outdoor use. As a result of the PPP, the lake is the first recreational lake to be exclusively filled with recycled water rather than potable water.
Energy Storage Project (ESP)	(1) Irvine Ranch Water District (IRWD) (2) Advanced Microgrid Solutions (AMS)	2015	2018	Installation of six 50 MW battery storage systems across IRWD properties to offset electric grid stress during peak energy hours and to reduce the cost of electricity. Batteries have a 6 hour capacity and store 3,750 KW/20,700 kWH (IRWD-DRES Portfolio, 2018). Batteries charge from the grid during off peak hours (from 6:00 PM until 9:00 AM) or from non-grid sources and are discharged during on-peak hours. Per the 10 year contract, AMS developed the project and operates the battery system. At the time of data collection, the project was the largest behind-the-meter storage system in the US.
Rialto Infrastructure Upgrade	(1) City of Rialto (2) Veolia (3) Table Rock (4) Ulico	2012	2012	Thirty year- concession agreement that establishes a joint venture called Rialto Water Services to provide water and wastewater structure improvements and operate all facilities. Private partners provided a total of $177 million in capital investment, with $41 million for 24 water and wastewater capital improvement projects, $43 million for operational funding, $27 million to refinance city debt, and $30 million for catch up lease payment by the Rialto Utility Authority

Cadiz Valley Water Conservation, Recovery and Storage Project	(1) SMWD (2) Fenner Valley Municipal Water Authority (3) Cadiz Inc.	1997	-- (Awaiting Permitting)	The project is composed of two parts: (1) pumping and "recovery" of 50,000 AFY of groundwater that "would otherwise become saline and evaporate" and (2) the construction of one million AF of groundwater storage to percolate imported water into the aquifer system (Cadiz, 2019).
Carlsbad Desalination Plant	(1) San Diego County Water Authority (SDCWA) (2) Poseidon Resources LLC	1998	2015	A reverse osmosis ocean desalination plant that provides SDCWA with 48,000 to 56,000 AFY for 30 years. The plant is the largest desalination project on the west coast and is the first voluntary carbon neutral infrastructure project in the state. At the end of the contract period, SDCWA has the option but not obligation to purchase the facility for $1.
Huntington Beach (HB) Desalination Plant	(1) Orange County Water District (OCWD) (2) Poseidon Resources LLC	1998	-- (Awaiting Permitting)	A reverse osmosis seawater desalination plant that will provide OCWD with 56,000 AFY per year for 30 years. Like its sister plant, the Carlsbad Desalination Project, the plant will be carbon neutral. At the end of the contract period, OCWD has the option but not obligation to purchase the facility for $1.
DataKind Project	(1) Moulton Niguel Water District (MNWD) (2) DataKind	2015	2015 (Project Completed)	Development and implementation of a machine-based learning model to forecast daily recycled water demand. The model assisted in determining the necessary storage capacity for recycled water. According to interview respondents, this is the first time a machine learning approach has been utilized to manage water services at a public water district.
Two Sigma Data Clinic Project	(1) MNWD (2) 2 Sigma	2016	-- (Model Refinement)	Development and implementation of a model that utilizes MNWD's hourly Advanced Metering Infrastructure data to identify faulty water meters.
Urban Runoff Project	(1) MNWD (2) County of Orange (3) cities of Laguna Niguel, Laguna Hills, Aliso Viejo, and Mission Viejo (4) OC Coastkeeper (5) Laguna Bluebelt Coalition	2016	-- (Data Collection Phase)	Management of urban runoff in the Aliso Creek Watershed through (i) targeted demand management campaigns, (ii) development of public education and outreach tools, and (iii) treatment and reclamation of dry weather run-off. Within the PPP, MNWD and the County of Orange have collaborated on two projects, the Urban Drool Tool and the Smart Watershed Network Project, which combine urban runoff data with hourly Advanced Metering Infrastructure data to manage dryweather runoff.

The focus of the research is on projects under the jurisdiction of six public water agencies: Orange County Water District (OCWD), San Diego County Water Authority (SDCWA), Irvine Ranch Water District (IRWD), Santa Margarita Water District (SMWD), Moulton Niguel Water District (MNWD), and the City of Rialto (Rialto). These water utilities occupy different roles in water provision. Wholesale water districts are large-scale water districts that secure water sources and sell the water in bulk to their retailers, or cities/city-level public water utilities that provide water directly to water users. Figure 3.2 shows the relationships between the wholesalers (OCWD, SDCWA) and retailers (IRWD, MNWD, SMWD, and Rialto) featured in this research. Metropolitan Water District (MWD), the wholesaler for Southern California, imports water from the Colorado River Aqueduct and the State Water Project and distributes it to 26 member agencies, including county-level wholesalers such as the Municipal Water district of Orange County (MWDOC), SDCWA, and San Bernardino County Valley Municipal Water Authority. Orange County also has a second county-level wholesaler, OCWD, which manages the groundwater supply basin in northern Orange County. Along with conducting independent projects to manage the groundwater basin, OCWD partners with MWDOC to recharge groundwater through a combination of recycled and imported water (MWDOC, n.d.). Approximately 50% of all of Orange County's water supplies are imported (MWDOC, 2017). Retailers, county-level wholesalers, and MWD also have access to locally developed supplies such as water recycling and re-use, surface and groundwater storage, and water transfers. For example, SDCWA also imports water through the Imperial Irrigation District Water Transfer and the All-American & Coachella Canal (SDCWA, 2014).

Figure 3.2 shows **the relationship between retailers, county-level wholesalers, and the regional wholesaler** (Metropolitan Water District). Apart from OCWD and its interactions with MWDOC and IRWD, the figure does not show alternative water sources (groundwater, recycled water, etc.) and how these are shared between utilities participating in the study.

The retail and wholesale water utilities included in this research vary in population served, available funding, technical capacity, district culture, and the degree of reliance on imported water supplies (see Table 3.2). These socio-technical differences impact the type of water management strategy of technology implemented by project partners. Projects included in the research focus on reclamation or re-use of water, demand management, potable water provision, and increased resource efficiency. Due to the differences in population served, projects also vary in terms of scale. While IRWD, Rialto, MNWD, and SMWD pursued predominantly local-level water PPP projects, both OCWD and SDCWA participated in PPP projects that would provide regional-level water provision.

Water Utility	**Year**	**Population Served**	**% of water imported**	**% of recycled water used to meet total water demand**
Irvine Ranch Water District (IRWD)	2017	380,000	27%	25%
Santa Margarita Water District (SMWD)	2014	165,000	100% of potable water	17%
Moulton Niguel Water District (MNWD)	2016	170,000	100% of potable water	25%
San Diego County Water Authority (SDCWA)	2014	3,340,594	76%	4%
Orange County Water District (OCWD)	2019	2,500,000	30.1%	69.9%
City of Rialto	2011	100,000	36.8%	Unknown

Table 3.2 Sources of water for districts featured in case studies prior to implementation of their first PPP (commercial operation of facilities or implementation of algorithms). Apart from OCWD, water utilities featured in this research predominantly utilize recycled water to meet non-potable uses such as irrigation. (City of Rialto, 2011; IRWD, n.d.; MNWD; n.d.-b; MWDOC, n.d.; SMWD, 2014, n.d.-a; SDCWA, 2014)

A third difference between cases featured in this study is project and contract length. While some projects began in the late 1990s, others were launched as early as 2016. Moreover, some projects have reached commercial operation, while others – such as Cadiz or the Huntington Beach desalination plant – are still securing permits. Inclusion of projects with a wide range of time-scales and project types enabled a more generalizable examination of critical barriers to PPP adoption and best practices of PPPs in California.

3.2 Data Collection and Analysis

This qualitative project utilizes semi-structured interviews, observations, shadowing, and analysis of primary and secondary documents to examine impacts and processes of public-private partnership projects in Southern California.

Interviews

Twenty-seven semi-structured interviews were conducted with twenty-one respondents from seven public agencies, three non-governmental organizations, and four private companies.

Table 3.3 shows the distribution of respondents between public, private, and NGO entities. Total interview time was 26 hours and 42 minutes, with an average length of 65 minutes per interview. Respondents included staff from partnering organizations who were involved in partnership formation, design, implementation, operation and management, and/or project oversight. Participants often had overlapping roles, and therefore, could speak about multiple stages of the project timeline. Respondents were identified through publicly available information on projects or from snowballing[13].

Type	Number of Respondents	Number of Interviews
Public Agency	12	19
Non-governmental Organization	4	4
Private Company	5	5
Total	**21**	**27**

Table 3.3 Distribution of respondents by organization type. Due to respondent's involvement in multiple projects, some respondents were interviewed more than once.

Interviews were conducted by phone or at the participant's place of work. Signed consent was obtained prior to the start of each interview. With the permission of participants, interviews were recorded using a recording device and were transcribed through Rev and Temi transcription services. A sample interview guide is included in the appendix. Each interview guide asked respondents to define a public-private partnership and describe a) each step of the project, including challenges encountered along the way, b) the distribution of obligations and risks between partners, c) the benefits and drawbacks of the project to the participating partners and the community the project serves, d) opportunities for stakeholder input and engagement, e) lessons learned by all participating actors, and f) pressing water challenges within their district and in the state of California. Interview guides were tailored to the role of respondents. For

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[13] The snowballing recruitment strategy aligned with IRB stipulations for the project. Interview respondents or points of contact at case sites would reach out to potential participants and request permission to share contact information and/or provide a virtual introduction. Once permission was granted to share contact information, the researcher would recruit applicants via email or phone.

example, respondents that were responsible for project design were asked questions in-depth on design considerations, partner goals, and the type of input that they received from project partners. To ensure anonymity, this dissertation does not include information on respondent's positions or affiliated organization[14].

Interviews provided an opportunity to gain a detailed account of each step throughout the project lifetime; the perspective of respondents particularly valuable in regards to the early stages of project development, as information on partnership formation and early partner motivations for entering PPPs was often absent from archival data. Additionally, interviews allow the researcher to understand how and why anticipated inputs, outputs and outcomes shifted throughout the project lifetime, created a more robust narrative during process tracing. Finally, interviews allowed for a deeper understanding of what respondents referred to the "human element" in projects – respondents described in detail collaborative governance strategies and how the roles and values of specific individuals hindered or enabled project and partnership development.

Three challenges emerged during the interview process. First, the recruitment process revealed that a smaller many of the projects are in the study began in the late 1990s. This long time horizon can reduce reliability of narratives surrounding the early stages of the project (Adams & Cox, 2008; Gerrits & Verweij, 2018). Points of contact at participating agencies have cycled out, making it challenging to recruit participants from each participating agency. Moreover, participants who were able to speak to the early stages of the project were recounting

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[14] Fieldwork revealed that members of participating public organizations would overlap through regional programming efforts (e.g. Joint Powers Authority Meetings, South Orange County Integrated Regional Water Management) and through networking events such as conferences. As such, respondents were familiar with the activities of other agencies within Southern California and the individuals who are spearheading these efforts. Including the titles of participants or even their affiliated districts would make it too easy for members from water district to recognize respondents.

information passed along to them by their predecessors or had difficulty remembering specific details regarding partnership formation and early informal discussions surrounding the projects. Secondly, information regarding revenue and contract negotiations can be proprietary (see Pessoa 2010; Valente 2010). At two of the cases, interview participants were restricted at speaking about impacts of the project due to non-disclosure agreements. Finally, respondents were cognizant that the perceived success of the project and the participating actors can influence future revenue streams or grant opportunities. Thus, interview respondents were hesitant to reveal information that would threaten partner rapport or the reputations of public and private partners. This research has also these limitations through the triangulation of data through observations, shadowing, and document analysis.

Observations

Five non-participant observation windows totaling 14 hours and 4 minutes were conducted to triangulate project processes, anticipated and realized outputs and outcomes, and the receptivity of projects by water stakeholders within Southern California. At all observation sites, the primary focus of jotting and field notes was of capturing the dialogue between participants in both formal (i.e. presentations) and informal (i.e. conversations during breaks between structured activities) settings.

Water infrastructure projects require a number of supportive actors and agencies to participate in technical support of project design, contract negotiation, permitting, monitoring of impacts, and implementation support. Therefore, throughout all observation windows, attention was paid to the professional background and project role of individuals included in observation events.

Two observations were conference symposiums composed of panel presentations and networking opportunities. The events were focused on identifying solutions to water supply and quality challenges in California. These events provided a unique opportunity to gain access to a diverse set of perspectives in a short period of time. Participants included members of water districts with varying levels of leadership and levels of public accountability (water district board members, general managers, and technical staff). The conference symposiums also featured individuals from private industries from agriculture, IT, and engineering sectors. Observation of these conferences allowed the researcher to observe how public and private actors communicate information on impacts and best practices of the PPP projects to other stakeholders in the water sector.

Two observations were kick-off meetings for one infrastructure and one data-focused project. These observations revealed concerns of public water managers in entering PPPs as well as the anticipated impacts of projects currently in development. The observations also provided opportunities to explore best practices of partnership formation and development: while interview participants discussed the process of joint goal development, observations windows allowed the researcher to see first-hand how participants established norms and expectations for collaboration, understood the interests and limitations of their partners, and divided roles and responsibilities.

The final observation event was an online meeting of public officials and board director members in Southern Orange County. During the meeting, project participants presented a public-facing tool developed by public and private project participants. The meeting provided an opportunity to observe how key stakeholders in the water sector responded to the use of data collaborative and Big Data methods. Special attention was paid to the tone of research participants and the types of questions and concerns raised by respondents. This opportunity was critical in providing additional context on factors that will impact uptake of data collaboratives in the water sector.

Shadowing

The total time for shadowing was 4 hours and 50 minutes. Tours were conducted at four of the seven infrastructure PPPs: the Energy Storage Project, the Gobernadora Multi-Purpose Basin, the Lake Mission Viejo Advance Water Treatment Facility, and the Carlsbad Desalination Facility. Shadowing allowed the researcher to collect data on day-to-day operation and management of the facilities, as well as uncover changes between the initial and final project design. Moreover, tours also presented a unique opportunity to observe how project information is communicated to individuals who are interested in replicating the project. Research participants conducting the tours were those that have previously led tours for media reporters, members of other water agencies, members of the public, or other researchers. At one of the shadowing opportunities, the researcher conducted the tour alongside 15 members of NGOs and representatives from other water districts. With the permission of research participants, photos of project facilities were taken at each site.

Document Analysis

Primary documents included preliminary and final design reports, implementation agreements, design schematics, MOUs, meeting minutes and videos from water board meetings, memos between participating actors, and state grant funding applications. Secondary documents included newspaper reports, academic articles, white papers, utility public outreach information, and features that spotlighted the projects on water-related websites. Differences across primary documents (i.e. changes between the MOU and the Implementation Agreement) allowed the researcher to examine how partner responsibilities and project goals evolved over time. Websites of water districts as well as external actors (state regulatory agencies providing grant funding, sub-contractors involved in various stages of the project lifecycle) provided additional information on the project timeline, actor roles, and economic impacts of projects. Finally, media articles and op-eds by oppositional groups were used to gauge public perception and user opinion, and thus, serve as a proxy for the social legitimacy of project (see Harris-Lovett, Binz, Delak, Kiparsky, & Truffer, 2015).

Coding and Data Analysis

As the research is exploratory in nature, coding of interviews, field notes, and documents utilized a grounded theory approach (see Gerrits & Verweij, 2008; Charmaz, 2003; Glaser & Straus, 2017). The first round of coding was conducted by hand. Line-by-line inductive coding was accompanied by memos to assist in creating categories. Subsequent rounds of coding were more focused: the researcher utilized Nvivo to assign codes that appeared across multiple sources of data and to group these codes into themes. Coding was conducted while data collection was ongoing, and additional questions were included in the interview guide to hone in on themes (see Charmaz, 2003).

4.0 CHALLENGES and PROPOSED SOLUTIONS in the WATER SECTOR

> *We have nineteenth century laws governing twentieth century infrastructure while facing twenty-first century challenges."*
>
> \- Head of a state regulatory agency (Observation, 8/29/19)

California's climate is highly variable, seasonally and geographically (Mount et al., 2018). Annual precipitation in the state ranges from 100 million acre-feet (MAF) to 250 MAF (CNRA, 2020). Most precipitation occurs during the winter months, with more than half of precipitation occurring between December and March (Hanak et al., 2011). Precipitation is also unevenly distributed across regions, with the southeast desert portion receiving less than 5 inches of rain while northern California can receive 50 to 100 inches per year (CA DWR, n.d.). The state also experiences cyclical periods of dry and wet years due to the El Nino/La Nina phenomena (Hundley, 2001). As a result of this variability, droughts and floods are natural to California's hydrology (CNRA et al., 2020; Stevens & Chong, n.d.). Over the past 160 years, the state's water management system has evolved to cope with this variability in seasonal and annual precipitation through the development of large-scale water conveyance systems, reservoirs, and water grids (CNRA et al., 2020; Hanak et al., 2011; Lund et al., 2018). However, in recent years, the infrastructure and institutions developed in the twentieth century have been unable to cope with large-scale, complex stressors - such as climate change - that cross political jurisdictions and watershed boundaries (Hanak et al., 2011; Mount et al., 2018; Pincetl & Hogue, 2015).

This chapter combines a literature review, document analysis, and fieldwork data to ***1) highlight pressing socio-technical challenges water districts in Southern California, 2) identifies proposed solutions to these challenges, and 3) examines factors that limit the ability of local water utilities to make the necessary infrastructure and governance reforms***. This chapter serves multiple purposes. First, it highlights the broader technical, regulatory, and socio-economic, and hydrologic context in which project participants developed and implemented PPP projects. This chapter also contributes to the rising literature on new institutionalism (see Schmidt, 2008, 2009, 2010) by illustrating how exogenous stressors shape sustainability and resilience narratives and how these discourses can legitimize the uptake of new practices, technologies, and partnerships.

4.1 A Brief History of California's Present Day Water System

The development of California's socio-technical water system was a highly contentious and controversial process, with private and public entities grappling for control of critical water resources since the late eighteenth century (Erie, 2006; Hundley, 2001). Three main drivers critically shaped the present-day infrastructure and institutions in California's water sector. First, the discovery of gold (1848) led to an influx of settlers, increasing the population from 160,000 to 1.5 million between 1848 and 1900 (Hanak et al., 2011). The Gold Rush represents the first period of large-scale water diversion and use to support hydraulic mining practices. The period also represents the first public – rather than private – management and provision of water resources. Increased runoff and flooding from hydraulic mining highlighted the need for a coordinated government response (Hanak et al., 2011). Therefore, in 1868, California legislature authorized the creation of local reclamation districts to fund and manage flood control projects. Early flood management proved ineffective, as each retail district constructed levees that impacted the water management of neighboring communities. Thus, these early efforts of flood management led to the recognition that greater coordination in water management was needed. The ineffective local responses also prompted the first intervention by the federal government in water management: the U.S. Army Corps of Engineers developed a large-scale flooding management plan in the Sacramento valley in the 1880-1890s.

Another key driver in the development of California's water management system was the rise of agriculture. As the population expanded and urban centers began to develop, there was a strong push by local governments to expand irrigation systems (Hanak et al., 2011). Local jurisdiction of water was strengthened through the Wright Act (1887), which allowed irrigation districts with the authority to acquire water rights, construct projects, sell bonds, and demand property assessments (Hanak et al. 2011; Hundley, 2001). The act ultimately laid the foundation for the present-day decentralized water system in the state.

The most significant growth of the system took place during the Hydraulic Era (1900-1960), a time period dominated by large regional, interregional and state-level water supply projects. During this time period, three state-wide projects were developed the Central Valley Project, the California State Water Project, and the Colorado River Aqueduct (see Fig 4.1). These projects were driven local technocratic interests, who were able to effectively lobby the state and federal congress for funding support for hydroelectric and water supply projects (Hanak et al., 2011; Hundley, 2001, 2006). The most prominent actors were city leaders within Los Angeles and San Francisco. Recognizing that securing water supplies was instrumental to promote economic growth of the city, technocratic elite within both cities launched aggressive measures to acquire water from near and distant sources (Feldman, 2018).

In the 1880s, Los Angeles sued neighboring cities and private groundwater users, arguing that the city's pueblo rights granted it super rights to the Los Angeles River (Hundley, 2001). The city also annexed nearby regions to gain control of additional water sources, nearly doubling the population. Realizing that the Los Angeles River was not sufficient in supporting the city at its current growth rate, Fred Eaton (Mayor of Los Angeles) and William Mulholland (superintendent of the Los Angeles Water Company) sets their sights north. Through secretive

Federal, state, and local governments have built separate systems of dams, reservoirs, and conveyance facilities to move water to cities and farms and provide flood protection. This map shows the largest such facilities.

Figure 4.1 Major reservoir and conveyance facilities in California (CNRA et al., 2020). More than 1,300 reservoirs have been built across the state to manage variable precipitation, with the largest constructed decades ago to collect snowmelt from the Cascade and Sierra Mountain ranges.

and nontransparent means, the two acquired the riparian and land water rights to the Owens River Valley (Erie, 2006) and then persuaded the general public to authorize $25 million dollars in bonds to fund the Owens River Valley Aqueduct (Hundley, 2001). The additional supply of water enabled further population growth; between 1900 and 1920 the city's population grew from 100,000 to 500,000 (Hank et al., 2011). As the city grew, so did its demands for water and electricity. Thus, Mulholland convinced key decision-makers in Los Angeles and in surrounding cities to develop a regional water strategy (Hundley, 2001). California legislature approved the MET Act in 1928, bringing together Los Angeles and 12 other cities as founding members for the Metropolitan Water District (MWD) (Zetland, 2009). The MET Act also granted provisional approval for the CO River Aqueduct. Constructed in 1941, the CO River Aqueduct has the capacity to transport 1.3 Million AFY from Colorado Southern California. To recover costs of the aqueduct, MWD rapidly annexed regions into its service area, growing from 900 to 4,900 square miles of coverage between 1941 and 1946. In 1963, the *Arizona vs. California* Supreme Court Case reduced allocations of the CO River 1.2 MAF to 0.55 MAF, forcing MWD to seek out additional water sources. Thus, MWD also began importing water from the North using the State Water Project in 1972.

Through the CO River Aqueduct and the State Water Project, MWD provides water to 19 million people across 26 member agencies within Southern California (MWD, n.d.). However, scholars and practitioners have expressed concerns that the present-day water system and its supporting institutions are unsustainable, and cannot withstand largescale stressors such as climate change (Hanak et al., 2011; Hundley, 2001; Mount et al., 2018; Zetland, 2009). The next section, therefore, examines threats to water supply in MWD's service area.

4.2 Threats to Water Supply

The present-day water systems face a number of threats to water supply and quality, including climate change, natural disasters, ageing infrastructure, and emerging contaminants of concern. At the same time, the population is expected to dramatically increase, placing additional demand and strain on water sources. Between 2016 and 2060, California's population is projected to increase from 39.4 million to 51.1 million (Shaheen, Totte, & Stocker, 2018). This section examines the primary threats to water security in Southern California. Special emphasis is given to the local hydrological conditions and challenges of regions in which case sites are located: Orange County, San Diego County, and San Bernardino County.

Climate Change, Regulatory Constraints, and Uncertainty

Climate change will stress water systems by shifting precipitation patterns, increasing the rate of evapotranspiration, and resulting in more extreme weather events (CNRA et al., 2016, 2020; Mount et al., 2018; MNWD, 2015; Pincetl & Hogue, 2015; SMWD, 2015). As temperatures increase, the state will face higher climatic variability, with droughts becoming more intense and frequent (Diffenbaugh, Swain, & Tourma, 2015). Precipitation patterns will shift to a greater proportion of rain rather than snow (Pincetl & Hogue, 2015). The Sierra Snowpack, which provides 30% of the state's water needs, is expected to decrease 60 to 85% by the end of the century (Berg & Hall, 2017). "That's all going to become rain, and that's ***not*** [emphasized by participant] what we built our infrastructure for. We can only capture a fraction of our rainwater with the current storage infrastructure" (Observation, 8/29/19; see also Mount et al., 2018; Pincetl & Hogue, 2015). Volatility has created uncertainty in future water conditions and has made it difficult for water managers to plan for future water conditions (#4; #10; #11-#13; #15; #16; #21; Baehler & Biddle, 2018).

The impacts of drought depend on hydrological factors and a region's economic, infrastructure, and institutional conditions (Lund, Medellin-Azuara, Durand, & Stone, 2018). Drought can exacerbate inequalities and vulnerabilities in water access, creating "winners and losers" (Pincetl & Hogue, 2015). Rural communities are particularly vulnerable to drought conditions, as they are reliant on groundwater and are often isolated from large-scale systems (Mount et al., 2018). Rural communities may also lack the resources to address water supply and quality problems (#11; Observation, 3/15/2019; CNRA et al., 2020; Mount et al., 2018; Pincetl & Hogue, 2015).

The droughts of 1976-1977 and 1987-1992 prompted utilities to diversify water resources through the development of surface and underground storage, recycled water systems, transfer agreements, and demand management programs (Lund et al., 2018; Mitchell et al., 2017). However, the state- and local-level water management systems were still not prepared for the effects of the most recent drought (2012- 2016). California experienced its driest four-year period in the instrumental record from October 2011 to September 2015 (Stevens & Chong, n.d.). For the southern Central Valley and the South Coast, this was the worst dry spell in almost 450 years. By January, 2014 over 60% of California was experiencing extreme drought (see Figure 4.2) and by August 2014, most of the state's reservoirs were below 50% of their total capacity (Stevens & Chong, n.d.). The drought reduced deliveries of imported water from local, regional, and federal projects. To maintain reliable water supplies, groundwater supplied nearly 60% of all water used by cities and farms (see Figure 4.3). More than 150 communities faced shortages of water and more than 2,500 wells went dry, requiring emergency aid for replacement water from the state (Mount et al., 2018). In response to the rising conditions of water scarcity, Governor Jerry Brown declared a statewide emergency on January 17, 2014, requiring

Californians to reduce their water use by 20% (Stevens & Chong, n.d.). While California water districts were able to reduce water usage by roughly 24.5% relative to the 2013 baseline (Spang, Holguin, & Lodge 2018), the economic[15] and environmental impacts of this may endure for decades (Lund et al., 2018).

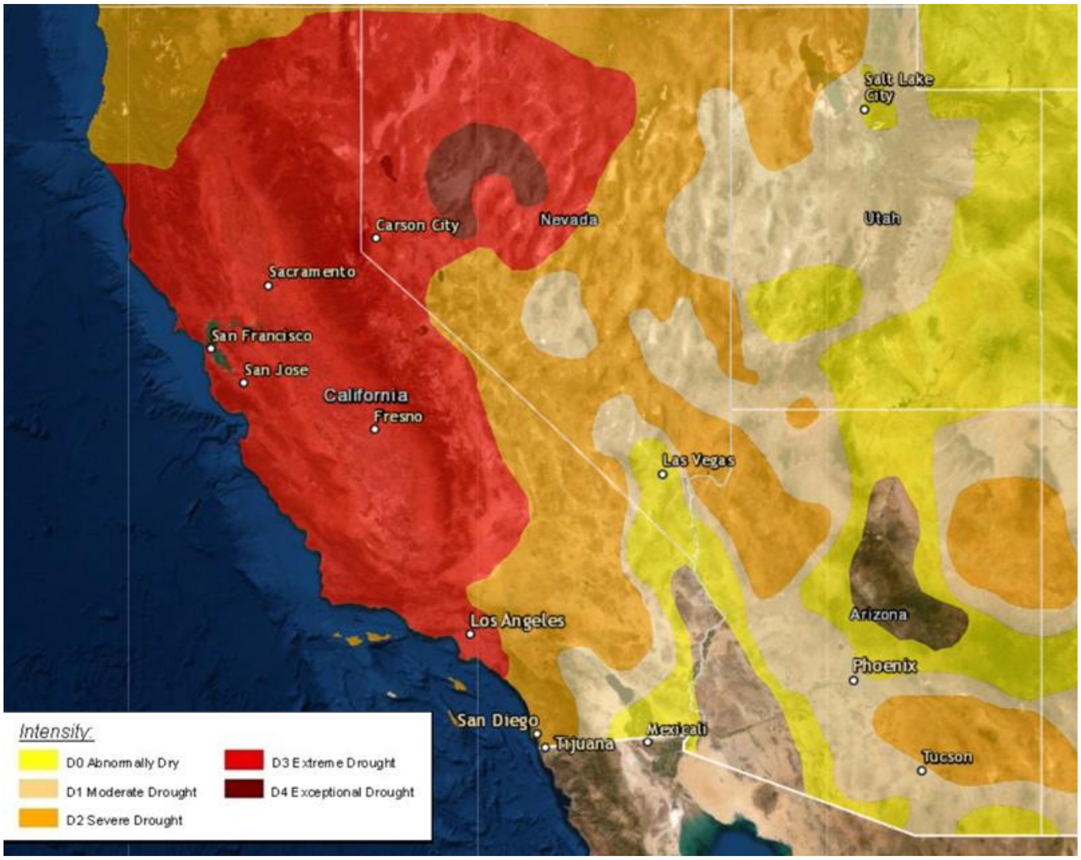

Figure 4.2. Proportion of California and the southwestern United States experiencing drought in January 2014 (U.S. Drought Monitor, cited by Stevens & Chong, n.d.)

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[15] Due to current water pricing systems, rapid and sudden conservation efforts can significantly reduce revenue for water districts. For instance, the Sacramento region saved approximately 53,000 million gallons between June 2015 and May 2016(Talbot, 2019). The region lost an estimated $25 million in revenues (a 12% drop) from reduced water sales from January through September 2015 (RWA, 2015, cited in Talbot, 2019). Total statewide revenue loss during the recent drought is estimated to be more than $3 billion (ACWA, 2016, cited in Talbot 2019)

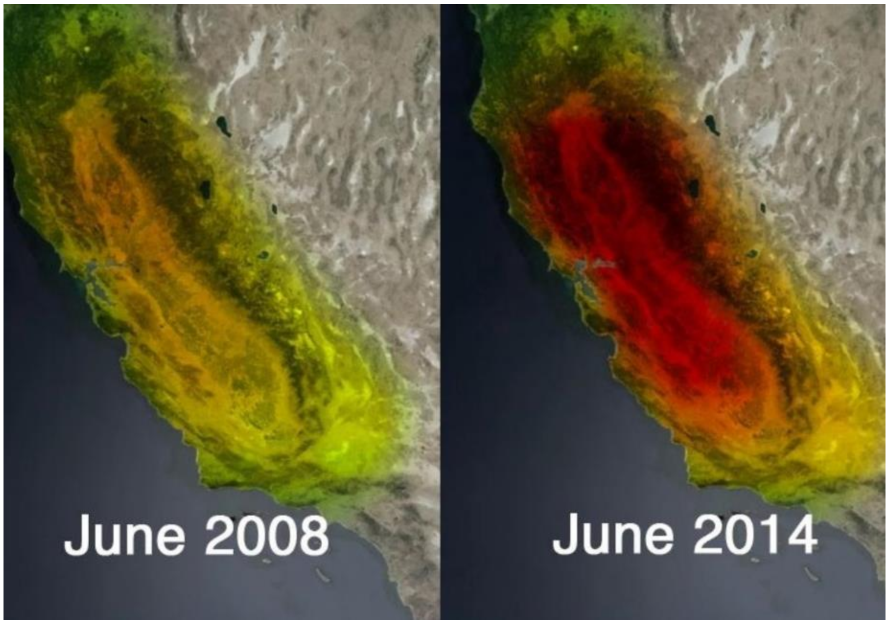

Figure 4.3. Satellite image showing the availability of groundwater supplies prior to and after the drought. (NASA, cited in Stevens & Chong, n.d.)

The state and local response to the most recent drought raises questions of future direction of water management (Mitchell et al., 2017). Governor Brown's Conservation Mandate marks an unprecedented intervention in local water demand management. The top-down approach was criticized by stakeholders for a lack of sensitivity to local conditions (#1-#4; #9; #10; #16; Observation, 8/29/19; Mitchell et al., 2017), as targets imposed by the State Water Board failed to take into account current local supplies such as groundwater systems, desalination plants, and banked surface water (#16; Mitchell et al., 2017). The State Water Board received more than 200 comments on the draft emergency regulation. Fieldwork revealed that water utilities are concerned that future top-down solutions and water use efficiency standards will curtail available supply and impact revenue streams (#11; #15; #16; #18; Observation, 8/30/2019). "It's hard to plan what your revenue program would be when you don't know how much of your product you're going to be selling in the future" (#18). Future management of droughts requires greater coordination between state and local agencies in building resilient and sustainable water use and stronger consideration of the socio-technical context (Dilling et al., 2019; Mitchell et al., 2017).

Natural Disasters

California’s water system also faces the risk of interruption due to natural disasters such as floods and earthquakes (Davis & Shamma, 2019). Three large-scale aqueducts provide roughly 50% of water needs of the 19 million people residing in Southern California (Davis & Shamma, 2019). All three aqueducts cross the San Andreas Fault. The likelihood of an earthquake of a magnitude of 6.7 or more occurring in Southern California over the next 30 years is 93% (Field et al., 2015). If an aqueduct is damaged, restoration of imported water provision would require six to eighteen months (Davis & O’Rourke, 2011; Davis & Shamma, 2019). As businesses are highly dependent on water use, the cost of interrupted imported water provision is estimated to be $53 billion and has the potential to drive the region into a recession (Jones et al., 2008).

Interrupted imported water services pose as a substantial risk to the population living in South Orange County (#11; #13; #18; Observation, 8/29/19; OCWD, n.d.). The region lacks a groundwater basin, and is therefore reliant on imported water “coming from 300 to 350 miles away” (#11) for 90% of its needs (OCWD, n.d.). Therefore, in the event of a natural disaster, South Orange County must be prepared to have sufficient water supply for a minimum of 60 days (an amount equivalent to 20 to 27.5 MGD). Yet, most storage options currently provide enough water for only 20 days (Observation, 8/29/19). An interruption of imported water provision for a substantial period of time will result in “significant economic and public health hardship. When you can't supply water, your economy is going to grind to a halt.” (#18). The economic loss of an 80% water outage for 60 days is estimated to be roughly $1.7 billion (Observation, 8/29/19).

Water Quality

Water quality within the state varies across regions (Chappelle & Hanak, 2015; CNRA et al., 2020) and is the result of both anthropogenic and natural processes. Annually, $10 billion is spent on control of point and non-point sources in the state of California (Chappelle & Hanak, 2015); however, a $500 to $800 million dollar funding gap remains to address contaminants from nonpoint sources. In interviews and observations, water quality concerns were central to discussions of current and future challenges in water provision (#11 - #13; #15; #16; Observation 8/30/2018, 3/15/2019. 8/29/2019; Shadowing, 12/18/2019).

Within the scope of this research, the city of Rialto and Orange County are the sites most acutely affected by pollution. Rialto suffers from groundwater contamination and has been declared a SuperFund Site. A series of industrial activities, dating back to 1942 has led to the leaching of perchlorate into the groundwater below the cities of Rialto and Colton. More than 40 companies are alleged to be involved in the contamination (Willon, 2013), which has forced the city to shut down city wells and import water. A state of emergency was declared by city officials in November, 2007 (Rosenblatt, 2007), with officials calling on state and local government intervention to assist in abatement. According to the declaration, “it is now beyond the city’s water department to continue to provide a safe, affordable and reliable water supply” (Rosenblatt, 2007, para 7). It was estimated that at least $20 million would be needed for cleanup efforts and legal fees for lawsuits, with total clean-up for the 160 acre site estimated to fall between $100 (Willon, 2013) and $300 million (Rosenblatt, 2007). The clean-up process is expected to take 30 or more years (Willon, 2013).

There is a rising concern among water districts and state regulators of per- and polyfluoroalkyl substances (PFAS) contamination of groundwater (#15; #16; Observation, 8/29/19). PFAS are man-made, heat-resistant substances that are used predominantly in industrial services (SWRCB, 2020a). PFAS contamination typically occurs near industrial sites, landfills, wastewater treatment plants, and fire training/fire response sites, and can contaminate surface and groundwater supplies. While more than 4,700 known PFAS chemical exists, the health effects and bioaccumulation properties of Pefluorooctanoic Acid (PFOA) and Perfluoroctane Sulfonate (PFOS) have been studied the most extensively (SWRCB, 2020b). Due to their ability to repel water, grease, and heat, PFOA and PFOS have been used in consumer products such as carpets, clothing, fabric for furniture, cookware, and packaging for food. While both contaminants were voluntarily phased out in the early 2000s, PFOA and PFOS are still found in soil, air, and water (EPA, 2017; SWRCB, 2020b). The contaminants pose as a large-scale public health challenges. PFAS has been detected in 97% to 100% of individuals tested (Lewis, Johns, & Meeker, 2015) and has been linked to cancer, high cholesterol, thyroid disease, reproductive and developmental health, immune system function (EPA, 2017; SWRCB, 2020b; Phillips & Pesce, 2019).

Currently, there is no enforced national or state-level threshold for PFAS contamination. The US EPA (2019) issued an interim groundwater screening level of 40 parts per trillion (ppt) in 2019. However, in 2020, the agency announced that it would not be regulating perchlorate levels under the Safe Drinking Water Act (EPA, 2020). The decision “fulfills President Trump’s promise to pare back burdensome ‘one size fits all’ overregulation for the American people” (EPA, 2020, para 2). Meanwhile, California’s State Water Resources Control Board (2020a) set new response levels of 10 ppt[16] for PFOA and 40 ppt for PFOS[17] in 2020. Districts in California are strongly encouraged – but not required - to remove sources of water that exceed the response level out of production. Districts are required to notify the public if the level of contamination exceeds 5.1 ppt for PFOA and 6.5 for PFOS.

PFAS concentrations above the new response levels have been detected at forty of the two hundred wells within Orange County Water District's jurisdiction (Observation, 8/29/19; OCWD, 2020; Wisckol, 2020). Voluntarily removal of these wells has reduced local water supply in nine water utilities (Wisckol, 2020). An additional 71 wells are at risk of future contamination (Observation, 8/29/19). The annual cost of replacing the well water with imported water from MWD is estimated to be $30 million. OCWD estimates that over the next 30 years, a total $850 million will be required to address PFAS contamination (#15; #16; Observation, 8/29/19; OCWD, 2019). Water bills may rise as high as 15%; residents in districts that require PFAS treatment will pay roughly $3 more per month for water services while those in non-PFAS districts may see an increase of $1 or more (Wisckol, 2020). If districts have to shut down all of their wells, average residence water costs could increase by $20 a month. OCWD has already launched a $1.4 million pilot treatment project to identify the best type of filter to remove contaminants from drinking water.

This water quality challenge is relatively new, but will be "one of the defining issues in California, environmentally, for decades" (Phillips & Pesce, 2019, para. 5). Addressing PFAS contamination will require furthering the understanding the impacts of PFAS on public health (EPA, 2019), as well as developing methodologies that allow water utilities to cost-effectively

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[16] For reference of scale, one part per trillion is the equivalent of one drop of water in 20 Olympic sized swimming pools (OCWD, 2020)

[17] The previous response level threshold was 70 parts per trillion (ppt) for the total concertation of the two contaminants (SWRCB, 2020a)

detect and remove contaminants (#15; #16). Public water utilities “need the research community and the private sector to give us a new game plan. We need innovative and cost-effective solutions to address this challenge” (Observation, 8/29/19).

Ageing Infrastructure

California’s water supply and treatment infrastructure has been ranked with a C grade; the wastewater system with a C+; and the stormwater management drains, pipes, ditches, canals, and channels with a D+ grade based on resilience, current physical condition, capacity, and funding capacity (ASCE, 2019). Los Angeles, for instance, currently has a 6,730 mile network of pipes (Poston & Stevens, 2015). One-fifth of Los Angeles’s water pipes was installed before 1931, and is quickly approaching the end of its lifespan. The Department of Water and Power has identified 435 miles of piping, or roughly 6.5% of the water network, that requires replacement by 2025. To meet this goal, the department would need to double the rate of pipe replacement and find additional funding sources. The DWP has already spent $250 million between 2007 and 2015 on ageing infrastructure, and will need to dedicate an additional $1.34 billion (or $135 million per year) to replace all piping rated with a D or F grade.

The rising cost of maintenance and repair has reduced the ability of local governments and states to fund new infrastructure projects (Observation, 8/29/19; Eskaf, 2015). Between 1980 and 2014, local-level spending on Operation and Maintenance (O&M) rose by 126% (Eskaf, 2015). Similar trends are seen across all U.S. infrastructure: between 2007 and 2017, spending on infrastructure O&M rose by 9.5% while spending on new capital projects has declined by 16% (Kane & Tomer, 2019).

The incremental replacement of these existing systems perpetuates large-scale, centralized water-grids rather than promoting closed-loop (decentralized infrastructure) water systems (Marlow et al., 2013). Ageing infrastructure also pose a significant challenge in maintaining affordability (Baehler & Biddle, 2018), and can serve as point of political tension (Observation, 8/30/2019).

4.3 Solutions to Water Challenges

Observations, interviews, and a literature review reveal that water stakeholders at case sites and in Southern California are concerned about interruptions or curtailments of water supply due climate change, shifting regulations and legislation, natural disasters, ageing infrastructure, and emerging contaminants of concern. In response to these challenges, there is a rising discourse in increasing sustainability and resilience of water systems by 1) diversifying and enhancing local water supplies, 2) collaborating across sectors, and 3) utilizing data-driven decision-making.

Resilience and Sustainability Discourse

The importance of providing sustainable water services frequently came up during fieldwork (#1; #4; #5; #9 - #13 #16; #18; #21; Observation, 8/30/2018) and in reports by regulatory agencies (see CNRA et al., 2016, 2020; DWP & LA County Public Works, 2017). However, there is variability in the way resilience and sustainability is defined and interpreted across regulatory agencies and water stakeholders included in this research. Regulatory agencies and state-level governance focuses on both the resilience of human and natural systems (CNRA et al., 2016, 2020; Executive Order N-10-19). Along with bolstering water system flexibility and regional-level planning, the *Water Resilience Portfolio* (2020) identifies restoration of environmental health and well-being through "adaptive, holistic environmental management" as a key step in achieving regional and state-level resilience (CNRA et al., 2020 p. 6). Likewise, the 2016 California Water management Plan emphasized that a "sustainable path to water management" in California "must strike a balance" between providing for public health and safety (e.g., safe drinking water, clean rivers and beaches, flood protection), protecting the environment, and supporting a stable California economy (CNRA et al., 2016 p.1).

Resilience was frequently raised by interview respondents and research participants as a critical element of future water management (#1; #5; #9; #10; #11; #17; #18; #21; Observation, 8/30/2018, 8/29/2019; Shadowing, 12/18/2019). While few participants formally defined the concept, discussions of resilience most frequently centered on the ability to "bounce back from shocks" such as climate change and natural disasters (#10; #11; #15 - #17; Observation, 8/29/2019; Sustain SoCal, 2020; Weston, 2016a). This interpretation is tied heavily to public expectations: one water manager stressed the public expects water districts to "be invincible" and to be able to recover from any loss or stoppage, including drought or a global pandemic (SustainSoCal, 2020). Public and private discussed the importance of implementing "drought-proof" and drought-resilient" infrastructure (#10; #15 - #17; #21; Shadowing, 12/18/2019; Observation, 8/29/2018; 8/30/2018). Similarly, presenters at a water-sustainability conference reiterated that the main "goal right now is to prepare for the next drought" (Observation, 8/30/2018). Only one interview respondent provided a broader definition that emphasized flexibility and adaptability of water supplies (#9). Overall, water utilities interpretation of resilience aligns closer to a traditional engineering resilience perspective rather than a social-ecological one (see Folke, 2006; Holling, 1996).

Likewise, sustainability discourse among interview respondents centered on the provision of "safe, reliable, accessible drinking water" (#4; see also #11; #13 - #16; #18) and the continuation of services above all else (#4; #9; #21). While ecological well-being is featured in the mission statements of districts participating in the research[18], discussions of the environment appeared to be considered within the context of affordability (#1; #2; #4; #11; #15; #16), financial solvency (#1; #4; #18; Observation, 8/30/2018), and stability and reliability (#4; #11; #15; #16; #21). “These rate payers that are depending on me to make sure there's water. That includes sustainability. And I don't want to have to go stand in front of them and say we did a crappy job of planning for the future […] So I just feel that's my duty” (#11). The focus on continuity and stability in changing conditions aligns closer to a business oriented definition of sustainability (Lew et al., 2015) rather the three pillars (ecological well-being, economic viability, and social justice) identified in academic literature (see Pinz et al., 2017; Silvius & Schipper, 2016) and the *Our Common Future* (1987).

This is not to say that water utilities disregard environmental impacts in water management decision-making. Respondents highlighted that water utilities have over time developed environmental sensitivity when designing and developing projects (#1 - #4; #11; #16). “If you look at the water industry in the past, sustainability was not the concern. It was - how cheap can I get this water here and how quick. That's changed” (#11). In discussing solutions to water challenges, respondents pointed to individuals in leadership positions within their organizations who encouraged considerations of ecological well-being (#11) and highlighted environmental benefits of projects pursued by water districts (#1- #5; #11 - #13; #15 - #17). However, while the primary role of regulatory agencies is to balance environmental conservation and meeting rising water demands of the state (Ocasio, 2015), the ultimate role of water utilities

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[18] The mission of IRWD (n.d.), for example, is “to provide high quality water and sewer services in an efficient, cost effective, and environmentally sensitive manner which produces a high level of customer satisfaction.” Meanwhile, SMWD (n.d.) provides customers “with quality water and wastewater service – maximizing human, environmental, and financial resources – to help guide South Orange County’s water and wastewater needs into the next century.”

is to meet the public’s expectations of stability, reliability, and affordability (#4; #11; #13). Sustainability and resilience are viewed as the district’s ability

> to provide safe, reliable, accessible drinking water through all the changing conditions in a way that anticipates customer behavior and work broadly and collaboratively to enhance the level of service. […] For the water, I think it's just really... that's what people expect. (#4).

Considerations of environmental wellbeing or social ecological resilience, thus, are primarily driven by those in leadership positions (#4; #11; #14; #16) or through regulatory oversight (#13).

Despite variations in sustainability and reliability discourse, there was consensus among the proposed solutions to water sector challenges. Fieldwork, literature review, and document analysis revealed three key priorities of public and private stakeholders in the water sector (#1 - #21; Observation 8/30/2018, 8/29/2019, 3/15/2019; Bruce et al., 2019; DWP & LA County Public Works, 2017; Executive Order N-10-19; CNRA et al., 2016, 2020; Smith, 2012):

1) Scalable, multi-benefit solutions that diversify and bolster local water supplies
2) Partnerships and collaborations among public agencies and across sectors to promote innovation and knowledge transfer
3) Data-driven decision-making at various political scales (local, watershed-level, and state-level).

This chapter will examine the first two priorities established by water stakeholders. The role of data in water management will be explored in greater detail in Chapter 6.

Diversifying Water Sources and Developing Local Supplies

Both regulators and utilities view the local-level actions as critical in in addressing current and future water sector challenges (Observation 8/30/2019, 3/15/2019; CNRA et al., 2020). Respondent spoke extensively of the importance of water utilities being pro-active in ensuring reliable water provision (#9; #11; #15; #16; #18):

> As the world has changed, the cost of water has gone up. Drought took place. The state legislature, not to mention even federal legislation and regulations, have made it obvious that we can't just rely on other people taking care of us. So it's a fundamental philosophy of make sure that you're taking care of yourself. (#11)

A critical component in achieving sustainable, resilient water management is the development of local water supplies (#11; #12; #15; #16; #18; #21; CNRA et al., 2016, 2020; DWP & LA County Public Works, 2017; Gonzalez & Ajami, 2017). The presence of diverse, local water sources enable water utilities to withstand interruptions to imported water and provides flexibility in the system to shift between water sources when one particular source becomes compromised (#11; #18; #21; CNRA et al., 2016, 2020; Gonzalez & Ajami, 2017). For local and regional-level water utilities, there is a stronger emphasis on utilizing “every drop of water that we can” (#1; see also Weston, 2016a) through re-use, storage, and conservation efforts (#3; #11; #18; #21). One respondent emphasized that even water reclamation projects that yield a few hundred acre feet per year are important. “When you start thinking "how much does a family need per year,” that represents *major* impacts” (#11). Overall, the goal of retailers and wholesalers is implementing technologies and methods on a pilot basis to identify scalable solutions for water management without interrupting water services (#1; #11; Observation, 8/29/2019). For one water utility,

> the goals are to do infrastructure repair and replacement so that we can maintain a high reliability, high quality water delivery system for the citizens that we serve. And as part of that, resilience and reliability are key components. […] So it's good public policy for agencies to look at trying to diversify their portfolio of water sources (#18)

Achieving local and regional level resilience will require shifting from crisis-driven responses (i.e. increased groundwater pumping during droughts) to an anticipatory approach that focuses on comprehensive risk reduction (Christian-Smith, Levy, & Gleick, 2015). Given the incremental nature of the water sector change, where “five years is overnight” (Shadowing, 3/15/2019), water utilities must begin planning now to prepare for conditions in the future. “You can’t just snap your finger and overnight turn the valve on” (#11). At the same time, uncertainty of future conditions creates concerns that water utilities may lock in to maladaptive technologies (Barnett & O’Neill, 2010). Thus, to minimize vulnerabilities to the system, utilities must pursue flexible, multi-benefit projects that consider impacts to ecosystem function, water supply, flooding management, and water quality (#11; #12; CNRA et al., 2016, 2020; Pinter, Lund, & Moyl, 2019).

PPPs as Part of a Broader Movement towards Collaboration

Achieving resilience and sustainability is a “shared responsibility” that will require extensive collaboration (Observation, 8/29/2019; Bruce et al., 2019; CNRA et al., 2020; DWP & LA County Public Works, 2017; Gonzalez & Ajami, 2017; Romm, Conrad, & Maren, 2018; Smith et al., 2012; Tortajada et al., 2017). Decentralization of water systems has resulted in highly siloed institutions in urban water systems (Bruce et al., 2019) and has created a disconnect between social and ecological system management (Hughes & Pincetl, 2014; Romm et al., 2018). Bolstering resilience, thus, will require building social networks and joint institutions and the “shared use of science, data, and technology” to promote regional approaches to water management (CNRA et al., 2020, p. 5).

Water districts already participate in a number of collaboration types to achieve their sustainability and resilience goals. Water utilities featured in the research frequently presented outcomes of pilot projects at conferences, held brainstorming sessions with smaller-scale districts to replicate water management technologies implemented at case sites, participated in technical advisory groups for state-level legislations, hosted tours of their facilities, partnered with non-governmental organizations, and increased levels of community engagement and outreach (#1 -

#4; #11; #13; #14 - #16; #18; Observation 8/30/2018; 8/29/2019, 3/15/2019; Shadowing 3/15/2019). These collaborations enable water districts to distribute risks, pool resources, and to rapidly distribute information about innovative strategies through networks (Lach et al., 2005). However, the level of collaboration is presently insufficient. Low coordination prohibits the development of a more resilient system at the regional and state-level (Romm et al., 2018; Tortajada et al., 2017) and exacerbates resource inequities among organizations (Hui, Ulibarri, & Cain, 2018).

Research participants stressed that overcoming hydrological, institutional, and technical challenges will require identifying and sharing best practices not only within the water sector, but also across all sectors (#1 - #10; #16; #21; Observation, 8/30/2018; 8/29/2019). There is greater demand for transferring skills and methodologies from the private sector that improve financial solvency and efficiency of water management strategies. Therefore, the adoption of public-private partnerships by water utilities can be seen as a response to the rising demand of building collaborative networks in order to achieve resilience and sustainability goals.

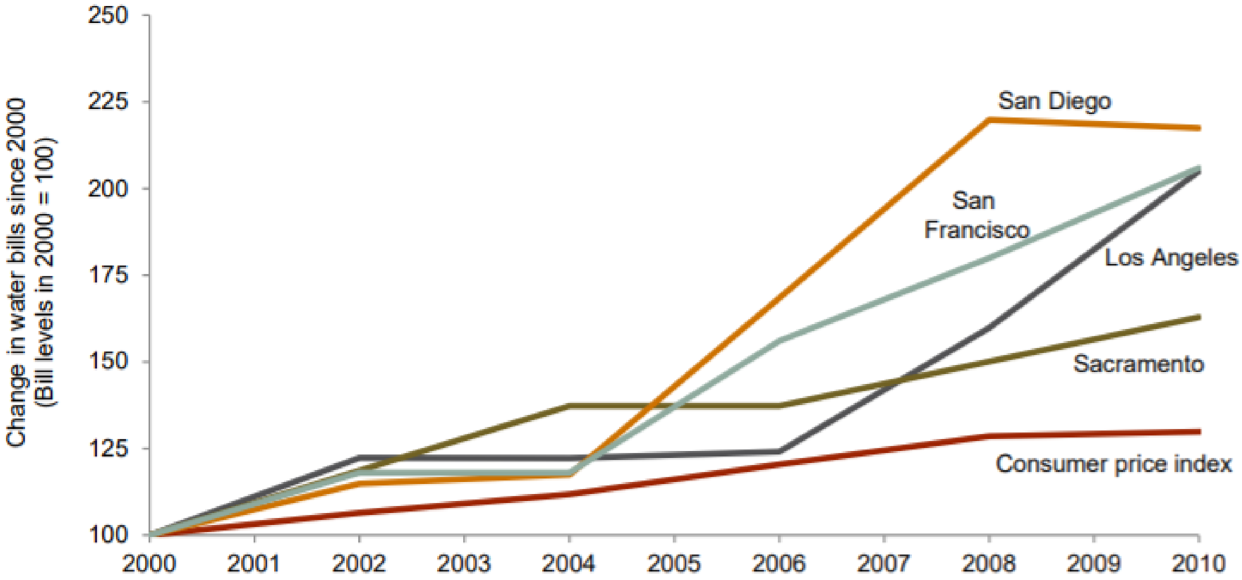
4.4. Factors that Limit Adaptive Capacity of Water Utilities

The previous section identified three broader goals among public and private stakeholders to increase sustainability and resilience of water management and supply within the Southern California. Three socio-economic and political factors constrain the ability of public water utilities to implement these broader infrastructure and governance reforms.

Decreases in Federal and State-Level Funding

Reliable funding is crucial in meeting water supply needs in the future (Mount et al., 2018). The EPA (2018) estimates that California's water system will require $51.03 billion in investment over the next twenty years to maintain and expand transmission, distribution, treatment, and storage systems. Ensuring fair, sustainable, and cost-efficient water access for current and future populations would require an additional 7% to 10% of tax revenue (roughly $150 to $230 annual cost per household) (Hanak et al., 2014). Yet, federal funding support for capital improvements and repairs has decreased over the last few decades. Between 1997 and 2019, federal investment in water has declined from 63% to 9% of total capital spending (Lee, 2019). In 2014, states and local ratepayers accounted for 96% of all public spending on water and wastewater services (Eskaf, 2015).

This decline in federal spending has shifted the financial responsibility of meeting resilience goals and maintaining ageing infrastructure systems to local water utilities. As a result, local water managers are struggling to meet public expectations of reliability and safety while maintain affordability of drinking water (#4; #11; #16; Baehler & Biddle, 2018). Between 2007 and 2015, the average price for drinking water in California has increased from $37.01 to $53.81, representing roughly a 45% increase in water service pirce (SWRCB, 2019). Meanwhile, median household income has decreased by six percent. Monthly water bills in urban areas have been rising two to three times faster than the rate of inflation (see Figure 4.4). The burden of rising water costs falls most heavily on low-income households, with households earning less than 25,000 and $10,000 per year spending roughly 2.1% and 5.3%, respectively, of income on water services (Feinstein et al., 2017). In 2014, nearly 13% of households in California exceeded the EPA's recommended affordability threshold of 2% income spent on drinking water (see Figure 4.5) (Hanak et al., 2014).



SOURCE: Author calculations using information from the American Water Works Association (2010) and water agency financial reports.

Figure 4.4 Percent change in water bills of major California cities relative to the rate of inflation (Hanak et al., 2014)

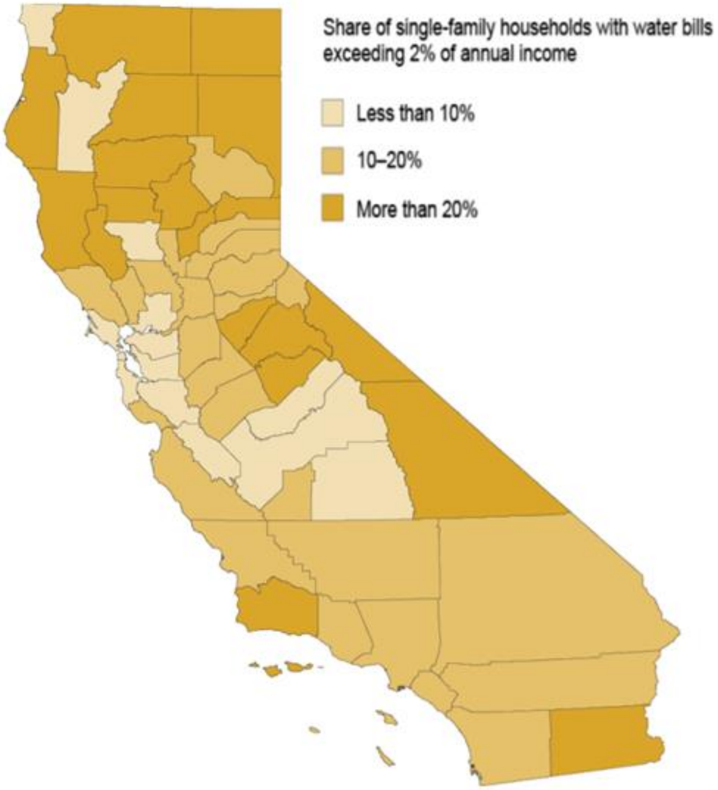


Figure 4.5 Proportion of single-family households with water bills exceeding the EPA’s recommended affordability threshold (2% of annual income) (Hanak et al., 2014).

Actors in a Decentralized System – Variability in Technical and Financial Capacity

The challenge of providing local water solutions is further exacerbated by decentralization. California's water system is highly decentralized[19] (Hanak et al., 2011; Hundley, 2001; Mitchell et al., 2017; Mount et al., 2018): while state and federal governments and courts create the regulatory context, it is the responsibility of local entities to provide water services, collect revenue, and comply with regulations (Hanak et al., 2011). More than 400 utilities serve roughly 90% of the state's residents (Mitchell et al., 2017). Hundreds[20] of additional local and regional agencies are responsible for wastewater treatment, flood control, and land use decisions related to water quality and supply (Hanak et al, 2011). Formal and informal groups are also involved in water management by providing data and information to decision-makers, lobbying, placing initiatives on ballots, and initiating lawsuits.

Decentralization allows for the development of flexible, contextualized solutions to water challenges that address the needs of critical stakeholders (Hughes & Mullin, 2015). However, low coordination across agencies can lead to fragmented, inefficient, and unsustainable water management and can produce gaps in understanding of critical water challenges (Hanak et al., 2011). Decentralization can also promote inequality (Pannu, 2012), as water districts vary in their level of technical and financial capacity (Allaire, Wu, & Lall, 2018; Ekstrom et al., 2018; Hanak et al., 2011; Pannu, 2012). Small-scale rural systems are challenged in cost-effective provision of safe drinking water due to low revenue streams opportunities to secure external

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[19] Scholars and practitioners have utilized two definitions of decentralized water systems: 1) closed infrastructure systems at household-or community-level that allow for the capture and re-use of water (see Daigger & Crawford, 2007; Piralta & Goverdhanama, 2015), or 2) the transfer of some decision-making and management power to lower levels of government (i.e. provincial, regional, district-level) (UNDP, 2006). This research utilizes the latter definition of decentralized systems and governance. This research also notes that decentralization is not a uniform concept across the globe, as the distribution of power between the central, state, provincial, and local institutions will vary based on a region's socio-economic, ecological, and political conditions.

[20] In Los Angeles County alone, nearly 100 public and private entities are involved in the management of potable water supplies (Pincetl & Glickfeld, 2015).

financing (Ekstrom et al., 2018; Allaire et al., 2018; Chappelle & Hanak, 2015). Small revenue streams reduce economic incentives for high skilled technical workers to seek out employment at these systems, resulting in lower levels of technical capacity. In California's Central Valley, for example, there are over 450 unincorporated communities who rely on networks of public and private wells (Padilla, 2011, cited in Pannu, 2012). Many of these communities are composed of low-income, marginalized populations who have been "structurally excluded" from cities (Pannu, 2012, p. 231). Low-income unincorporated communities spend more than 10% of their annual income on water provision. Water quality in the region has been historically poor; the associated health costs of water-borne diseases and illnesses further exacerbate the vulnerability of these communities.

Value-Driven Constraints on Decision-Making

Multiple competing attitudes have shaped water uses, allocation, and views in the western United States (Feldman, 2016; Hanak et al., 2011; Hughes & Mullin, 2015; Hundley, 2001). For example, early forms of water management in the region relied on minimally invasive, local strategies of water management (Hundley, 2001). Native Americans primarily settled near water sources (rather than diverting them), and viewed water as a resource that is interconnected with nature and is essential for human and animal survival (Hundley, 2001). Spanish Imperialism and Colonialism (1769 – 1846) introduced the belief that man has dominion over nature, which was amplified by the first waves of American settlers within the state (1846 and onward). The first waves of American settlers also brought with them the Democratic ideals of individual rights and low interference by federal government in infrastructure and resource provision. As a result, water management during the 19th century was guided by individual, corporate, and local actions, with the federal government taking a laissez-faire approach to the development of local water systems (Hanak et al., 2011; Hundley, 2001). The Progressive Era (1890s to 1920s) shifted perceptions among the public and decision-makers of the role of federal and state-level government in infrastructure and service provision (Hundley, 2001), resulting in greater federal investment in large-scale water, agricultural, and hydropower projects as the CO River Aqueduct and Hoover Damn (Feldman, 2016).

During the Hydraulic era, water supply projects were pursued with little consideration of environmental impacts (Hanak et al., 2011; Hundley, 2001). The global environmental movement (1960s) amplified values and ideologies focused on sustainability, resource conservation, and greater consideration of environmental harm (Fuenfschilling & Truffer, 2016; Hundley, 2001). As a result, at the state and federal level, there has been a gradual policy shift from developing water resources toward improving operation efficiency while optimally managing vulnerable supplies (Feldman, 2016). There is a greater focus on integrating adaptive management practices and changing operational and infrastructural designs to blend with natural systems, rather than re-shape them (e.g. changing operation of dams to mimic historical flows) (Feldman, 2016; NRC, 2004). Regulatory agencies, thus, are striving to balance economic development and rising water needs with ecological well-being and environmental conservation (Ocasio, 2015).

Competing values and uses of water can contribute to policy deadlock (Hanak et al., 2011; Marhsll & Alexandra, 2016). Presently, there are six main water uses in the West: agriculture; municipal and industrial use; energy; minerals; fish, wildlife, and recreation; and tribal uses. Irrigation is the dominant use of water in the western, with almost 80% of supplies devoted to agriculture (Mount & Hanak, 2019). The divergent values and needs of participants across these sectors can result in competition over resources among water stakeholders (Lach et al., 2005; Hanak et al., 2011; Hundley, 2001). Concerns that progress in one organization's mission may negatively impact other organizations. As a result, stakeholders are "responsive but narrowly" and will only support policies that promote their own interests (Hanak et al., 2011, p. 7).

Water utilities are also constricted by the values and perceptions of the general public (Dolnicar & Hurlimann, 2011; Harriss-Lovett et al., 2015; Kiparky et al., 2013). Public acceptance can impact policy decisions, can constrain alternative pathways for water management (Marlow et al., 2013), and can even lead to project failure (Fielding et al., 2018). Public acceptance (or lack thereof) of technologies and water management strategies is influenced by a variety of psychological, hydrological, and socio-demographic factors including age, income, degree of disgust/perceived risk of the original source of the water, degree of environmental concern, perceived water scarcity, and degree of trust in government official to mediate potential risks (Dolnicar & Hurlimann, 2011; Fielding et al., 2018). Increasing public acceptability requires significant public engagement and intervention to shift perception of risk and to demonstrate reliability, safety, and appropriate use of the water (Harriss-Lovett et al., 2015; Markus & Torres, n.d.; Ormerod et al., 2019).

For example, public acceptance has been identified as a critical barrier to introducing recycled water schemes (Fielding et al., 2018; Fuenfschilling & Truffer, 2016). Proposed projects for recycled water facilities in San Diego and Los Angeles were halted in the early 2000s due to public concerns of safety, stigma, and social justice (Ormerod et al., 2019). OCWD was able shift public acceptability through an extensive campaign (#16) that began nine years before the facility was constructed and operational (Markus & Torres, n.d.). OCWD is considered to be an "enduring symbol of success" in recycled water projects (Ormerod et al., 2019). The multi-faceted campaign highlights the challenges of implementing water infrastructure solutions that do not align with the dominant social values of a community.

4.4 A Tailored Approach - Variations in Water Management Approaches across Districts

The socio-technical needs and challenges of each water utility are unique. Each district develops resilience and sustainability goals based on their availability of local water supply, level of predicted future development, available budget, present infrastructure, technical capacity, and the values and judgments of individuals in leadership positions (i.e. General Managers, Boards of Directors, etc.) and the general public (#1; #4; #11; #13; Observation, 8/29/19; CNRA et al., 2020; Gonzalez & Ajami, 2017). These differences can be seen in the current and proposed water management strategies of Santa Margarita Water District and Moulton Niguel Water District. The districts are located next to each other (see Figure 3.6), were established roughly within the same time frame, and both serve a population of roughly 170,000 residents (MNWD, n.d.-a; SMWD, n.d.). As there are no natural sources of water in South Orange County, both are 100% reliant on imported water (#1; #3; #11; #15; #18; SMWD, 2015). Recycled water needs currently meet 25% of each district's outdoor water usage demands (MNWD, n.d.-b; SMWD, n.d.-a). Members of each district have expressed rising concerns regarding future reliability and sustainability (#1-#4; #11; #13; MNWD, 2015). However, the two districts differ drastically in their approach to meeting the water needs of their water users.

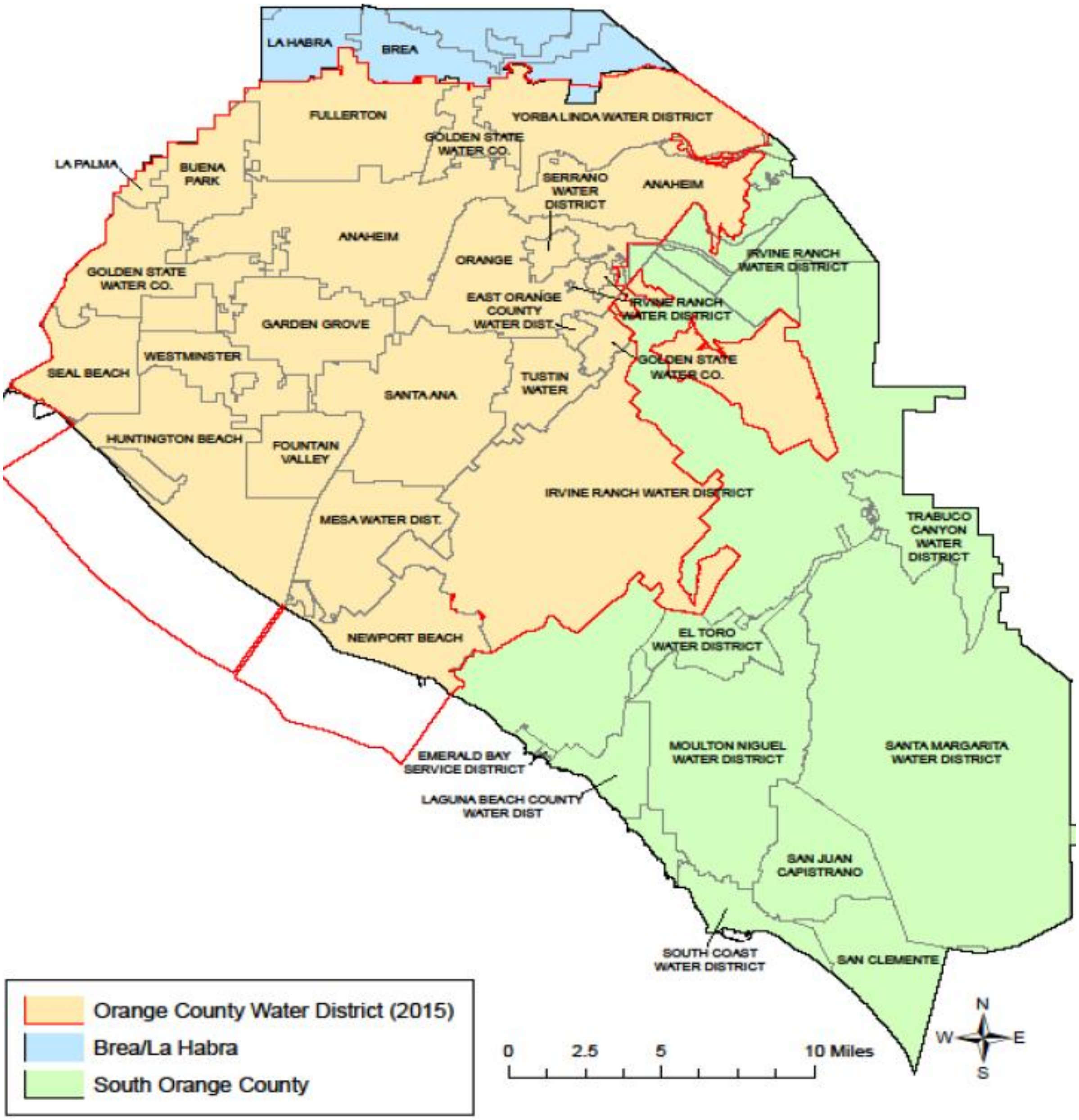

Figure 4.6. **Map of Orange County Water Utilities and Wholesaler jurisdictions**. MNWD and SMWD are located in South Orange County, and fall outside of the groundwater supply managed by OCWD. Instead, both SMWD and MNWD receive water through the Municipal Water District of Orange County (CDM Smith, Inc., 2018)

Santa Margarita Water District was established in 1964 to support the development efforts of Rancho Mission Viejo, LLC (RMV), a developer is Orange County (SMWD, n.d.-a; Shadowing, GMB). The district has been focused on resilience since the 1970s (Observation, 8/29/19), which it views as providing “safe, reliable, long-term supply of water” through water management strategies that are cost-effective and innovative (Observation #1; SMWD, n.d.-a). Due to concerns over the risings costs of imported water (#11; Observation, 8/29/19), the risk of disruptions, and climate- or regulatory driven reduction in potable water supply (Observation, 8/29/19), SMWD is "actively pursuing and searching for alternative sources of water" (#11). SMWD's goal is to replace 30% to 50% of imported drinking water with local supplies (#11; #13; Observation #1; SMWD, n.d.-a). The district planned to recycle 100% of wastewater by 2019 and will develop reservoir storage for six months by 2030. To do so, it is pursuing multiple water projects, including Trampas Reservoir, the Cadiz Water Project, and the Gobernadora Multipurpose Basin. While these projects have high capital costs, the investments in local storage seen as "avoided costs" of interrupted services (Shadowing, 3/15/19).

Moulton Niguel Water District was established in 1960. Between 2010 and 2015, the district's approach to maintain long-term water reliability "evolved from supply-driven projects into a comprehensive portfolio of both demand management strategies and sustainable supplies" (MNWD, 2015, p. 2). The district places a heavy emphasis on "cost-effective" and water efficient solutions to meet future water demands (#1-#4; MNWD, 2015). The district has invested $70 million in system reliability projects between 2008 and 2016 to increase available emergency supplies from 2 days to 24 days in the event of an emergency outage from MWD (MNWD, 2015). It has also pursued strategies to reduce water demand since 2009, decreasing potable water use by 26% between 2007 and 2015. To meet future water demands, the District plans to improve demand management programs, utilize data management to improve efficiency, and identify opportunities to expand its local water supply portfolio. The emphasis is on small-scale pilots of alternative water supply projects (#1; #3; Observation, 8/30/2018). However, there is a less of an urgency to reduce reliance on MWD than observed at SMWD and the other districts featured in this research:

> The fact that there isn't really a local water source […] is something we're cognizant of, but we don't necessarily want to just go build a bunch of big projects that are going to require that our customers pay fixed costs, even though they might not ever use that water or need to have used that water. […] We don't really have a basin that we can utilize to store that water. […] Building for the sake of independence from Metropolitan.... to us isn't really necessary other than [to prevent] potential interruptions in supply. And Metropolitan has been reliable (#1; see also #4).

These differences in the urgency of developing local supplies can be explained by several socio-technical factors. First, while the districts serve comparable population sizes, they vary in their opportunities for future development (#1; #4). Currently, only 20% of the RMV's land is built out (Shadowing, 3/15/2019). Between 2015 and 2035 the population within SMWD's jurisdiction will increase by 27%, from roughly 170,000 to 200,000 (SMWD, 2015). Assuming demand can be curtailed through targeted and natural water savings, Santa Margarita predicts that total water demands will still increase by 5.68% from 34,405 AFY to 36,360 AFY (M. Cubed, 2016, cited in SMWD, 2015). Meanwhile, by 2035, MNWD's population is projected to increase from 170,000 to 176,500 (a 4.2% increase) and total water demand is expected to decrease by 4.84% from 26,618 to 25,331 AF (MNWD, 2015). Thus, there is a greater sense of urgency for SMWD to develop additional water supplies – particularly recycled water supplies - to meet future needs.

Leadership and management of the district also plays a role in the approach to resilience and future water management. Members of various public and private agencies repeatedly highlighted the "business-oriented" and "cost-efficient" nature of MNWD (#1-#5; #9; #13), and credit the General Manager in establishing this district culture (#1; #3; #4; #13). To MNWD, "the drop that's not used [a demand management approach] is the cheapest new water supply source. (#3). Meanwhile, a respondent remarked that SMWD “has not only a different management style, but a different vision of the future for the district (#13)” The district is willing “to pay a premium in order to have that reliability and sustainability” from local supplies (#11); cost-effectiveness is viewed as gaining independence from Metropolitan and the rising costs of imported water (#11; #13; SMWD, 2012a). Thus, the district has prioritized increasing operational efficiency and diversifying supplies. Members in leadership positions at each district argue that their approach to cost-effectiveness and financial sustainability is the one in which their customers are served best in the long-term (#1; #3; #4; #11; #13; Observation, 8/29/19).

4.5 Discussion

There is consensus within California’s water sector that the state is facing unprecedented socio-technical and hydrological challenges. Water utilities within the state and across the U.S. are challenged with addressing both ageing infrastructure systems and complex and uncertainty threats to water supply due to climate change, evolving regulatory regimes, and natural disasters (#1 - #21; Observation 8/30/2018. 8/29/2019; Hanak et al., 2011; Mount et al., 2018; Pincetl & Hogue, 2015). The 2012 to 2016 drought provides a “window into the future under a warming climate” (Mount et al., 2018, p. 4), and has highlighted tensions in the role of the state and local government in the provision of water supplies in conditions of scarcity (Mitchell et al., 2017). Moreover, reductions in state and federal level funding, mounting maintenance costs, and rising costs of detecting and treating emerging contaminants of concern (e.g. PFAS) have created financial strain for water utilities and for rate-payers. All of these challenges are compounded by the fragmented and siloed nature of California’s decentralized system as well as the conflicting values and logics amongst water users (Pincetl & Hogue, 2015; Romm, Conrdad, & Maren, 2018).

Organizational fragmentation and specialization, competing interests of water stakeholders, the built environment, and expectations of the public have created incremental responses to water management (Hanak et al., 2011, Hughes & Mullin, 2015; Lach et al., 2005). Addressing the water sector's socio-technical challenges will ultimately "require changing how we manage water" (Observation, 8/29/2019). Indeed, scholars argue that water crises are often crises of governance than true resource and technology limitations (Pahl-Wostl, 2008; Pincetl et al., 2019). Unsustainable water governance creates poor connectivity and water security, placing an undue burden on ratepayers, especially those of a low socio-economic status (Krueger et al., 2020). Yet, peer-reviewed literature on water sector resilience places a higher emphasis on engineering resilience solutions rather than governance mechanisms that enable adaptation and transformation (Rodina, 2019).

For resilience to be a useful concept, it must move beyond engineering resilience, and must consider that systems have the potential to "bounce forward" and transition to sustainable water pathways (Vale, 2014). Yet, the majority of practitioners in the water sector view resilience as the ability to "bounce back" and maintain the status quo (Chelleri, Waters, Olazabal, & Minucci, 2015). As a result, most attempts to operationalize resilience focus on robustness of engineered and natural systems relative to standards defined by technocratic institutions (Sivapalan et al., 2012, 2014, cited in Gonzalez & Ajami, 2017). In other words, present day tools for evaluating resilience often reflect the needs of centralized/top-down and supply-side focused water management (Gonzales & Ajami, 2017), thus reducing opportunities for transitions to more flexible and adaptive water management systems.

Transitioning to a sustainable and SES resilient approach will require additional discourse between scientists, water stakeholders, citizens, and regulators. There is a lack of evidence and understanding of how the water sector must adapt governance structures, technologies, and alter behaviors on a broader scale to adapt to different hydrological futures (Rodina, 2019). Without a mutually agreed upon definition of resilience there will be variability in the success of implementation strategies (Lawson et al., 2020). Dewulf et al. (2019) argue that "determining which systems are resilient, with respect to what threats, at what purpose, and for whose benefit represent choices that are often not neutral technical choices but political ones" (p. 3). Technocratic forms of governance are more likely to lead to more unilateral definitions of resilience while adaptive, collaborative, and polycentric forms of governance allow for greater variety in definitions (Warner et al., 2018). Resilience discourse and research must consider resilience "of what" and "for whom" (Dewulf et al., 2019; Meerow et al., 2019; Porter & Davoudi, 2012; Vale, 2014). To ensure resilience is not achieved at the expense of ecosystems or marginalized communities, a broad range of actors must participate in how resilience is defined (Dewulf, 2019; Vale, 2014).

This chapter revealed that there are variations in the way water utilities and regulatory agencies define and interpret sustainable and resilient water strategies. Regulatory agencies and state-level decision-makers have prioritized strategies that can benefit both ecological and social system well-being (CNRA et al., 2016, 2020). The emphasis of these approaches is on long-term adaptation to large-scale stressors such as climate change as well as sustainable development. Meanwhile, sustainability and resilience discourse of public and private stakeholders in the water sector was tied closely to the public expectations of affordability, reliability, and quality. These findings align with the constraints identified by Lach et al (2005) and Rayner et al. (2005), who argue that these expectations can create system-wide inertia and risk-aversion (see also Baehler & Biddle, 2018; Brown et al., 2011; Farrelly & Brown, 2011; Feldman & Ingram, 2009). While operational and strategic decision-makers at water utilities consider environmental impacts when weighing water management solutions, interpretations of sustainability and resilience prioritize continuous water service above all else. Regulatory agencies serve as the driving force of integrating ecological system consideration in strategies.

These differences in perspectives between water utilities and regulators highlights that resilience is understood and experienced by different actors in different ways (Cooke et al., 2016, cited in Dewulf et al., 2019). Resilience and sustainability solutions must be tailored to local political, socio-economic, and hydrological contexts (Eriksson et al., 2014). As demonstrated by a comparison between Moulton Niguel and Santa Margarita, a utility’s resilience and sustainability goals and opportunities are shaped by the political context, socio-economic conditions, available water supplies, and organizational leaders. These cultural variations, as well as differences in technical and financial capacity, ultimately influence the types of PPPs adopted by the public agencies participating in this research.

This chapter identified diversification of local water supplies, collaboration across sectors and scales, data-driven decision-making, and tailored local solutions as the top priorities of regulatory agencies and utilities for achieving sustainable and resilient water systems. These findings reveal that discourse has shifted away from strictly command-and-control infrastructure-oriented approaches. Instead, there is a greater emphasis on social learning and connectivity across hydrological and political scales. This collaboration and connectivity is critical to achieving sustainability and resilience goals (Rodina 2019) and it can overcome sector-wide inertia by distributing risks between actors (Lach et al., 2005). The inclusion of diverse stakeholders with niche knowledge can also result in the development of alternative water pathway solutions. PPPs, thus, have emerged as one of the many collaborative strategies developed by water utilities to achieve broader resilience and sustainability goals. The next chapter continues to explore the origins of PPPs in California’s water sector by examining endogenous and exogenous of PPP adoption.

5.0 DRIVERS of PPPs in CALIFORNIA

> *Here in the US, the P3 is just coming into its own. It's just becoming a legitimate consideration. I think that there are benefits but there are also deficiencies.*
> *- Member of a NGO, Respondent #13*

> *P3s need to be recognized as a viable option for getting infrastructure built. […] I think they have their place. I think they can be very useful. […] It's not going to work in all cases, but we surely shouldn't exclude it as a tool in the toolbox.*
> *- Member of a Public Water Utility, Respondent #21*

The previous chapter examined threats to water supply in Southern California and identified three solutions to building sustainability and resilience in the sector. The chapter also presented three factors that limit the ability of water utilities to implement these resilience and sustainability goals: funding constraints, limitations in technical capacity, and divergent values and uses of water. This chapter builds on this discussion by examining ***the endogenous and exogenous drivers enabled the uptake of an innovation form of infrastructure and service provision in the traditionally risk-averse water sector***. The chapter showcases how these constraints on achieving their sustainability and resilience goals increased internal demand for a PPP approach. The chapter also identifies motivations of private actors in entering into PPPs, even when the PPP market in the United States is underdeveloped. The findings contribute to the growing literature on innovation uptake within the water sector (see Brown et al., 2011, 2013; Kiparsky et al., 2013, 2016, 2020; Lach et al., 2005; Marshall & Alexandra, 2016; Rayner et al., 2005, Rayner & Lach, 2017).

This chapter begins with a broader literature review of PPP enabling institutions, as well as the degree of federal- and state-level support for PPPs as a mechanism for infrastructure provision. Next, the chapter utilized fieldwork to delve into the perceptions of PPPs in California. How do participants in PPP projects define public-private partnerships? What endogenous drivers may encourage public water managers to select a PPP contract rather than traditional procurement? Finally, the chapter explores the case-specific exogenous drivers of the infrastructure and data-oriented projects. Examining the early stages of partnership formation can ultimately maker clear what elements enabled traditionally risk-averse public water utilities to experiment with a new form of infrastructure and service provision.

The adoption of PPPs around the world and in the United States is the result of an exogenous and an endogenous process (Hodge & Greve, 2013, 2017; Nizkorodov, 2017; Pessoa, 2008). Public-private partnership arrangements date back to the era of mercantilism in the 1600s (Wettenhall, 2010). However, the present day notion of the PPP did emerge until the late twentieth century. The growing belief that the governments lack the capacity to provide public services in an effective and efficient manner (see Hood 1991; Boston 1996; Minogue *et al.* 1998; Polidano 1999 gave rise to the Private Finance Initiative[21] in the UK, which was later reframed as a public-private partnership (Hall, 2003). The approach was then proliferated around the world by international organizations such as the World Bank and the International Monetary Fund under the "Washington Consensus." PPPs were also promoted by the UN in the Millennium (2000) and the Sustainable (2015) Development Goals to achieve critical development milestones.

PPPs have also been diffused around the world due to the growing demand from policy-makers and public agencies; public entities have invited greater private sector participation in order to accelerate infrastructure provision, efficiently allocate risk, gain access to resources, and

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[21] It is important to note that some scholars argue that the infrastructure PPP existed in various forms long before the introduction of the PFI program (see Bovaird, 2010; Grimsey and Lewis 2004, Grimsey and Lewis 2005, Southland, 2010; Wettenhall, 2010, Yesecombe, 2007). However, academics who have traced the history of the PPPs argue that the concept of the modern day PPP can be attributed to the rebranding of the Private Finance Initiative (Wettenhall, 2010).

increase value for money of projects (Ameyaw & Chan, 2013; Beevers, 2016; Chou & Pramudawardhani, 2015; Liu & Wilkinson, 2011). Motivations for adopting PPPs vary across countries, with individuals more likely to adopt a PPP structure in countries with a mature PPP market and a strong understanding of potential benefits and outcomes of these kinds of partnerships (AWWA & EY, 2019; Chou & Pramudawardhani, 2015). In the US water sector, the most significant perceived benefits of PPPs are technical innovation and operational efficiency (AWWA & EY, 2019). Studies have also identified opportunities for cost-savings, low-risk cost recovery (Albalate, Bel, & Geddes, 2013), risk transfer, and accelerated project delivery as the main drivers of PPP adoption in the U.S. (AWWA & EY, 2019). U.S. public water managers also noted that the participation of the private entities can reduce the likelihood of deferring critical maintenance of ageing infrastructure, as water districts are able to free up resources to pursue other priority needs (AWWA & EY, 2019). PPP adoption may also be driven by perception of resource scarcity: 77% of PPP water re-use contracts are awarded in countries with high levels of water stress (Lloyd Owen, 2016). Countries with low levels of water stress only account for about five percent of all water re-use PPP projects.

5.1 PPP-Enabling Institutions in the United States and California

PPPs have undergone several phases of evolution in the US. Arrangements similar to the PPP-model can be traced back to the 1700s (Brown, 2020). These arrangements were often driven by the public and private sectors to achieve greater social and economic value through a pooling of resources, services, and skills (Kivleniece & Quelin, 2012; Southard, 2010) For example, to ensure cost-effective electricity development, utility managers and politicians in the early 20th century entered into a utility consensus, which granted eminent domain and government-sanctioned monopoly status to energy utilities in exchange for increased regulatory oversight and government price-setting (Southland, 2010). This exchange of benefits through a long-term contractual relationship is highly reminiscent of present-day PPP concession contracts.

PPPs were first adopted by the transportation sector in the late 1990s. Since its introduction in the US market, 37 states have utilized public-private partnerships for infrastructure delivery (Wunderman & Dunn, 2019). Between 2005 and 2014, 48 infrastructure Design-Build-Finance-Operate-and-Maintain (DBFOM) PPP transactions (an aggregate value of $61 billion) reached the formal announcement phase (Deye, 2015). The financial crisis in 2008-2009 significantly restructured the US PPP market. The PPP focus has shifted from monetizing existing assets through "brownfield" projects (rehabilitation of existing infrastructure) to a broad range of "greenfields" (the construction of new facilities or projects. Over the last ten years, the PPP market has expanded due to the recognition that local and state governments lack the funding resources to deliver critical infrastructure services and the rising investor focus in long-term investment has expanded the PPP market (PwC, 2016). There has also been a recent rise in informal collaborations between public and private actors to develop local and regional infrastructure (Lebeck, 2018).

The EPA (2015) has recently presented a new form of a PPP, the community-based PPP (CBP3). The CBP3 model is a "*true* long-term partnership between public and private parties" that "stresses social and environmental benefits" (Brown, 2015 [emphasis added]). CBP3s are distinguished from the traditional P3s by the emphasis on a municipality's long term goals rather than the priorities of investors (Brown, 2015). The EPA (2015), thus, defines CBP3s as long-term flexible partnership structures that foster trust and relationships between public and private partners. Public and private partners must create a "transparent framework that aligns public, private, and stakeholder community stakeholders into a long-term legal arrangement with an outlined governance structure founding in the spirit of stewardship and common purpose. Partnerships should avoid an adversarial contract-oriented management structure. That requires a change in mind-set from government contractor to business partner" (EPA, 2015, p. 24).

While the PPP market has expanded in the USA, it remains underdeveloped (Cournoyer, 2013; Deye, 2015; PWC, 2016). Between 1985 and 2011, PPP infrastructure projects in the US accounted for only 9% of the global PPP investment. Low PPP activity can be explained by inconsistent political support for PPPs, a lack of national PPP legislation, and the widespread availability of tax-exempt debt for public agencies (Deye, 2015; Kline, 2017; Southland, 2010).

Support for PPPs was high during the Obama administration (2009 – 2017). The Transportation Department formed the Build America Bureau in 2016 to provide technical assistance in utilizing the Transportation Instructure and Finance and Innovation Act (TIFIA)[22] (Mann & Hughes, 2017). The Water Infrastructure Finance and Innovation Act (WIFIA), a credit program similar to the TIFIA, was established in 2014 to "accelerate investment in the nation's water infrastructure by providing long-term, low-cost supplemental credit assistance for regionally and nationally significant projects" (EPA, 2018, para. 5). The EPA (2017) estimates that funds appropriated to the program can be leveraged at a ratio of 50 to one, meaning that a $17 million budget can allow the EPA to stimulate about $2 billion in total infrastructure investment. Demand for the WIFIA program already exceeds supply: in 2018, the EPA received 62 letters of interest collectively requesting $9.1 billion for projects led by public agencies, corporations, and PPPs (EPA, 2018), an amount that is almost double the agency's annual budget of $5.5 billion.

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[22] TIFIA is a federal credit assistance program established in 1998 to finance surface national and regional transportation projects, including PPP projects (Gilroy, 2014; US Department of Transportation, n.d.)

The investment climate under the Trump administration (2017 – present) for PPPs is more uncertain. PPPs as a funding mechanism for critical infrastructure was a critical element of President Trump's campaign platform and was featured in early drafts of his infrastructure framework (Bryan, 2016). In February 2018, President Trump submitted legislative principles to congress that outlined a new infrastructure framework, which promised to generate

> an unprecedented $1.5 to $1.7 trillion investment in American infrastructure. We're going to have a lot of public-private. That way it gets done on time, on budget, [....] much more rapidly than you would get them done as a government, as good as some of these governments are. [...] Washington will no longer be a roadblock to progress. (WhiteHouse.gov, 2018, para 14).

Yet, in private meetings with congressmen, President Trump has remarked that public-private that PPPs "don't work" (Newmeyer & Paletta, 2017; Dawsey, 2018) and are "more trouble than they're worth" (Mann & Hughes, 2017, para 2). White House officials within the Trump administration have remarked that PPPs

> are not the silver bullet for all of our nation's infrastructure problems and we will continue to consider all viable options. Just like with any new policy, there are legitimate questions about how P3s can best be incorporated into our nation's infrastructure program. [...] How do we best use the private sector in delivering infrastructure and infrastructure-like services, and we're looking for that balance (Mann & Hughes, 2017, para 5-6, 12).

These contradictory statements have created mixed signals and uncertainty surrounding the administration's commitment to leveraging private equity (Dawsey, 2018)

PPPs in California

At the state-level, legislation of PPPs is currently varied (FWHA, 2018), with eleven state (including California) providing a broad statutory authorization for P3 engagements (Gebhardt & Patella, 2017) and thirty-three states enacting statutes that enable the use of PPP approaches for transportation infrastructure provision (see Figure 5.1) (EPA, 2015).

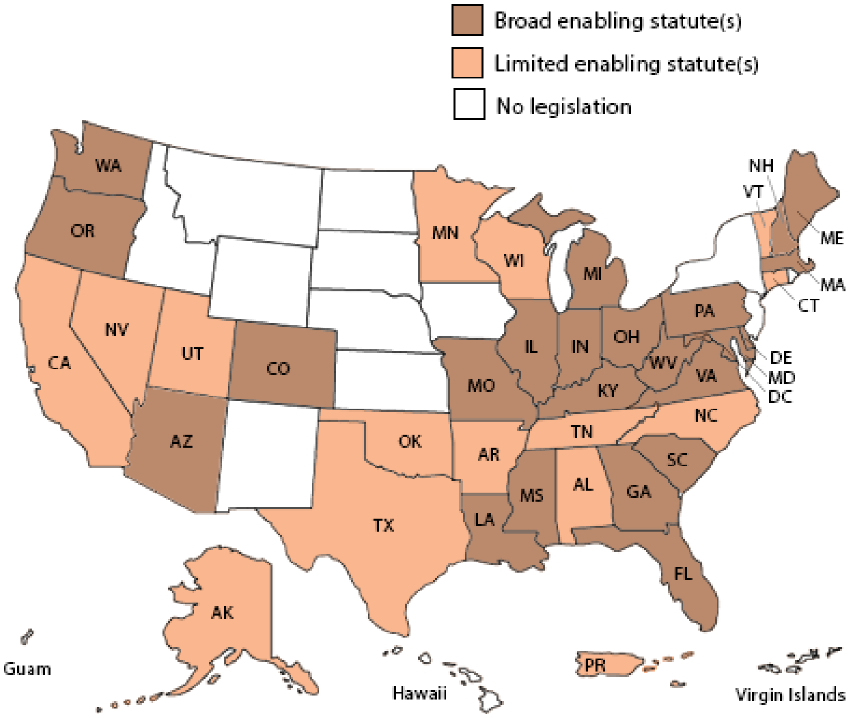

Figure 5.1. **Variations in state-level PPP enabling legislatures across the U.S.** Broad statutes are those that authorize a number of different agencies to participate in PPP development and/or include a variety of eligible projects. Meanwhile, limited statutes are those that limit PPP adoption to specific sectors (i.e. strictly toll roads) or to specific (FHWA, 2018)

California was one of the first states to pass state-level P3 legislation (Hewes & Randolph, 2018). AB-680 (1989), AB-1467 (2006); and SB-4 (2009) all authorized toll road projects within the state. The primary PPP legislature within the state of California is the 1996 California Infrastructure Finance Act (IFA) (California Government Code Section 5956). The goal of the IFA is to allow local government agencies to replace deteriorating infrastructure or build and expand new infrastructure facilities through private investment capital. The act provides a broad and flexible authorization for local government agencies to enter into P3s for "fee-producing[23]" infrastructure facilities including water, solid waste, and energy utilities, airports, harbors, transportation, and transit projects (California Legislative Information, n.d.).

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[23] Per California Government Code 5956 *et seq.*, a "fee-producing infrastructure facility" is one in which operation of the infrastructure project will be paid for by the persons or entities benefiting from or utilizing the project.

Local governmental agency may receive unsolicited proposals from private entities. However, final selection criteria of the private partner must demonstrate competence and qualification of the private entity. Following the selection process, “a competitive negotiation process” shall ensure that the “facility be operated at fair and reasonable prices to the user of the infrastructure facility services” and that the agreement includes a “provision for a buyout of the private entity by the governmental entity in the event of termination or default before the end of the lease term.” Public and private actors must coordinate with regulatory agencies to comply with the California Environmental Quality Act (CEQA). If the partnership results in an increase in user fees, the public partner shall conduct at least one public hearing at which public testimony will be received prior to imposing a new user fee. The IFA, thus, provides local agencies with “substantial discretion” on the procurement process and the contract structure of an infrastructure project (Strickland, 2012).

Under this state-level and local-level legislation, PPPs have been used to build a Civic Center for Long Beach; academic, recreational, and student housing facilities the University of California, Merced; an automated people mover and rental car facility at Los Angeles International Airport; and state routes 241, 261, 133, and 73 (Wunderman & Dunn, 2019). The County of Orange has also recently entered into a PPP agreement with Dana Point Harbor Partners to design, fund, and build improvements to the harbor and to lease the property for 66 years (Ritchie, 2018).

PPPs steadily gained traction and political support under the Schwarzenegger administration (2003 – 2011). The administration viewed PPPs as “an important tool that can help rebuild California's vital infrastructure while saving taxpayer dollars” (Schwarzenegger, 2010, para 2). In public speeches, Governor Schwarzenegger announced that “miracles can happen when the public sector and private sector work together" (Janis, 2008, para 5). Yet, political support shifted for PPP projects shifted under Governor Brown and Governor Newsom. Legislation authorizing toll road PPP projects expired on January 1, 2017 and has not been renewed by either governor (Hewes & Randolph, 2018). While Brown's administration (2011 – 2019) amended existing PPP legislation (Gruzen, n.d.) or enacted legislation that expedited specific projects (City of Long Beach, 2015), the administration provided no public statements in favor or against PPPs.

The Newsom administration (2019 – present) has launched preliminary discussions on the role of PPPs in California's housing crisis (2019). However, PPPs have not been identified as a dominant strategy for infrastructure or resource provision. In a recent interview, Governor Newsom stated "I absolutely support public-private partnerships, but [...] I have a stronger bias toward public-public partnerships." The Governor referred to public agency collaboration as "low-hanging fruit that gets no real attention" (Shueh, 2016). The focus on public-public collaboration is also stressed by state-level regulatory agencies such as the California Natural Resources Agency, California Environmental Protection Agency and Department of Food and Agriculture. In the 2020 State Water Resilience Portfolio, only one mention is made towards cross-sector collaboration: regulatory agencies will "establish an inter-agency and public-private task force that includes diverse stakeholders to prioritize key scientific questions [on how] to best manage water supplies and flood risk for all of California's needs. (CNRA, Cal EPA, & CFFA, 2020, p. 24).

COVID-19 Pandemic – Shifting Political Support of PPPs?

The COVID-19 pandemic may shift the federal- and state-level stance on PPPs. The pandemic has created a growing recognition that this public health challenge cannot be resolved without pooling resources and expertise across a variety of stakeholders (NLC, 2020). In April, the Trump Administration announced a public-private partnership to expand coronavirus testing capabilities (Taylor, Miller, Colvin, & Mascaro, 2020). The National Institute of Health also launched a PPP with biopharmaceutical companies to accelerate the development of a vaccine and treatment options (NIH, 2020). Similarly, in April 2020, Governor Newsom announced the formation of PPPs to promote distance learning and to provide financial support to undocumented immigrants impacted by the virus (Office of Governor Gavin Newsom, 2020a, 2020b). The partnerships appear to primarily focus on the provision of emergency funds and resources rather than the traditional form of infrastructure or service provision. The COVID-19 public-private response, thus, may create new PPP models and structures for addressing pressing public challenges.

This section established reviewed the broader regulatory frameworks in the United States and in the state of California for PPP adoption. While support for PPPs at the state-level has fluctuated, broad and flexible regulation has created an opportunity for partnerships to form between public and private actors. The remainder of this chapter examines the endogenous and exogenous drivers that enabled partners to move forward with projects rather than pursuing traditional procurement or consulting contracts to achieve their water management goals.

5.2 Defining PPPs

> *We're excited about it, but we haven't really tried. We're waiting for that right opportunity. But ... from everything we're hearing, it's something we should be pursuing. Or at least talking and having conversations with others about.*
>
> *- Member of a public agency, Respondent #5*

> *"Well, there are P3s and then there are…. **P3s"** [emphasized portion spoken with frustration and a grimace]*
>
> *- Member of an NGO, Respondent #13*

Figure 5.2: Top 55 words utilized by respondents in defining public-private partnerships. WordCloud created using NVivo.

Fieldwork revealed that definitions of a public-private partnership also varied across public and private water sector stakeholders in California. Figure 5.2 provides a visual representation of the language utilized by respondents to define public-private partnerships. Often, participants would struggle to come up with a definition, with many respondents laughing, sighing, or shaking their head (#1; #3; #5; #9; #13; #15; #20): “you're asking me to define something that's inherently expansive and it's.... “[shakes head and then laughs] (#1). The only element of the definition that respondents could agree on is that a PPP includes a public and a private actor (#1 - #21). However, respondents would differ on the type of private actor participating in the partnership, with some including non-government organizations and voluntary organizations into the definition (#1 - #3; #7; #8) while others referred strictly to the participation of a private company. Overall, definitions were often closely tied to the specific PPP project experiences of respondents (#1; #2; #6 - #8; #11 - #14; #19; #21). For example, one respondent who participated in a data-oriented project defined a PPP as “a group of people at a

	#1	#2	#3	#4	#5	#6	#7/ #8	#9	#10	#11	#12	#13	#14	#15	#16	#17	#18	#19	#20	#21	**Total**
Range of partnership types	X	X					X	X		X								X		X	**8**
Consultation as PPP		X		X														X			**3**
Includes public and private partner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**21**
Potential partners include both NGOs or private industry	X	X	X				X														**5**
Definition specific to past PPP experience	X	X				X					X		X	X	X			X		X	**9**
Output-Based Definition																					
Provides a public benefit	X		X	X		X							X		X						**6**
Provides infrastructure														X		X	X	X		X	**5**
Produces a turnkey project															X			X		X	**3**
Results in faster project completion time		X			X							X								X	**4**
Results in cost-effective infrastructure or resource provision		X			X							X									**3**
Has benefits and drawbacks												X						X			**2**
Process-Based Definition																					
Partnesr are working towards a common goal				X	X		X	X	X				X								**7**
Private partner driven by profit	X			X									X					X	X		**5**
Includes incentive structure for private partner	X		X																	X	**3**
Involves risk-sharing between partners	X											X	X			X	X				**5**
Partners pool resources or skills		X					X						X					X	X		**6**
Private partner mobilizes its superior resources					X				X			X						X			**4**
Private partner provides technical expertise		X				X						X							X		**4**
Involves knowledge transfer between partners		X					X														**3**
Public partners as an active participant																X					**1**

Table 5.1 Definitions of PPPs

[private] company getting officially 10% or some fraction of their time allocated to projects to benefit nonprofits and public sector organizations who need that kind of skillset" (#6).

Public and private respondents included potential benefits and drawbacks alongside (or sometimes instead of) the definition, suggesting that they view PPPs as a vehicle to accomplish specified outcomes or to gain access to benefits (see Table 5.1). Overall, PPPs were seen as a mechanism for providing infrastructure or addressing a specific problem in the water sector through knowledge transfer, risk sharing, pooling of resources, and leveraging the financial technical expertise of the private sector (see Table 5.1). Respondents stressed the "unique" or "innovative" nature of the partnership (#1 - #4; #11; #12; #17; #21), as organizations with "different background, different expertise, were coming together" (#7; #8; see also #12) under a common purpose or a mutual benefit (#4; #5; #7 - #10; #14). Four respondents immediately highlighted the profit-seeking nature of the private partners in the definition (#3; #4; #13; #14), but only two individuals suggested that PPPs inherently presents tensions and drawbacks in achieving policies that benefit the public (#13; #19).

Definitions usually included socio-economic outputs and outcomes as well as processes that enabled partners to realize these goals (see Table 5.1). Respondents with a background in contract agreements or economics prioritized risk allocation and performance-based guarantees as a distinguishing feature of PPPs (#3; #21), whereas those in leadership positions (i.e. General Managers, public officials) or those who were responsible for project development emphasized the benefits of a PPP to the public organization or to ratepayers (#1; #4; #5; #11; #15 - #17).

Respondents acknowledged that PPPs "can take on multiple forms" (#11), ranging from a traditional consultation (#2; #4; #19) to a design-build (#11) to a collaboration between diverse actors. Interestingly, even individuals working within the same district varied in their distinction between a collaboration and a consultation/design-build. According to one respondent, a traditional consultation model is one in which the private partner will “come in and build for you and then leave. I wouldn't necessarily call that a partnership. It’s paying for services.” (#1). Meanwhile, a respondent who worked on the same projects as #1, argued that consultation is a form of partnership because

> you're not confined to dealing with the problems inside the public sector. We bring in some private expertise from the private sectors and their knowledge and background. […] It’s an exchange, a collaboration of ideas and thoughts, to solve a problem. (#2).

5.3 Endogenous Drivers of Partnerships

How do you improve your community infrastructure or provide a higher level of service if you don't have money? Everything is about money.
- Member of a Public Agency, Respondent #19

Respondents highlighted three characteristics of PPPs that could motivate members from the public sector to collaborate with a private company. The first element is the efficiency of the private sector (#2; #5; #13; #20). Public partners saw opportunities for partnership when traditional approaches

> might take us too long or might cost us too much to do. […] If we were to try and meet some of these challenges on our own, it might take us years to do or it might not get done at all. But with a public-private partnership, you're able to leverage what each entity does best and get things done a lot more effectively - a lot quicker and a lot cheaper. And it's in the best interest of the public, in most cases. The project is done quicker, there’s less cost to taxpayers, and they end up with a better product in the end (#5)

Secondly, partnerships provide opportunities for members of public agencies “to work with people who are experts in their field” (#18; see also #1- #5; #21). Respondents highlighted learning from the private sector’s responsive nature to market changes or exogenous shocks (#4; #16). “We can look at their tools, their ways and learn from that. Because if we can do our job better, that automatically helps the people that we serve” (#4). Partnerships also presented opportunities to learn new methods (e.g. Machine Learning) or to adopt new technologies at a reduced risk to ratepayers (#2; #11; #15; #16; #21; Wunderman & Dunn, 2019).

Finally, respondents viewed PPPs as a way to overcome funding and technical capacity limitations of the public sector (#19; #21). One respondent stated that he was forced to turn to PPPs "because the feds and the state don't want to give us money to do infrastructure. So they're encouraging us to go out and find private sector capital" (#19). A water district has "tremendous financial obligations in providing reliable water service" (Shadowing, 12/18/2019). Public agencies can benefit from not spending money on a project in its conception phases (#11; #15; #16; #21; Shadowing, 12/18/2019). In a performance-based agreement, there are no upfront financial expenses to the public partner (Wunderman & Dunn, 2019). Moreover, risk of cost overruns are minimized throughout the project lifetime. To water managers, this element of upfront savings is critical (#21), as "all the cheap water sources are gone. Other than through conservation or conserving, the low hanging fruit [for developing local supply] has been plucked other than through conservation or conversion" (#11). PPPs, thus, are viewed as a form of long-term infrastructure provision that enables public agencies to shift budgets to meet immediate needs (#16 #19; #21):

> When should you do a P3? Well, you do it when you don't have funding to do it a different way. […] It's going to be more expensive at the end of the day. But you use that as a tool if you don't have the cash today. It's a bit like using a credit card. (#19)

These characteristics – private sector efficiency, opportunities for capacity building, and freeing up budgetary constraints – can be seen in the Rialto infrastructure upgrades. Due to limited budget constraints, the city of Rialto has chronically provided insufficient funding for the water and wastewater systems. While wastewater revenue was budgeted at $11.3 million, the division spent $14 million in the 2009-2010 fiscal year (Dulaney, 2010). Similarly, the water division budgeted $8.9 million, but spent $10.7 million during the fiscal year. Given the long history of contamination and poor financial health, Rialto councilmembers felt that the city would benefit from outside expertise. According to Councilman Ed Scott, “Water is not our [the city’s] primary focus and we don’t do a good job of managing and running it” (Dulaney, 2010, para. 11). City officials argued that a lease agreement could allow Rialto to address its ageing infrastructure system during “these tough economic times” and “could bring a big payment to the city up front” (Dulaney, 2010, para 17). Due to the critical condition of the water system, water users would be facing “significant rate hikes whether or not [a private company] entered the scene” (Steinberg, 2011c, para 10).

Funding constraints and limitations in technical capacity drove the city to issue a Request for Proposals (RFP) in March 2010. The City opened a competitive procurement process for either concession or O&M contracts for water, wastewater, and recycled water services (Callahan, 2012; Hughes, 2016)

5.3 Exogenous Drivers of PPP Adoption

Process tracing of projects revealed that the exogenous push to adopt PPPs emerged 1) as a direct response to regulatory-driven or drought-induced water scarcity, and 2) through unsolicited proposals by the private sector.

Drought as a Driver of Change

Drought can contribute to public sector uptake of PPPs through two separate mechanisms. First, drought highlights system vulnerabilities to climate vulnerabilities and hydrological reductions in water supply (#5; #13; #16; #17; #21). The 1987 to 1992 drought for example, was one of the prominent drivers of the Carlsbad Desalination facility (#17; #21; Shadowing, 12/18/2019; Rivard, 2017a; SDCWA, 2019a). During the drought, Metropolitan

Water District was forced to cut urban delivery supplies by 20% and agricultural deliveries by 50% (Zetland, 2009). The water agency most affected by this curtailment was the San Diego County Water Authority (SDCWA, 2019a). San Diego County lacks local water sources (#17; #20; Rogers, 2014) and at the time of the drought was 95% reliant on MWD for imported water (#20; Shadowing, 12/18/2019; Rivard, 2017a; SDCWA, n.d.). The severity of the drought forced MWD to cut deliveries to the San Diego region by 31% (SDCWA, n.d.), resulting in economic losses of millions of dollars. The drought highlighted SDCWA's reliance on MWD and the need to diversify its supply (Shadowing 12/18/2019; Fikes, 2015; Zetland, 2009). The Water Authority stated "Never again!" (Shadowing, 12/18/2019; see also Phillips, 2013, p. 4; Weston, 2016b, para 1) and approved a $4.3 billion capital improvement budget to guarantee that the region would have a reliable water supply, with many of the proposed projects creating duplicate infrastructure to MWD's (Weston 2016a, 201b; Zetland, 2009). As early as 2000, the Water Authority identified seawater desalination as a potential new local water supply source in its Urban Water Management Plan, citing the City of Carlsbad as a likely location for a new facility (Weinberg & McCraner, 2012). By November, 2002, SDCWA Board of Directors approved a Term Sheet with Poseidon outlining key roles, obligations, and benefits of partners (#21; SDCWA, 2002). Thus, "the die was cast" to pursue desalination once the project was included in the SDCWA's water supply portfolio (#21).

> It was in the planning documents, so I would have seen SDCWA moving forward with that project under a different... You know, it may have still been under a public-private partnerships similar to the one that SDCWA is in now. It just might've been with a different company (#21).

The recent drought (2011-2017) provided a similar impetus for public utilities. The drought was "a huge wake up for both the water purveyors across the state […] Water supply agencies started looking at ways to build and expand on their water supply portfolio. They realized that they could no longer just depend on imported water" (#5; see also #11; #13; #15; #16; Observation 8/30/2018; Observation, 8/29/19). The drought has also highlighted the importance of collaboration. Water sector stakeholders are "realizing that […] we can no longer be successful moving forward working in silos. We all have to work together and integrate, and partner, and collaborate" (#5).

Water managers and project participants may also pursue PPP projects in direct response to concerns of regulatory responses to drought that mandate current and future water use and allocation. The 2015 Conservation Mandate "pushed districts in new directions," and forced water managers to pursue more innovative and aggressive solutions to manage water locally (Observation, 8/30/2018). Representatives from one district expressed concern that similar regulations will create challenges in providing future water supply.

> During the drought, we were forced to cut back even more than everyone else [because the mandate did not account for already developed local supplies]. Well, that didn't mean that the people we serve didn't need the water. It just meant we almost got penalized for planning ahead and doing a good job of maintaining our water. And I don't ever want to be in that position again. (#16)

The representative wanted to secure additional sources of local supply to ensure adequate availability in the future, even in the face of regulatory curtailments.

Unsolicited Proposals – Creating Alternative Approaches to Water Management

The second source of exogenous pressure for water managers to adopt public-private partners is unsolicited proposals (USPs) from private companies. Six of the seven infrastructure PPPs began with a potential private company proposing a partnership (#11; #14; #15; #16; #20; #21). Only the Rialto PPP was initiated by the public partner through a procurement process (Hughes, 2016).

Private partners may be motivated to enter into partnerships for a variety of reasons. First, USPS allow the private partner to enter into a previously closed market. Under state regulation, a private entity cannot legally distribute water to homes and businesses without oversight from the California Public Utilities Commission (Strickland, 2011). Private project developers such as Cadiz and Poseidon, thus, must seek out a public entity to purchase the water produced through a project. For instance, the Carlsbad desalination project is

> a private venture in terms of the development [meaning Poseidon bears all development risks]. It's a public-private partnership because water in California, for the most part, is conveyed through public agencies. […] Poseidon is essentially a wholesaler and the water then is conveyed to [public] retail water agencies who do have the statutory authority to deliver water to homes and businesses. The private entity couldn't. They'd be stuck with a plant that's producing drinking water that couldn't go anywhere [chuckles]. That's why you need the public side of the public-private partnership. (#17)

The PPP, thus, provides an opportunity for the private sector to "put private capital to work and to realize a return for their investors that is fair and steady" (#17) while adhering to regulatory constraints on resource provision. In other words, the partnership is a way for private partners to achieve "their business model. They're trying to make money on better [resource] management" (#14).

Private partners may also pursue USPs as an opportunity to pilot new technologies (#1 - #4; #11; #12; #14; #17; Phillips, 2013; Rogers, 2014; Perry, 2015). For AMS and Poseidon, for example, a demonstration of success provides opportunities to enter into new partnerships. Proof that the technology can be effective and financially viable can reduce barriers to adoption, particularly in a risk-averse environment such as the water sector (#1; #14; Observation 8/30/2018, Observation 8/29/2019). According to the perspective of one respondent, AMS has grown "probably grown 10 times its size" since IRWD partnered with them (#14). The success of behind-the-meter storage in locations such as IRWD has expanded demand for this type of technology (see Wesoff, 2020).

In discussions of the Carlsbad facility, interview respondents argued that the facility was "a poster child for the success of a P3 in the water sector" and is proof that the private sector can be effectively involved in water management and provision (#17; see also #21). Media articles have also viewed the Carlsbad facility as a test case for future desalination in California (Phillips, 2013; Rogers, 2014; Perry, 2015). While desalination has been widely used in Israel and Saudi Arabia, the technology has only been introduced within the state at a smaller scale in areas where water supply is limited (e.g Catalina Island). (#16; Fikes, 2015). Fifteen desalination facilities are proposed to be built along the West Coast (Rogers, 2014). Thus, "for Poseidon Water and for the international desalination industry — [the plant] presents an opportunity to try to disprove the criticism that dogs such projects: that they are exorbitantly expensive, hog energy and damage the environment" (Perry, 2015, para 5). "Everybody is watching Carlsbad to see what's going to happen" (Rogers, 2014, para. 10).

Finally, private partners will propose PPPs to achieve broader water-related goals and policy objectives. In the case of the Energy Storage Project, the retirement of the San Onofre Nuclear Generating Station (SONGS) created a 2,000 to 2,2000 megawatt (MW) gap in local power capacity (#14; Observation, 8/30/2018; IRWD Board of Directors Meeting, 2016). The California Public Utilities Commission requires utilities to demonstrate that they have enough energy capacity to meet 115% of peak load (Observation, 8/30/2018). Southern California Edison awarded Advanced Microgrid Solutions (AMS) with a 10-year contract to provide 50 MW of behind-the-meter energy storage (#14; Observation, 8/30/2018). "Once AMS won that contract, they were trying to find homes for where they can start parking the energy. And IRWD was one of those at the top of the list because of its facilities, its energy usage: IRWD is one of the bigger water utility agencies in the area" (#14). AMS entered into a partnership with IRWD in 2016, and coordinated with the water district to design and install the battery storage systems by 2017 (#14). Both partners benefit from cost-savings While SCE is not a formal partner, the electricity provider is able to reduce peak energy loads by instructing AMS to dispatch battery energy for anywhere between 15 minutes to 4 hours a day, for up to 80 hours per month (IRWD Board of Directors Meeting, 2016). The Energy Storage Project, thus, is part of a broader effort by SCE to meet regulatory compliance and to smooth out fluctuations in energy demand (SCE, 2020; Wesoff, 2020). By 2017, SCE had nearly 400 MW of energy storage under contract across various locations, and has signed seven new contracts for an additional 770 MW of lithium-ion battery-based energy storage (Wesoff, 2020).

The Gobernadora Multipurpose Basin is part of a broader effort to meet local land-use requirements. When Rancho Mission Viejo (RMV) first began construction of Coto de Caza in the 1980s, a channelized creek, Canada Gobernadora, was built within the community to remove stormwater from the region as quickly as possible (SMWD, 2014). The creek did not include the means to reduce or detain flows. As a result, largescale storm events damaged water district infrastructure (SMWD, 2014) and caused "significant ecological erosion damage" along Gobernadora Creek and to GERA[24], the downstream ecological preserve (Zenger, 2015, para 5). Thus, when the County of Orange granted land use entitlements and EIR approval for the development of 14,000 new homes and five million square feet of land for non-residential uses (RMV, n.d.), the regulatory agency required RMV to build and maintain a storm water

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[24] Gobernadora Ecological Restoration Area (GERA) is a 105-acre area that has been restored from agricutral land into wetland and woodland (RMV, n.d.). The protected area was created in cooperation with the CA Department of Fish and Game, the US Fish and Wildlife Services, and the Army Corps of Engineers in 1994 as part of broader mitigation efforts for the Ranch.

mitigation facility in Gobernadora Canyon to control flooding and urban storm runoff (#12; #20; County of Orange, 2012).

Finally, the Lake Mission Viejo project was driven by the need to protect property values surrounding the recreational lake. Lake Mission Viejo (LMV) is a 124- acre man-made lake that was built in 1976. The lake holds approximately 3,800 AF of water (LMV, n.d.), and loses about 500,000 gallons a day to evaporation and natural seepage (SMWD, n.d.-c) or roughly 300 (#11) to 600 AFY (LMV, 2015). LMV has historically been re-filled with precipitation and potable water imported from MWD. During the recent drought, Governor Jerry Brown raised questions of "nonessential" water usage and publicly criticized Lake Mission Viejo for filling the lake with potable water while others "use buckets to collect water in their showers" (Stevens, 2014, para 3). Similar concerns were raised about the LMV in the 1974-1977 drought, when the State Water Resources Control Board (1977) declared filling the lake a "waste and an unreasonable use of water," and prevented Mission Viejo Company from filling the Lake until the water rationing mandates had been lifted. The lake is viewed as a symbol of the town and it culture (#11) and serves as a "big boost for local property values" (Shimura, 2015, para. 1). Regulatory restrictions threaten to reduce LMV's shorelines and water quality, thus negatively impacting property values of homes in the city of Mission Viejo[25] (see Kashian & Winden, 2015). To prevent future physical or regulatory restrictions on sources of lake refill, the LMVA Board of Directors approached SMWD with the goal of identifying a "sustainable, reliable, cost-effective source of local non-potable water" (SMWD, n.d.-c, para 10) that "consistently meets water quality standards that will allow for the continued recreational use of the Lake" (SMWD & LMVA,

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[25] For example, Kashian & Winden (2015) estimate that regulatory restrictions on the water level in Lake Koshkonong, Wisconsin, reduced property value of each home by roughly $20,000. The next impact of homes lost was calculated to be roughly $8.3 million, or 10% of aggregate value of the waterfront homes.

2017). SMWD and LMVA agreed on a facility design and water quality standards that will ensure that the Lake meets regulatory standards and maintains water quality levels suitable for recreational activities (#11).

5.4 Discussion

This chapter explored the motivations of public and private partners to enter into PPP agreements. PPP adoption is driven by a combination of both internal demand by public and private entities to pursue projects and broader natural and regulatory drivers. Together, these endogenous and exogenous forces create windows of opportunity for entering into PPP arrangements.

The regulatory environment played a pivotal role by legally establishing a market for PPPs. A broad regulatory framework for PPP participation was enacted in California in 1996. The Infrastructure Finance Act opened the market for potential PPP projects in all sectors: private partners such as Cadiz, Poseidon, and Rancho Mission Viejo began pursuing opportunities to participate in water PPPs as early as 1998. The high flexibility of the PPP regulation in California enabled the development of projects that are well-suited for local community needs (see EPA 2015a). Support during the Schwarzenegger administration may have buoyed private sector confidence in PPP projects, while later on the Obama administration directly increased opportunities for water sector PPPs through the Water Infrastructure Finance and Innovation Act. One project has even already benefitted from the program. A WIFIA loan for the Huntington Beach Desalination facility has reduced the cost per acre foot of water by $200 (#15).

Next, droughts promoted institutional and technological change by creating a sense of urgency (Lund et al., 2018). The salience of water scarcity concerns can lead to the adoption of supply-driven hard-infrastructure approaches that may otherwise be rejected by the public or government officials (Farrelly & Brown, 2011). This may be how projects that are traditionally considered to be controversial, expensive, or maladaptive (see Barnett & O'Neill, 2010) such as desalination and the Cadiz groundwater storage project to became politically feasible options for water districts. Supply reductions – particularly those driven by climate change –can also encourage new cross-sector partnerships. Rising demand for climate resilience among actors can foster innovation and can enable the development of collaborative responses (Averyt et al., 2018). The perception that PPPs will lead to efficient and cost-effective projects, transfer knowledge or skills to the public sector, free up public agency budgets, and allow the water sector to close the infrastructure gap at the state and federal level have encouraged public water districts to form formal and informal collaborations with the private sector.

The internal demand for PPPs, coupled with the push to develop local supplies or to increase water use efficiency, can also create opportunities for private companies to submit unsolicited proposals (USPs). Unsolicited proposals are a relatively new development in the United States (Hewes & Randolph, 2018). USPs may allow projects to reduce bottlenecks in early stages, as the private sector have the technical and financial resources to conduct feasibility studies (PPP Knowledge Lab, 2019). However, as private partners propose projects that support their own needs, USPs may divert public agencies from their original water management strategy. When PPPs are over-designed or overestimate demand, ratepayers bear the costs (Fridegotto, 2017) for maladaptive or ill-suited projects that are not aligned with a community's needs (Mert & Dellas, 2012). Private partners such as Cadiz and Poseidon selected projects that they believe will be profitable and will deliver a steady return on investment. While respondents assure the proposals are driven by the needs of public agencies (#11; #21), USPs may create pressure to adopt a water provision strategy that the district might not have otherwise pursued:

> It is kind of a unique opportunity for a private company to come in and develop such a large water supply in your backyard. And you have to wonder, will this opportunity ever be there again if you don't take advantage of it right now? (#15)
>
> Some people say, "it may not be the time right now." But I could argue - you can't time projects like this. And if you ever do get an opportunity to do a project of this nature that you ought to do it, even though it might be a few years ahead of its time. (#15)

USPs, thus, reduced additional barriers to entry for PPP projects. In the case of desalination, for example, OCWD had previously constructed a desalination facility in 1975 (#16) in collaboration with the Department of the Interior's Office of Saline Water (OCWD, n.d.). Water Factory 21, a recycled water treatment plant and multi stage flash distillation seawater desalter, was developed to create a seawater intrusion barrier and to develop a local supply of potable (OCWD, n.d.). Unfortunately, the Arab oil embargo increased energy prices to a point where the project was no longer feasible. The facility was operational for only one year before the federal government withdrew funding and the project was stopped. While the facility was torn down (#15), the piping infrastructure for the project remains (#16). Poseidon's development of the project presents an opportunity for OCWD to re-evaluate desalination as a source of local water supply.

This chapter ultimately reveals a combination of factors must come together for water utilities to adopt PPP arrangements. These endogenous and exogenous drivers are interrelated and feedback to on each other to create the initial opportunities for partnership formation. The momentum for partnerships is maintained by broader definitions of district sustainability and resilience (see Chapter 4). For example, the IRWD Energy Storage was brought together by four factors (#13; Observation, 8/29/2018). First, the retirement of the San Onofre Power Plant in

2013 produced a local resource gap and brought the salience of the issue to SCE and small businesses. Second, AMS's unsolicited proposal allowed IRWD to identify a private partner capable of installing, programming, and operating the technology. Third, $11,000,000 in funding opportunities through SCE and the Self-Generation Incentive Grant Program created the means to purchase the technology and install the batteries across six sites at the water district. Finally, there was a shift in IRWD's approach to resource management, with a growing focus on recovery and beneficial reuse of water and its related resources such as energy (e.g. biosolids). Within the state of California, the transportation, heating, and treatment of water accounts for 20% of total electricity and 30% non-power plant related natural gas consumption (IRWD, 2017). The district spends roughly $10 million per year on energy usage, equivalent to 9 to 12% of IRWD's total costs (Observation 8/29/2018; Cook, 2016). To minimize these costs, IRWD has designed and implemented an Energy and Greenhouse Gas Master Plan. The district also commission a "groundbreaking" study to examine "energy use associated with collection, use, reuse, and disposal of water and biosolids in IRWD's service area" (Navigant Consulting & HDR Engineering Inc., 2015, p.vi) and to quantify energy savings and GHG reductions from water conservation programs between 2005 and 2013. This is the first time a public water agency actively commissioned this research (IRWD, 2017). Thus, while economic value served as an incentive to consider the agreement, the district's recent focus on energy efficiency reduced barriers to entry for the partnership formation.

Policy Recommendations

The examination of the origins of the first water sector PPPs has highlighted three challenges for PPP adoption. First, political support for PPPs has fluctuated throughout the last two decades as state and federal level political administrations have changed political parties.

Past empirical studies have identified political risk as a critical failure factor of PPPs (Trangkanot & Charoenngam, 2014). In California, the shifts in political support did not serve as an ultimate deterrent for PPP adoption. Because PPP legislation is enacted at the state rather than the federal level in the US, projects are more sensitive to the political support and values of lower levels of government (EPA, 2015a). However, a shifting political climate may have ultimately increased project costs in the long run by heightening regulatory risk for the private sector. Political support for PPPs by the main political parties must be stable over time in order to create a climate that bolsters private sector confidence and creates consistent procedures for procurement and PPP management, (Dulami et al., 2010; Matos-Castano et al., 2014).

Second, the chapter highlights the definitional ambiguity of PPPs. Similar to the academic literature (see Greve & Hodge 2013; Hodge & Greve 2007; Nizkorodov, 2017; Miraftab 2004; Weihe, 2008), respondents defined PPPs with variations in levels of private sector involvement, project outputs, and ways of structuring the partnership (performance-based, pooling of resources, etc.). Some respondents also blurred the lines between privatization, design-build practices, and public-private partnerships. This imprecision can hinder PPP project success. If definitions of P3s do not align between partners, then partner expectations and obligations will not be complementary (Weihe 2008). Moreover, slight variations in the definition in the political sphere can promote different agendas either in favor or against the policy mechanism. Developing PPP-enabling institutions at the state and federal level will require greater clarity on the definition of PPPs and their various applications.

Finally, the research revealed the diverging motivations for public and private partners to enter into PPPs and confirmed that uptake of PPPs require projects to generate both social and economic value (see Kivleniece & Quelin, 2012; Parado & Reynaers, 2018). Public partners were motivated to enter into PPPs to reduce vulnerabilities to water supply and to overcome technical and financial constraints. Conversely, private partners are motivated to enter into a PPP arrangement to gain direct and indirect economic value. Past studies reveal that private companies enter into PPPs to achieve profits, gain new consumers, increase access to resources, increase the reputation and legitimacy of the firm, and increase the likelihood of future contracts (Kivleniece & Quenlin, 2012; Shambaugh & Matthew, 2016). These motivations are also seen across the 10 cases: private companies approached public partners to pilot technologies, achieve water-related objectives (e.g. new development, maintaining property values), and receive returns on private equity (#14; #17; #20).

Diverging priorities between public and private partners may promote the adoption of maladaptive projects. Because Design-Build-Operate PPP contracts provide opportunities for the public sector to defer payment until the facility reaches commercial operation, PPPs have been described as a mega-credit card policy mechanism (Hodge 2004, p. 46; see also Hodge & Greve, 2007). This credit card rationale has the potential to bias policy-makers and public managers away from cheaper or more robust alternative approaches to infrastructure provision (van der Hurk, 2018) or will encourage the public sector to adopt water management pathways that are driven by private sector- rather than public sector interests (see Chapter 7). Public sector participants must view PPPs as a way to improve long-term service delivery through private sector efficiency and value for money – rather than as a merely form of private financing to make quick gains infrastructure projects. This shift in perspective allows decision-makers to adopt a long-term view of PPP development (Matos-Castano et al., 2014) and can thus incentivize policy-makers and public entities to incorporate lessons learned into a broader PPP agenda.

6.0 PUBLIC-PRIVATE DATA COLLABORATIVES: an ALTERNATIVE APPROACH TO WATER MANAGEMENT

The rise in complex socio-technical challenges that cross boundaries and jurisdictions has pushed the water industry into the "fourth revolution" (Sedlak, 2014). At the same time, the water sector is undergoing a digital transformation (Lach & Rayner, 2017; SustainOC, 2020) driven by the global digital revolution (Garrido-Baseba et al., 2020). The development of remote sensing technology and wireless communication has provided unprecedented opportunities to cost-effectively collect large sets of data (Zhao & An, 2019). There have also been advancements in the ability to store, retrieve, and process large data sets (Ponce Romero, et al., 2017; Zhao & An, 2019). It is estimated that 80% of utilities in developed countries and 50% of utilities in developing countries are expected to undergo a digital transition by 2025 (Wotezel et al., 2018).

Yet, a recent survey of members in the American Water Works Association (AWWA) suggests that only one in five utilities utilize data mining to improve the operation and maintenance of their water and sewer systems (Walton, 2019). Without the correct analytical tools, the rise in the speed and volume of data coming in can result in a data-rich and information-poor[26] environment (Timmerman et al., 2010; Ward et al., 1986). Data is often stored across various platforms (Excel spreadsheets, text documents, internal databases), making it difficult to build a comprehensive understanding of water usage and efficiency (Zhao & An, 2019). "Vast amounts of data are languishing in databases, which are best described as data graveyards and can certainly not be considered data mines" (Corominas et al., 2018, p. 89). Introducing new ways of analyzing and consolidating these data sets can assist in monitoring and

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[26] Data-Rich Information-Poor (DRIP) Syndrome was first introduced in the business sector by Peters & Waterman Jr., (1983). It refers to a situation in which data is being collected without a clear view or defined process of how to produce meaningful information from it.

evaluating water management strategies and policies in real-time (Gariddo-Baserba et al., 2020; Verhulst et al., n.d.) and can improve efficiency of existing systems (Woetzel et al., 2018).

Data collaboratives, or cross-sector (and public-private) data partnerships in which parties collaborate to combine, integrate, and process data in order to solve public problems (Susha et al., 2017a, Verhulst & Sangokoya, 2015), may be a way to overcome data-rich and information-poor environments in the water sector. These data-oriented collaborations can lead to innovative solutions to pressing social challenges (Klievink et al., 2018; Susha et al., 2017a), can enable effective decision-making policy-making, and can improve resilience of natural and human systems (Data Pop Alliance, 2015). However, while studies suggest that data collaboratives face institutional, technical, and relational challenges (Klievink et al., 2018; Mikhhaylov et al., 2018; Susha et al., 2017b), little is known about how such collaborations are formed and sustained (Susha et al., 2019). This chapter, therefore, examines the uptake, formation, implementation, and outcomes of three public-private data collaboratives at Moulton Niguel Water District (MNWD).

Past practitioner and academic literature on data collaboratives has primarily been conceptual rather than empirical (Susha et al., 2019): a literature review of data-driven social partnerships found that only 8 out of 38 papers between 2003 and 2017 are empirical works. These empirical studies have focused largely on public-public partnerships (see Johnson, 2005; Love et al., 2008; Masser & Johnson, 2006; Priest et al., 2014), creating a gap in understanding of the processes of managing public-private collaborations. Due to diverging values and organizational cultures between public and private actors (see Chapter 5 and Chapter 8), methods for developing public-public partnerships cannot be transposed to public-private ones. The private sector may require different value propositions to be willing to share sensitive data or to dedicate resources to social challenges (Robin et al., 2016; Susha, 2020). Thus, this research closes a critical literature gap in the growing field of cross-sector data collaborations.

Following a brief literature review, the chapter then provides a brief summary of three data-collaborative projects, and examines cross-cutting themes across cases on processes and impacts of these data-oriented PPPs. The chapter concludes with a discussion of factors that may impact replicability and scalability of public-private data collaboratives within the water sector and highlights data-related and privacy risks of these new partnership structures.

6.1 Literature Review

The private sector can participate in data collaboratives in several ways. Corporations can share private data (see McKeever et al., 2018), or can assist directly in building the infrastructure to collect, analyze, or share datasets[27] (Robin et al., 2016). The private sector can also leverage its expertise in new data analysis methods. Big Data Analytics applies artificial intelligence[28] (AI) and machine learning (ML) to large data sets to provide tools for decision-making. ML methods allow for the analysis of non-linear and complex data-sets, and can uncover relationships that may not be detected by traditional statistical methods (Onyeneho, n.d.). These methods have been rapidly adopted by businesses worldwide[29], and have the potential to increase

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[27] For example, in 2015 NOAA partnered with Amazon, Google Cloud, IBM, Micrsoft Corp, and the Open Cloud Consortium to create a cloud-based open data platform (Commerce.gov, 2015).

[28] Artificial Intelligence trains computers to identify patterns and complex interactions among variables within large data sets and to make predictions based on the rules discovered (Onyeneho, n.d.). Machine learning is a type of AI that allows computer systems the ability to “learn” and improve pattern recognition and application with minimum human intervention. Machine learning can be supervised (applying past relationships or information from an old data set to a new one), unsupervised (unlabeled and unclassified exploration of a data set to draw out inferences), semi-supervised (the introduction of a few predicted relationship to train the machine), or reinforced (human intervention reinforces which paths or contexts are ideal) (Expert System Team, n.d.).

[29] Businesses primarily utilize Big Data Analysis to identify opportunities for cost-savings, streamline operations, and predict consumer preferences (Onyeneho, n.d.). A simulation of the impact of AI on the global economy suggests that roughly 70% of companies will adopt at least one type of AI technology by 2030 (Bughin, Seong, Manyika, Chui, & Joshi, 2018)

economic output by roughly $13 trillion by 2030 (roughly 1.2% of global GDP) (Bughin et al., 2018).

There is a rise in demand for the application of Big Data Analytics to environmental resource management (Walton, 2019), as classical methods of data analysis may be insufficient in coping with the size, speed, and diversity of information sources that support higher level decision-making (Gibert et al., 2018; Ponce Romero et al., 2017). However, application of ML and AI methods to the water sector is currently limited (Corominas et al., 2018; Hadjimichael et al., 2016; Ponce Romero et al., 2017). A review of 340 papers on improved wastewater treatment operation through data solutions found that 84% of papers were “an academic exercise,” while only 9% of publications resulted in products that were tested in a real setting (Corominas et al., 2018).

The water sector has always collected and analyzed data to aid in decision-making and operation (Rayner et al., 2005; Rayner & Lach, 2017). In O&M, the sector has traditionally relied on “predict-and-plan” methods– water managers forecast desired states of water supply and then identify the infrastructure needed to achieve these goals (Gober, 2013). This approach, however, assumes that key features of systems can be predicted. If conditions shift suddenly, utilities will be locked-in to infrastructure that is no longer the best available approach to water management. To increase resilience and flexibility of water systems, there is a need to develop new methods and practices. However, public expectations of reliability, safety, and affordability create high risk-aversion among water managers and reduce incentives to invest in novel data applications (Feldman & Ingram, 2009; Kiparsky et al., 2013; Lach et al., 2007; Lopez & Haines, 2017; Rayner et al., 2005; Sustain SoCal, 2020). For instance, while weather forecasting tools were developed in the 1980s, water managers only began to adopt the technology twenty to thirty years later (Feldman & Ingram, 2009; Lach & Rayner, 2017; Lowrey et al., 2009).

Scholars have identified two main reasons to explain the slow uptake new data tools such as climate forecasting. First, climate and hydrological forecasting technology has been producer- rather than user-driven (Cash et al., 2006; Rayner et al., 2005), creating a “water information gap” between those producing forecasting tools and those using them (Corominas et al., 2018; Feldman & Ingram, 2009; Hadjimichael et al., 2016; Timmerman et al., 2010). When knowledge producers have limited practical experience in water management practices they fail to provide data or tools that are relevant and customized to user needs (Corominas et al., 2018; Hadjimichael et al., 2016). Second, water managers are constrained by past policy and infrastructure decisions (Rayner et al., 2005) and existing norms and heuristic practices (Feldman & Ingram, 2009). Water managers often viewed these new decision-making tools in terms of how much work it would be to make a new strategy fit into the old system (Rayner et al., 2005). Moreover, uncertainty (lower levels of forecasting confidence) was viewed as unreliability (Feldman & Ingram, 2009; Lopez & Haines, 2017), creating distrust among water managers towards the efficacy of climate forecasts (Rayner et al., 2005). Thus, while water managers could imagine multiple uses for this technology in other agencies, they were reluctant to pursue the strategies themselves (Rayner & Lach, 2017; Rayner et al., 2005).

These organizational constraints on adopting novel data-oriented solutions can create additional barriers in developing and implementing data collaboratives. Data collaboratives are an emerging experimental form of addressing public challenges with private sector resources; the impacts and risks of these partnerships and are not well understood by public managers and policy-makers (Blumenstock, 2018; Susha & Gil-Garcia, 2019). Empirical studies suggest that data collaboratives experience not only data-related and technical challenges (e.g. matching research/policy questions to available data), but also regulatory and organizational ones due to diverging institutional logics and values between participants (Mikhaylov et al., 2018; Susha et al., 2017b, 2019; Susha, 2020). To incentivize the private sector to share data or dedicate technical expertise to the collaborative, partnerships must be designed generate both economic and social value (Kivleniece and Quelin, 2012). Private sector companies may be incentivized to enter into data collaboratives to pursue new revenue streams; gain access to other valuable datasets, especially those that might affect the company's business decisions; comply with regulations; and to increase their reputations (e.g. publicity, increased public support) (Klein & Verhulst, 2017; Holton, 2018; Robins et al., 2016). If power asymmetries emerge within the partnerships, these economic goals may be pursued at the expense of social benefits of partnerships (Klievink et al., 2018)

Challenges in collaboration due to diverging goals, faulty assumptions, and low communication have been identified as one of the biggest obstacles for data for social good initiatives (Susha et al., 2019; Vaitla, 2014). Coordination challenges increase when there are multiple data providers or multiple data users, as it becomes difficult to align incentives and objectives of participants (Klievink et al., 2018; Susha et al., 2017b). Water agencies or private companies may be reluctant to share datasets due concerns of violating privacy of resource uses (Garrido-Baserba et al., 2020; Robin et al., 2016; Susha et al., 2019) or possible misuse misinterpretation of data by third parties (Eggimman et al., 2017; Klievink et al., 2018; Sugg, 2018; Zuiderwijk & Jannsen, 2014). Data may be collected for one purpose, but may be used for another purpose once shared (Susha et al., 2017b), creating negative consequences such as reduced competitive advantage in the market or greater scrutiny of past organizational decisions

(Klievink et al., 2018; Patterson et al., 2019; Sugg, 2018). These real or perceived data-related risks and vulnerabilities often result in the development of strict governance and contractual arrangements (Klievink et al., 2018), which can hinder collaboration and innovation (Parrado & Reynaers, 2018). Facilitating data collaboratives ultimately requires new forms of organizing: participants must consider what skills are necessary for the project, who should be involved, the conditions on which data can be shared, what conclusions can be made and enacted from policies (GovLab, n.d.; Mikhaylov et al., 2018; Susha et al., 2017a, 2017b).

Within the water sector, institutional constraints and risk-aversion may limit the extent to which water utilities can invest in new data capabilities and develop new ways of organizing. Thus, to understand factors that might influence uptake of data collaboratives and Big Data Analytics within the water sector, this research examines the development and implementation of three data collaboratives.

6.2 Overview of Cases

Moulton Niguel Water District was established in 1960, and presently provides drinking water, recycled water, and wastewater services to 170,000 customers across six cities in Southern California (MNWD, n.d.-a). MNWD has been described by staff and external participants as business-oriented, placing a heavy emphasis on cost effectiveness of projects, affordability, and long-term financial sustainability (#1; #3; #4; #9). To support this philosophy, MNWD places a high emphasis on data-driven decision-making (#1-#5; #9; MNWD, 2015) and is a proponent of sharing data analysis approaches with other organizations: the district has co-organized and participated in hack-a-thons (Observation, 8/29/19), and members of the District have frequently spoken at public events and conferences about the need for data-sharing infrastructure and the use of big data analysis in decision-making (#4; #5; #9; Observation, 8/29/19). According to interview respondents (#1 - #4) and media articles (Robinson, 2019), the district is also one of the few public agencies that has rate analysts/data-science experts in-house.

> And it's been vastly helpful for our agency…. Not having rate experts in-house is a deficiency. A consultant would come in every three to five years and they build you these dashboards and models, and none of your staff know how to use it. [...] And so you don't have that capability designed and functioning. When you bring this expertise in-house, you can build models, you can improve on them, you can explain the rates better. (#4)

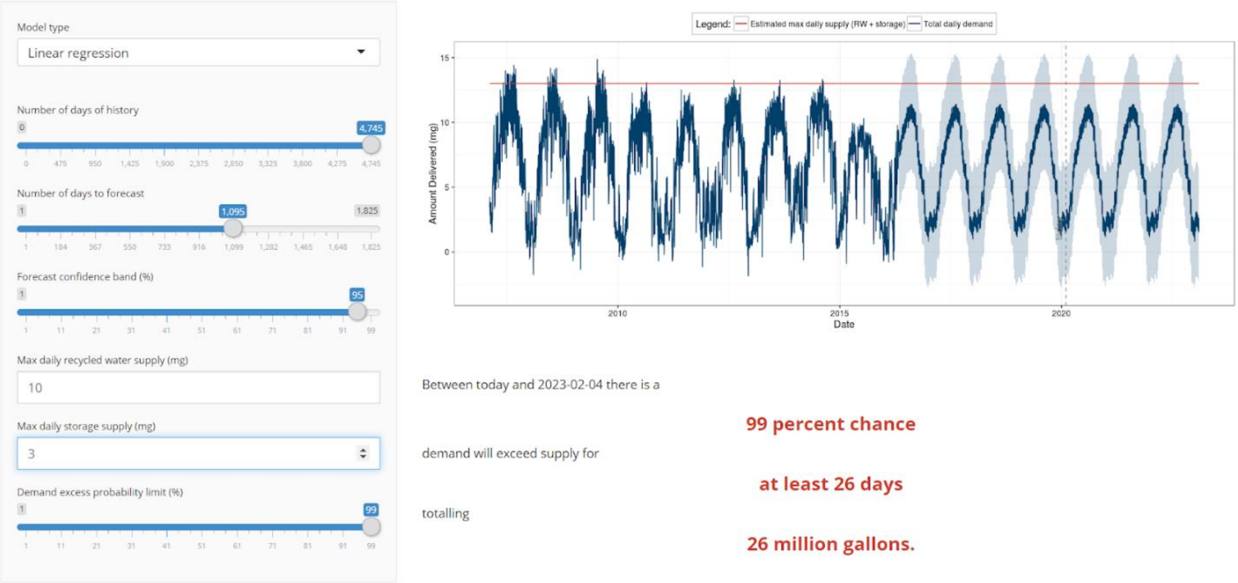
MNWD has also created leadership positions that oversee both the financial and the water resource and efficiency planning at the district. This role allows for greater collaboration between the two departments, and has allowed the district to mitigate revenue losses as customers shift towards water conservation (#3). The priority of the group is to "utilize data to help in the operations, the decision making, and long term planning for the district" (#1). Three of the districts data collaborative projects are described below.

DataKind Project - Recycled Water Demand Forecasting

Twenty-five percent (roughly 8,000 AFY) of MNWD's total water demand is met by recycled water (MNWD, n.d.-b). The recent drought raised questions whether current and future recycled water supply was sufficient to meet the need of water users within the district (#1 - #3). Thus, MNWD staff became interested in forecasting future recycled water demand (#1; #3). To address this need, the CaDC introduced MNWD to DataKind (#3; #4), a non-profit whose mission is to "[harness] the power of data science in service of humanity" (DataKind, n.d.). DataKind connects NGOS or public agencies to top technical experts in academia and private industry (DataKind Ambassadors), who then develop algorithms and utilize advanced analytics to address pressing social problems (#6; DataKind, n.d.). The NGO operates through chapters, which are located in cities across the globe and has pursued projects focused on education, poverty, health, human rights, the environment, and urban planning.

After an initial project pitch, DataKind and MNWD jointly refined the research question to focus on the volume of necessary reservoir and storage space to accommodate seasonal fluctuations of recycled water demand (#1- #3; #6). Demand for recycled water is highest in the summer and lowest in the winter; if the demand for recycled water exceeds supply, districts will supplement the recycled water with potable water (#1) The "traditional solution" in addressing this challenge is building a storage facility to store excess water in the winter for use in high demand periods (#1; #2). In South Orange County, one of the projects proposed to overcome seasonal fluctuations and "enhance water reliability and storage capacity" is the Trampas Canyon Reservoir and Dam (SMWD, n.d.-b). The storage would create 5,000 AF (or 1.6 billion gallons) of recycled water storage, allowing for 100% of wastewater in the surrounding area to be recycled. The reservoir would cost $123 million to construct. To reduce potable make-up water, MNWD was planning on purchasing storage space at the Trampas reservoir. The model developed by DataKind volunteers would determine how much storage capacity is necessary to meet the water district's needs (#1 - #3).

The collaboration lasted for four months. DataKind Ambassadors developed a gradient boosted decision tree model (see Figure 7.1 for an off-line version of the model) to answer two questions: (1) Accounting for daily weather conditions and seasonal demand fluctuations, how many times in the past has demand exceeded supply? (2) What is the likelihood that demand will exceed supply in the future? (#2). A preliminary version of the model was shared with Operation & Management staff at MNWD to ensure that the model was appropriately developed to meet end-user needs (#2; #9). When the model was implemented by data scientists at the water district, MNWD staff discovered that there is a low likelihood of demand exceeding supply in the future. "In all but the most extreme scenarios, it is never going to be cost effective to actually invest in this storage facility at all" (#1). Instead, the district could eliminate the need for potable makeup water through a demand management approach (#1-#4). The district was able to re-allocate the $20 million to fund other priority projects that promote system and supply reliability (#3; #4).


Model type
Linear regression

Number of days of history
4,745

Number of days to forecast
1,095

Forecast confidence band (%)
95

Max daily recycled water supply (mg)
10

Max daily storage supply (mg)
3

Demand excess probability limit (%)
99

Between today and 2023-02-04 there is a

99 percent chance

demand will exceed supply for

at least 26 days

totalling

26 million gallons.

Figure 6.1. Screen-shot of the off-line version of the water demand forecasting tool (CaDC, n.d.-b). An off-line version is one in which information/data sets must be manually inputted into the program. A live version would automatically import and run data to produce an output. Due to time constraints and challenges with data reliability, DataKind was unable to develop a live version of the app (#6).

The project increases overall efficiency of water management (#1; #2; #3; #4; #6; Datakind, 2016). By reducing the amount of potable make-up water needed to meet irrigation demand, the district can reduce the amount of water it imports (DataKind, 2016) or free up potable water use for other purposes such as development (#4). The project has also yielded a new tool for decision-making, especially when the District needs to account for seasonality of water usage in forecasting future water demand (#1; #2).

Two Sigma Data Clinic Project - Identifying Anomalies in Water Meters (2018-present)

The District has 55,000 meters, 47,500 of which are residential (#3). In 2015, MNWD began upgrading to an advanced metering infrastructure (AMI) system, a fixed based radio system which automatically transmits hourly water usage data to the district (roughly 780 reads per month). The technology is highly demanded by the public, as it allows the district to provide real-time water usage information to their customers (#2; #3). The rapid increase in the scale of data collected created additional opportunities for the district to monitor its water efficiency and reduce water loss.

MNWD pitched a proposal to Data Clinic, the pro bono data-for-good initiative within Two Sigma which strives to "help [their] partners "to translate data into actionable insights" (Two Sigma, n.d.). The partners jointly refined the research purpose to build a predictive model that detects anomalies in water meters (#1; #2; #3; #7; #8; Data Clinic, n.d.). Prior to the program, faulty water meters would only be flagged with a lagged delay by the billing system or when customers inquired about their water bill (#1; #7; #8). The algorithm identified 100% of the work orders that the billing system/customer accounts staff identified flagged as faulty (#1). In some instances, the algorithm was able to detect these work orders by about three to six months sooner than the existing process (#1; #2). Currently, the model is in the refinement stage (#1; #2; #7; #8). While partnership began as a three-month collaboration, both parties extended the project to keep working on supplementary questions (#3).

The model allows the water district to reduce water waste, enables the customers to save money on their water bill (#2; #3), and increase financial viability. "[Water] losses can account for a significant amount of money. For MNWD, in this last fiscal year, those costs increased by over $300,000 just for meters under registry" (#1). Finally, once the tool is implemented, the rapid response in detecting broken meters can streamline customer service and operations (#2).

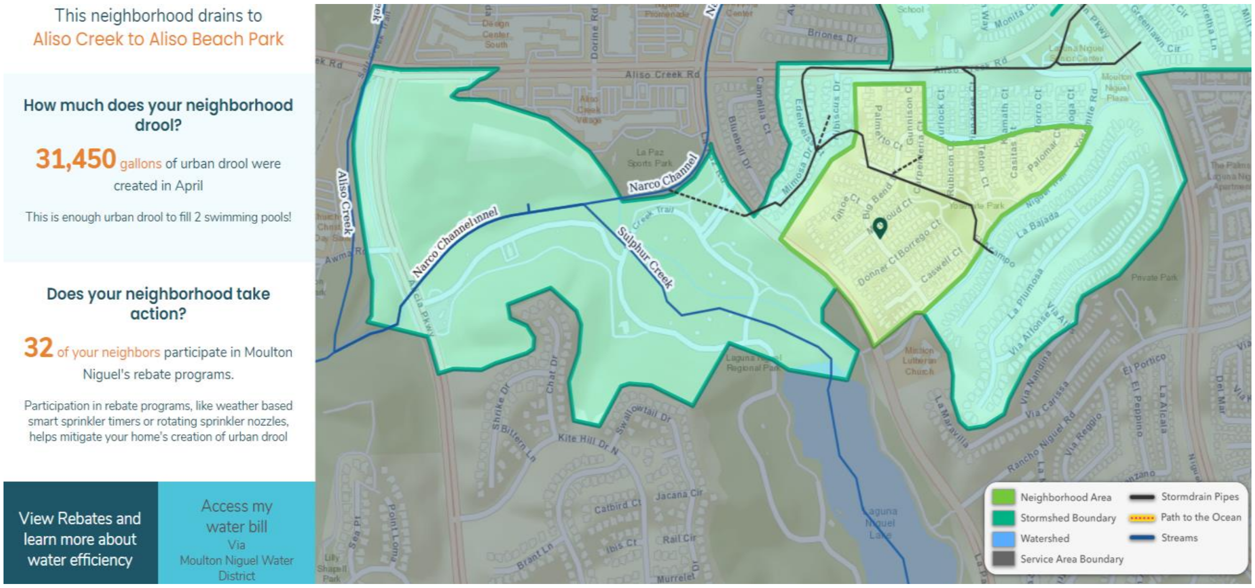
Urban Runoff Project (2017 - Present)

National Pollution Discharge Elimination System and the Municipal Separate Storm Sewer Systems (MS4) permits require cities in the US to utilize Best Management Practices (BMPs) in order to minimize point-source and nonpoint source pollution of water systems (Abbaszadeh, 2018). The cost of MS4 compliance in South Orange County is estimated to be upward of $1 billion (#1). Thus, addressing unnatural water balance has been identified as a high priority in the South Orange County Water Quality Improvement Plan (MWDOC, 2018). In 2018, MNWD assembled a working group of local NGOs, cities, and public agencies to "fill data gaps and leverage a variety of perspectives" to address dry weather runoff (MNWD, 2018, p.1; see also Lopez, n.d.; Mukherjee, n.d.). Participants drafted an MOU (2018) and committed to developing a "pilot program for testing and monitoring water efficiency measures such as marketing, educational workshops, rebates and other incentives to reduce over-watering" (p. 2) The task force meets every three to four months (#5) to "share lessons learned and evaluate the impacts of different strategies to reduce irrigation overwatering" (Abbaszadeh, 2018, p.1). To meet the goals of the MOU, MNWD, in partnership with Orange County Public Works (OCPW), has pursued two interrelated projects: the Urban Drool Tool and the Smart Watershed Network.

Urban Drool Tool

Collaboration between MNWD and OCPW was first initiated in 2016 by members of the water district in leadership positions (#5). Both agencies hypothesized that there is a direct relationship between neighborhoods that exceed water budgets and storm drain flows during dry weather conditions (#1; #2; #5). To test this hypothesis, the partners combined MNWD's AMI water usage data with OCPW's data on water flow and water quality (#1-#3; #5; Mukherjee, n.d.).

The Urban Drool Tool is a visualization tool developed with the help of OC Code Lab, CaDC, and Geosyntec. There is a public-facing and an internal-use component to the app. Internally, the app will be used to determine where unnatural, unpermitted flows are occurring, and will allow the partners to mitigate the flow through structural or conservation BMPs (Mukherjee, n.d.). The public-facing element allows "local customers to understand the impacts of urban runoff. […] We wanted to help message to people the importance of avoiding overwatering" (#3). Water users within MNWD's service area can view water use data at a neighborhood scale (see Figure 6.2) and see where runoff from that neighborhood drains to (#1 - #3; #5; Mukherjee, n.d.; Observation, 8/6/2020). The tool also includes neighborhood-level data on rebate participation and provides direct links to learn more about water efficiency rebates (Observation, 8/6/2020). The app went live in June 2020, and has already been used by NGO groups within the Urban Runoff MOU to identify neighborhoods that will most directly benefit from targeted outreach and education campaigns (#5).



This neighborhood drains to
Aliso Creek to Aliso Beach Park

How much does your neighborhood drool?

31,450 gallons of urban drool were created in April

This is enough urban drool to fill 2 swimming pools!

Does your neighborhood take action?

32 of your neighbors participate in Moulton Niguel's rebate programs.

Participation in rebate programs, like weather based smart sprinkler timers or rotating sprinkler nozzles, helps mitigate your home's creation of urban drool

Figure 6.2 A screenshot of the live Urban Drool app – the application allows users to examine urban drool and rebate participation at both the neighborhood- and watershed scale. (MNWD, In the past, the district pursued a different approach to demand management. In the 2009 drought, water users were assigned days during which they would be able to irrigate their lawns (#1). Users that did not abide by the irrigation schedules would be ticketed. The strategy did not lead to reductions in water usage, as individuals would over-water during their scheduled times. The approach led to “increased administration costs and pissed off customers. So all around, a kind of a fail of a way to go about achieving water use reductions. So with that, there was definitely recognition that something else needed to be done” (#1). The district shifted to a water budget based-rate system, and prioritized communicating information about rebates and conservation strategies to customers. The Urban Drool tool aligns with the long-term demand management strategy of the district:

> The idea behind the tool is not to hammer people and shame them. It's to make them aware of their water use in comparison with their surrounding neighborhoods [...]. They're going to see water use flow, where it goes, so they can begin to put it all together. That their behavior at home and in their neighborhood actually have an impact on the Creek system. And then also at the beach as well. (#5; see also #1; #4)

Smart Watershed Network

While working on the Drool Tool, the partners realized that there was insufficient high resolution data on flow meters (#5). To collect additional data, sixty portable water flow meters will be deployed in storm drain outfalls throughout Moulton Niguel's service area (#5; Observation, 11/26/2019). Prior efforts collect stream large-scale flow data was too cost-prohibitive due to the costs of data transmission and the sensor technology (#3; #5); however, the presence of AMI across the watershed made large-scale deployment more economically feasible (#5), as the flow meters could transmit the data through AMI system (Observation, 11/26/2019). MNWD management staff also identified a grant opportunity through the Metropolitan Water District of Southern California to fund flow water meters (#2; #3).The total cost of the project is

$411,000, with $205,000 funded through the MWD Future Supply Action Program (MWDOC, 2018). The Smart Watershed Network project has just finished pilot testing the technology (Observation, 11/26/2019) and is currently in the implementation phase.

The Urban Runoff PPP and the OCWP/MNWD data collaborative ultimately assists in long-term planning and water use efficiency programs (#2; MWDOC, 2018). To date, there has been no comprehensive database that examines the urban water balance and supports informed decision-making regarding urban runoff and recovery (#1 - #3; #5; MWDOC, 2018). Through targeted BMPs, the project presents an opportunity to manage non-point source pollution and improve the overall health of the watershed and ocean (#1; #2; #5). The project is also an opportunity for MNWD to "increase their local water supply portfolio by identifying locations where it might make sense to capture flows, treat it, and redistribute it to customers for use as a reclaimed water for irrigation." (#5; see also #1 - #3). The recovery potential is estimated to be 1,100 AFY for dry-weather urban runoff and 1,300 AFY for stormwater, representing 8.9% of MNWD's total water demands (MWDOC, 2018).

6.3 Cross-Cutting Themes across Cases

Comparison across the cases revealed three themes: 1) elements critical to developing and implementing robust models and data tools through data collaboratives, 2) the perceived role of data collaboratives in current and future water management, and 3) considerations of scalability and replicability of collaborative Big Data methods.

Elements Critical to Developing and Implementing Data Collaboratives

Development of the public-private data collaboratives and novel data tools was facilitated by 1) an organizational culture of innovation and experimentation, 2) a collaborative, iterative process of model design, 3) inclusion of diverse stakeholders throughout all stages of the collaboration, and 4) and ongoing support from the California Data Collaborative.

Opportunities for Innovation and Experimentation

Public and private respondents emphasized the importance of creating safe spaces within water utilities for innovation and experimentation. Respondents frequently referred MNWD’s culture as one that encourages collaboration and experimentation (#1 - #5; #9; Observation 8/30/2018). One project participant stressed that this kind of work environment empowers staff and allows them to “take risks or try projects that haven't necessarily been done before. A lot of the industry is pretty risk averse. MNWD breaks from some of that mold. They have leadership at the top [that’s] super supportive of all the data work” (#9; see also #1-#5; Observation, 8/29/30; Robinson, 2019). Staff in leadership positions provide “cover for staff as they venture out to do new things. I give them the space and the opportunity, but ultimately if it fails, I take that. You never lay out your staff. You give them a safe environment to try things because, for me, failure is acceptable” (#4). As a result, staff “wanted to guide the frontier of that [data analysis] themselves instead of being sort of passive receivers, where the innovation is all coming from the private sector necessarily (#9).

Indeed, all three projects have been launched as explorations of how data could be utilized to aid water operators and strategic decision-makers. Private partner participants described perceived one project to be an initial exploration in understanding “What would a silicon valley type of person do with this kind of data?” (#6) The DataKind project began with “an open hypothesis - what could you do with better demand forecasting?” (#10; see also #3) while the Data Clinic project was an exploration of the way AMI data could be applied to increase water efficiency (#3; #5). Project participants acknowledge that these new methods pose risks.

> We were going out on the limb, because we knew that we would be sharing data and information with a very unusual, untraditional, unconventional partner. We did all the due diligence legally with nondisclosure agreements and things like that. But it was still something that was unknown to us. But I wasn't afraid to manage something I didn't know. Because you don't learn until you try. (#4).

These kind of pilots allow the utility to “go through all of the growing pains” prior to implementing organization-wide, thus allowing staff to experiment while insulating the utility from any negative repercussions (#1; #9). Project participants ultimately viewed the endeavors as opportunities for learning new skills and gaining a deeper understanding of resource management (#1 - #8).

> I think the greatest risk is - what if we're totally wrong? [...] We're making investment here in resources and time, effort, and money. [...] But no matter what happens, we're going to learn something, right? And we'll be able to apply that to our next project and our next idea. I've no doubt about that. (#5)

A Collaborative, Iterative Process

A key element highlighted by both public and private partners was the importance of developing a shared understanding of the project goals and model parameters early on in the design process (#1 -#3; #5-#9). These goals would be identified through an iterative joint decision-making process in the early stages of partnership formation (#1-#3; #6-#9). Project partnerships would begin with MNWD staff “pitching” project goals to potential partners (#1; #2; #6 - #8). Private partners then assist in refining research questions that align with the data available, the capacity of the public partner, and the water utility’s broader interests (#6 - #8). One private partner referred to this stage as the “white glove approach,” where significant staff time is invested to ensure that the model has as much impact as possible (#6). Private partners then develop a model that meets the needs of the district. During the design phase, partners participate in weekly phone calls (#2; #6). As the model is developed, MNWD staff provide input on the model parameters, explained data outliers, and clarifying water system operations (#2; #6 - #8). Private partners would utilize the information to refine the model. Feedback allows the developer to design a product that accurately reflects the conditions of the water utility (#6-#9). "The public partner come to the table with the content area expertise in that domain. And that is something that the private partner does not have" (#7; see also #6, #8, #9). One private partner even has a checkpoint built into the process of collaboration, thus allowing the model developers to "redirect [and] change course if they need to" (#7; #8). Development of models, thus, requires a "pro-active," iterative, collaborative decision-making process (#2; #6 - #8).

Inclusion of Diverse Stakeholders

"It takes a village" to build a data design tool (Rocha & Porensky, 2020). Inclusion of diverse perspectives throughout entire partnership also allowed for a more holistic development of models and a stronger understanding of its potential outputs and applications (#5; #9; Observation, 11/26/2019). Individuals included in the early stages of partnership development included those "with their boots on the ground" and those in leadership roles (#5; #7; #8; Observation, 11/26/2019). In the case of the Urban Runoff Project, start-up meetings were attended by individuals from seven different organizations (Observation, 11/26/2019). Inclusion of technical advisors and private consultants in the project design phase allowed project partners to develop new applications for the data and to brainstorm additional parameters to include in the model (the proportion of impervious vs. pervious surface in communities, for example). Inclusion of field staff also allowed participants to gain a better sense of potential site meter locations and the type of infrastructure available to assist in sensor installation.

Ongoing Support from the California Data Collaborative

A key actor in MNWD's uptake of data collaboratives is the California Data Collaborative (CaDC), a non-profit that creates data-driven decision-making tools and provides research support planning and analysis for water districts (CaDC, n.d.-a). The CaDC was formed as a direct response to the drought and the state's top-down response to water conservation efforts (#3; see also #1; #2; #4; #9; #10; Observation #1; Observation, 8/29/19). MNWD and other agencies formed a coalition to develop solutions and recommendations to the state (#3). The experience demonstrated the value of data science to the participating agencies. As a result, the CaDC was established in 2016 (#3; #9; #10) to "help water utilities to meet their resiliency objectives" (#10). Over the last four years, the CadC has expanded to include 14 member agencies (CaDC, n.d.-a), representing a total of 21 million Californians (#1; #3; #10). The ongoing collaboration with the CaDC "opened [MNWD] district to all these new types of partnerships" (#3; see also #4).

The CaDC assists in regional decision-making and implementation of data-science by cleaning, standardizing, and compiling datasets on water use and efficiency, facilitating opportunities for data access, and providing implementation support for data analysis models[30]. Members of the CaDC were the ones that initially connected MNWD staff to DataKind and the Data Clinic (#1- #4; #9; #10). MNWD staff also stressed that the CaDC's role in cleaning and aggregating the data increased the likelihood of finding a private partner (#1; #3; #4). Data clean

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[30] The CaDC's current mission includes four pillars: (1) developing analytical tools that support planning and operational decision-making, (2) providing opportunities for research by external partners by cleaning data and creating a centralized database, (3) supporting agencies in complying with state regulations, and (4) building a diverse community around water data by hosting workshops and an annual Data Summit (#9; #10). Previous programs by the CaDC (n.d.-b) include evaluation of conservation and water efficiency programs and rate modeling tools that illustrate impact of prospective rates on customer bills and district revenue.

up allows public agencies and private companies to “speak the same language” (Sustain SoCal, 2020):

> We had data, but it was in papers and files. And when you are talking to Netflix, Facebook, and academic institutions, you can’t just hand them boxes of files. You have to have the data in a way that they can go in and look it - so standardization, centralization…. (Sustain Socal, 2020).

Finally, the CaDC served a “translator” and provided implementation support for the new data tools. In the design phase of the district’s first data collaborative, a member of the CaDC helped explain the goals of MNWD to DataKind Ambassadors using mathematical concepts and relationships (#9).

The Role of Data Collaboratives and Big Data Analytics in Decision-Making

In interviews and observation events, public and private stakeholders were enthusiastic about the role of data collaboratives and Big Data Analytics in meeting future water needs (#1-#10; Observation, 8/30/2018, 8/29/2019). MNWD staff predict that over the next 10 years the district has over $320 million in planned expenses (#1). “That's a significant amount of money that has to come from ratepayers” (#1). Insufficient data and methods will yield insufficient policy response (#1; #2; #4; #6; #9). “If you really want informed policymaking, you can't do that without information. The data is what's going to tell you that” (#1).

Machine Learning and Artificial Intelligence provide the opportunity to “deal with massive amounts of data” (#6) and can play “a critical role in resource management” (Observation, 8/29/19) by identifying linkages between variables that were not previously seen (#5; #6; #9). An AI forecasting approach could enable the use of cost-effective, tailored solutions that can be scaled to regional levels (#2):

> If you can predict demand for water at a high accuracy, including the peaks and troughs of volatility over the course of a year and decades, then you can

> efficiently allocate resources and spend money to purchase the reservoirs and the catchments and the facilities that you need to meet that supply and no more (#6).

For example, in the case of the DataKind project, the forecasting technology allowed “the board of directors to have data to support the decision that they're going to make [not purchasing storage capacity], and to go back to the public and show […] why they made that decision. And so it helps get buy-in from the public as we move forward for either this decision or other projects (#3). Had the district utilized traditional tools for decision-making, the outcome of the cost-benefit analysis would have resulted in the purchase of the reservoir space (#1). While the district has always “relied on data for a lot of our other efforts for engineering and planning, but this was definitely different” (#1). These new methods have “helped to shift the way that the district operates to be more of a data-driven organization, where we have a question, we'll frame it in a specific way so that you can explore the data that we have to ultimately lead to metrics to help inform that decision” (#3).

Data collaborative also provide opportunities for project participants to gain access to new skill sets (#1-#3) and to be exposed to diverse perspectives (#2; #5; #6 - #8). Private partners “are coming in sort of with fresh eyes. So, sometimes we notice things that others who have been working in the field for a long time might not simply because we're applying methodologies and techniques that aren't maybe traditionally used in that domain (#7; #8). Partners are able to adopt practices that “have been vetted and figured out in other industries” (#1) and to gain an understanding of how other stakeholders approach water management decisions. The Urban Runoff project, for example, provides an opportunity for members from NGOs, public agencies, and water utilities “to sit around the table and to share ideas and strategies without the pressure of having.... You know, there's no regulatory pressure. […] It's been a great forum to just share information and talk about all the different things we're working on. […] It's been a really positive and at the same time very productive group. (#5). The cross-sector partnership has allowed agencies to pool data, resources, and staff time to pursue an integrated water management approach:

> The broader benefit of all of this is that it helps to develop a framework of sharing data across different institutions that all work in the same watershed, who all manage different pieces of it, so that we can all collaborate. Because the best solutions are multi-benefit solutions in a watershed, and they're very complex. Each agency often has their own piece or view of the watershed, and having all of this data shared helps provide a common picture of what the full, best solution would be. (#3; see also #1; #5)

One project participant believed that if agencies attempted to resolve this challenge on their own, "we would have **zero** chance of being successful" [emphasis added by respondent] (#5).

Finally, research participants also view data collaboratives as an opportunity to develop tools that shift community perceptions and behaviors surrounding water usage. Respondents hope that granular data "can provide users with good, actionable information" (#5) and that tools such as the urban drool tool will allow the public to "feel more empowered and able" to make decisions about their water usage (#2; see also #4; #5).

> Our advanced metering infrastructure gives the customers the tool and the opportunity to manage their own water use. They didn't have that information before. They would get it after the fact in their bills. And now through apps and customer portal they could see their water usage time on a real time basis. […] So it made them much more engaged participants of what we were trying to accomplish, what California is trying to accomplish. (#4)

Deviating from a Traditional Hard Infrastructure Approach

Respondents highlighted that the three projects align with the broader changes in water management (#1; #4; #5).Water stakeholders are shifting the way they view and utilize resources related to water management (#4; #5; #11; #13; #14; Observation, 8/29/2018). For example, there is a growing recognition that traditional approaches to stormwater management have been insufficient in meeting community needs (#5; EPA, 2015). Until recently, stormwater was always viewed as “wastewater” rather than a resource (#5; #12; #20; Feldman, 2017). The recent drought (#4; #5), as well as the complexity of managing water resources in a rapidly urbanizing area (#5), has incentivized practitioners and regulators to adopt new stormwater management strategies. Green Infrastructure (EPA, 2015) and an integrated water management approach have provided new opportunities for previously siloed organizations to simultaneously mitigate flood risk, improve water quality and habitats, and enhance local water supply sources (#5).

> The old school way of doing things is "no, we'll, we'll do flood management in one silo, storm water management in another silo, water supply in a silo and wastewater treatment in a silo." […] That mentality is not going to work for us. We need to rely on each other, to establish partnerships, to work together. (#5)

Water utilities have undergone a similar transition for water conservation.

> The world is changing not only in terms of technology, but how water is regarded. Conservation is a way of life. That IS a new era, right? We have always understood the supply challenge, but conservation was really looked at - even when I started - as sort of a PR thing. Conservation demand management was not part of the resource management portfolio. [It] was more of a feel-good. (#4; see also #11)

Demand management can increase water efficiency and improve environmental well-being (#1-#4; #6; #12). By eliminating the need for building additional water infrastructure, demand management can also free up revenue for other critical needs (#1). MNWD staff view “the drop that's not used [as] the cheapest new water supply source” (#3).

Ultimately, project participants perceived MNWD’s PPPs as a deviation from the traditional large-scale infrastructure path of water management (#1; #4; #5).

> We're seeing now that through environmental constraints, regulatory challenges, public's expectation of management of public funds, you can't just build and build and build. It's really great for ceremonies, building. It sounds great. A lot of the solutions in water have been based on engineering solutions (#4).
>
> Now we're looking at things in a different way. We could do a lot more with than we have. Demand management. Data. Human interaction, communication with the public. These are not the areas that have always been played up as glamorous

> in the industry. But is it effective? Yes! We are the proof of that. And do the communities and the customers and the public like it? Yes. (#4)

Scalability and Replicability

During design, partners considered features that would increase increased the ease of scaling and replicating models. For example, the algorithm for the Data Clinic project is general enough that it can "be implemented anywhere that has AMI data, the idea being is you can scale it to the state, if we wanted to" (#1; see also #7 & #8). To do so, partners focused on ensuring that the model was not "too tailored for a micro region" (#7; #8).

> If you think about what impacts water usage, there are a lot of things like the immediate local temperature and evapotranspiration and all these other environmental variables that are on a very local level. There's always a tradeoff, right? You want [the model] to be as effective but as simple as it can be. To scale, you then need to kind of generalize those things with respect to data. A model that is particular for a tiny local area […] wouldn't scale to a broader region with a different environmental climate (#7; #8).

For the Urban Runoff Project, a portion of the start-up meeting was dedicated to ensuring that the resulting code and program dashboard for the Drool Tool would be open-source (Observation, 11/26/2019). Along with creating open source code, Geosyntec will provide lessons learned from the project. Sharing the code and project challenges (such as the challenges during visualization of the dataset) can assist others who want to replicate these efforts. (Observation, 11/26/2019).

Respondents emphasized that scaling or replicating data-driven methods within the water sector is only possible by demonstrating the success of pilot projects (#2; #5). Even within MNWD, the importance of data science had to be "taken on faith a little bit" until the DataKind project (#1). Overall, the three projects have "shown the value of this new skill set" to the various departments within the district and the Board of Directors (#3; see also #1; #2). The district has increased the number of staff dedicated to data analysis from one staff member to two full-time analysts and two data science interns (#1). The process of participating in the data-oriented PPPs has been viewed as “an investment in innovation, changing the way we think about problems” (#3).

To facilitate replicability, public and private partners presented the outcomes of these collaboratives at conferences geared towards the water sector (e.g. California Water Summit) and the data sector (e.g. Bloomberg Data for Good Exchange) (#1 - #3; #7 - #9; Observation 8/30/2018; Rocha & Porensky, 2020). Partners hoped the open-source code and demonstrations of success would provide other water utilities with the tools and the knowledge to adopt novel data methods (#1 - #9) and facilitate additional data collaboratives (#5; Rocha & Porensky, 2020).

> And our hope is that we would be able to expand that and share that with other organizations and that we could use this as a model to then establish partnerships with other agencies that we're already working with. [...] I think that's what I'm hoping is the greatest impact, not just on our organization but on others - that we can use this as a model or a template to then apply in other areas (#5).

The tools developed through the data collaborative have been well-received by public officials stakeholders (Observation, 8/30/18, 8/6/20). One board member in the South OC watershed stated that she “loved, loved, loved” the Urban Drool Tool (Observation, 8/6/20). Other board members and NGO groups were enthusiastic about the opportunities to educate residents on their water use, and even proposed additional ways to integrate the Drool Tool into children’s outreach and education programs (#3; Observation, 8/6/20). However, others remained skeptical of the uptake and reach of the public-facing tool. After a demonstration of the tool, a city mayor stated “I doubt very many people will actually log in and want to use it, but it would be a cool tool for the nerds to see their water use in their neighborhoods” (Observation, 8/6/20)

6.4 Discussion

This chapter utilized a qualitative, comparative case study approach to examine 1) factors that facilitated the uptake, development, and implementation public-private data collaboratives and 2) their outputs and outcomes. Respondents viewed data collaboratives and Big Data Analytics as critical to meeting future water needs in California. The data collaboratives enabled Moulton Niguel Water District to strengthen decision-making in capital-infrastructure investment, monitor water use in real-time, develop targeted responses to water inefficiency, and to proactively engage with the public by providing water users with visualization tools and relevant demand management strategies. Project participants perceived these PPPs as an innovative deviation from traditional hard infrastructure approaches. These gains in efficiency align with past academic applications of Big Data Analytics in the water sector (Chen & Han, 2016; Kim et al., 2016; Newhart et al., 2019; Ponce Romero et al., 2017; Uddameri, 2018).

The cases illuminate three factors that facilitated the uptake of novel data methods and partnerships at MNWD. First, leaders within participating organizations promoted a culture of collaboration and provided safe spaces for innovation. This supportive organizational culture increased the flexibility of project participants in seeking out innovative solutions and leveraging cross-departmental resources and technical capacity to meet data collaborative goals (#1 - #5; #7 - #9). Failure to implement explicit procedures or norms surrounding R&D can serve as a barrier to adopting new practices within the water sector (Kiparsky et al., 2016). Conversely, support from senior positions within organizations reduces transaction costs of forming partnerships and piloting new methods (Farrelly & Brown, 2011). For example, respondents frequently pointed to MNWD's General Manager as a driver of change within the district and credit her for development of in-house data capacity within MNWD (#1 - #5; #9). This greater focus on data capabilities and experimentation may be driven the GM’s background; the GM served as an assistant general manager at a private water company.

The second factor was the iterative, inclusive process of designing the model goals. Identifying a research question which can be answered with available data and also advances the goals of multiple organizations has been identified as a critical challenge in forming data collaboratives (Susha et al., 2017b; 2019; Susha & Gil-Garcia, 2019; Susha, 2020; GovLab, 2018; UNDP & UN Global Pulse, 2016). The process requires significant investment in resources and time for both public and private partners, as it requires identifying potential gaps in the data, and the assumptions underlying the development of the model/tool explicit (The GovLab, 2018). Through multiple back-and-forths, potential partner develop a shared theory of action (see Emerson & Nabatchi, 2015) that ensures that partners fully understand the size of the problem and the scope and scale of activities to be undertaken (Mikhaylov, et al., 2018; Susha & Gil-Garcia, 2019). Inclusion of diverse stakeholders in the early design phases also increases input legitimacy of the collaboration (GovLab, 2018; Raesche et al., 2019) In the case of MNWD, the iterative process ensured that the partnership goals complemented the district’s rising focus on demand management and cost-effective decision-making (MNWD, 2015).

Finally, the uptake and development of data collaboratives within MNWD was facilitated by boundary spanning organizations. Data collaboratives require organizations to identify project goals, establish new procedures regarding data sharing and use, and to dedicate resources, time, and skills to achieving a mutual vision (Klievink et al., 2012; Mikhaylov et al., 2018; Susha et al., 2017a, 2017b, 2019). This process requires the development of trust (Robin et al., 2016; Susha, 2020, Sutherland et al., 2018) as well as understanding the norms, values, and jargon of partnering organizations (Klievink et al., 2018; Susha et al., 2019). Boundary spanners can forge new connections across networks, thus increasing opportunities for organizations to efficiently leverage private sector expertise. Both Data Clinic and DataKind connect data for social good volunteers with public agencies. This role is critical, as these projects are

> really hard for individuals to do alone. [...] There is a scaling limit of one-on-one interpersonal network relationships. It's a hard ceiling and you realize it very quickly. You know, [a volunteer] can juggle maybe 10 to 20 volunteer professional relationships, when really hundreds need the benefits of technology and machine learning. [...] So having a third party facilitate that process, it turns out to be surprisingly necessary. (#6)

Boundary spanners also facilitate information flow and communication *within* networks by providing translation and mediation services (Feldman & Ingram, 2009; Long et al., 2013). Boundary spanners are often familiar with the practices and “ways of knowing” of multiple sectors (Perkmann & Schildt, 2015). By turning technical jargon into useful information (Ingram & Stern, 2007, cited in Feldman & Ingram, 2009) and by establishing a common vehicle for conversation, boundary spanners enable potential partners to overcome cultural, technical, or organizational barriers and to develop a mutual understanding and trust between partners (Feldman & Ingram, 2009; Long et al., 2013; Susha et al., 2017b). Therefore, boundary spanners play a pivotal role in closing the water information gap and ensuring that the developed data tools align with user needs (Feldman & Ingram, 2009; Latonero & Gold, 2015; Long et al., 2013; Perkmann & Schildt, 2015).

The cases feature three boundary spanning organizations: the CaDC, DataKind, and the Data Clinic. The California Data Collaborative establishes procedures for sharing anonymous water use and efficiency data with researchers and other third parties. Utilizing a reputable third party with institutionalized procedures for processing and handling sensitive data can incentivize risk-averse participants to pursue data collaboratives (Perkmann & Schidlt, 2015; Robin et al., 2016; Susha, 2020). The CaDC also reduces financial and technical barriers to collaboration by cleaning aggregating data sets and providing implementation support for data tools. Data cleaning and analysis have been cited as a critical financial and technical barrier to collaborations due to the high costs and time required to anonymize, clean, verify, and combine large and complex data sets (Haug et al. 2011; Susha et al., 2019; Susha & Gil-Garcia, 2019). Improper data collection or cleaning can result in the development of flawed tools and policy response (Verhulst et al., n.d.). Thus, entrusting a skilled third party to clean data sets and provide quality assurance can mitigate data-related risks of collaboratives.

Uptake of Public-Private Data Collaboratives and Big Data Analytics

Local-scale experiments – such as the three data collaboratives pursued by MNWD - are valuable learning platforms for urban water practitioners (Farrelly & Brown, 2011) that can enable the development of new innovative practices. However, their effectiveness and diffusion are limited by the risk-averse and techno-rationalist operating culture of the water sector (Kiparsky et al., 2013; Lach et al., 2007; Rayner et al., 2005). In the last ten years, the water sector has undergone a transformation, incorporating a wide range of computer modeling, forecasting, real-time monitoring, and web-based platforms as a new “way of knowing” the water system (Lach & Rayner, 2017; Sustain SoCal, 2020). These changes have been hastened by drought and by the increased level of interaction and engagement between knowledge producers and users (Feldman & Ingram, 2008; Kirchhoff et al., 2013; Lowrey et al., 2009; Lach & Rayner, 2017). Trainings and webinars on these new data tools have reduced barriers for water managers to integrate these practices into organizational routines (Lowrey et al., 2009). Yet, water managers still view new data methods as a supplemental form of water system management (Lach & Rayner, 2017). There is a concern that an over-reliance on data solutions will lead to a loss of “craft skills” and the local knowledge necessary to operate and maintain water systems.

The adoption of public-private data collaboratives and data analytics is slowly starting to take place at other utilities. Staff at MNWD “have seen other agencies now kind of copy that same model, where they bring in data scientists, and invest in that same resource” (#3). For example, two water utilities in San Francisco partnered with Fracta, a private company, to predict which water pipes have the highest likelihood of failure and will require immediate replacement[31] (Onyeneho, n.d.; Walton, 2019). However, data collaboratives and applications of Big Data analytics remain limited. The diffusion of these practices will require broader institutional and organizational reform as well as additional investment in in-house capacity of water utilities (Adamala, 2017; Eggimann et al., 2017; Lund, 2018; Rayner et al., 2005).

Three factors may promote the discussion of data collaborative within the sector. The first is the adoption of state-wide mandates on open-data sharing. In 2016, to promote innovation, cross-agency collaboration, and effective water management within the state of California (Observation, 8/29/19), Governor Brown enacted Assembly Bill 1755, the Open and Transparent Water Act. AB 1755 requires the Department of Water Resources to create, operate, and maintain a statewide integrated water data platform in collaboration with other state-level regulatory agencies such as the CA Fish and Wildlife, CA Water Quality Monitoring Council, and the State Water Resources Control Board (CA Department of Water Resources, 2019). Enacted during one of the most severe droughts on record, the bill is a “a call to action for a renewed approach to accessing water data that builds trust, supports planning, improves operations, and produces exponential benefits” (Water Data Advisory Council, 2019, p.1). AB-

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[31] Fracta utilized machine learning to develop a forecasting model that combined archival data of pipe age, material, and break history with environmental factors such as flow rates, soil chemistry, and temperature (Onyeneho, n.d.).

1755 Implementation strategies prioritize a user-based approach in which data must be accessible in a variety of forms and must be sufficient to support decision-making (CA DWR et al., 2018). Strategies have also identified public-private partnerships as a critical component of cost-effectively achieving the goals of AB1755 (Huttner, King, & Whitney, 2018).

Water utilities are more likely adopt invest in new data methods when the methods are labeled as “best practices” by reputable organizations such as the Army Corps of Engineers (Rayner et al., 2007). By establishing a clear level of public and political support for data-driven decision-making, AB-1755 may crease may create a sense of legitimacy among water utilities in investing in additional in-house capacity. Moreover, aggregating datasets can uncover data gaps at the regional and state-level and can increase demand for private sector datasets through data-sharing initiatives.

The COVID-19 global pandemic may also push the water sector towards new data methods and digital practices (Poch et al., 2020; Sustain SoCAL, 2020). The pandemic has awakened the water industry to the fact that “technology is no longer ‘a nice to do.’ It is a necessity. It made us [the water sector] realize that moving forward, it will be even more critical to integrate technology and connectivity” (Sustain SoCal, 2020). Social distancing and work-from-home mandates have required water utilities to adopt new digital systems while meeting public expectations of reliability, safety (water quality), and affordability (Poch et al., 2020). The pandemic has also shifted opportunities for utilities to engage and to interact with their customers; there is an increased demand among the public and utilities for real-time water use tracking and smart water meters (Sustain SoCal, 2020). Finally, the pandemic may incentivize public and private agencies to consolidate public health and wastewater data to develop early warning systems for infectious diseases (Poch et al., 2020; see also Eggimmann et al., 2017).

Thus, the pandemic will restructure the water-human-data interface and may create new digital solutions to “wicked challenges” such as climate change (Poch et al., 2020).

Uptake of new data methods and partnerships can also be assisted through the use of networks and the boundary spanners operating within and between them. At a regional scale, fragmented governance structures and the variation in technical and financial capacity limit opportunities for city-level decision-makers to learn from risky and innovative decisions of others (Deslatte, Feiock, & Wassel, 2017). Social learning processes will be low if organizational networks only include project participants (Gunderson et al., 2006; Pahl-Wostl, 2009). New practices, technologies, and rules can be diffused if participating organizations are highly embedded in their organizational field (Lawrence et al., 2002; Long, 2020). In other words, high number of connections within networks and frequent opportunities for sharing innovation will result in broader adoption of new norms and practices. Conversely, innovations that promote sustainability will not be adopted when the costs of adoption are high and if there are few opportunities to learn from similar “peer” communities or groups (Deslatte et al., 2017). Conferences, water summits, and hack-a-thons can serve as an opportunity to forge new connections and to discover new methods and best practices across sectors (Kiparsky et al., 2013). The Bloomberg Data for Good Exchange, for example, allowed MNWD to connect with other organizations such as Data Clinic (#3; #9). Similarly, a city-level landscape manager first learned about AMI sensors in 2018 from an annual conference geared at sustainable water solutions (Observation, 8/30/2018). The following year, the individual shared how the adoption of this technology allowed the city to identify faulty leaks at a business property, reducing water usage at the site from 100 gallons/hour to 9 gallons/hour (Observation, 8/29/19).

Identifying and Mitigating Data-Related Risks

Data public-private partnerships are distinct from infrastructural PPPs due to the presence of sensitive and proprietary information and the added challenge of mitigating data-related risks (Mikhaylov et al., 2018; Robin et al., 2016; Susha et al., 2019). Data-related risks exist at every stage of data collaboratives (Verhulst et al., n.d.). Identifying and mitigating these risks is a "pivotal" point in the design of data collaboratives (Susha & Gil-Garcia, 2019, p. 2897). These risks are often the result of low technical capacity, institutional norms and practices, misaligned incentives between partners, or poorly defined research problems (Patterson et al., 2019; Verhulst et al., n.d.). Imperfect inputs (datasets that are incorrectly aggregated, incomplete, or inaccurate), logics (assumptions underlying the model), or interpretations of data tools can introduce bias, reinforce historical discrimination, or result in negatively impactful policy decisions (Blumenstock, 2018; Executive Office & Podesta, 2014; Janssen & Kuk, 2016; Klein & Verhulst, 2017; Verhulst et al., n.d.). Algorithms often reflect the institutional logics of designers and policy-makers, and thus, could reinforce entrenched beliefs (Janssen & Kuk, 2016).

Misaligned policy responses as a result of data-related risks raise questions of accountability in data collaboratives. Private firms and public entities diverge in values and levels of accountability. Public agencies are accountable to the public while private organizations are accountable to shareholders (Mikhaylov et al., 2018). Private firms, thus, are not subject to the same political accountability pressures and bureaucratic oversight. If the ML approach is faulty, who is responsible - "the one who provided the data? The person who built the AI? The person who validated it? Operates it?" (House of Lords, 2018, p. 309). Mitigating this risk requires evaluating and reviewing internal capacity of partners (GovLab, n.d.); developing norms and procedures surrounding quality assurance checks of the data (Susha, 2020); assigning clear roles for participating actors (Susha & Gil-Garcia, 2019);and including third parties or translators (such as the CaDC) to verify the inputs and outputs of models (Mikhaylov et al., 2018; Patterson et al., 2019) and to ensure that the data tools are designed to meet the needs of end users (Blumenstock, 2018; Feldman & Ingram, 2009).

The second risk that must be addressed in the early stages of data collaborative development is protecting user privacy and to preventing misuse of data (Klein & Verhulst, 2017; Klievink et al., 2018; Susha, 2020; Susha et al., 2019; Susha & Gil-Garcia, 2019). While the digital revolution has rendered traditional notions of privacy obsolete (Enserink & Chin, 2015), sharing sensitive data with external organizations creates new ethical challenges (Susha et al., 2019). When datasets are shared, anonymization techniques may be absent (Raymond, 2016) or subjects can be re-identified through novel combinations or uses of datasets (Klein & Verhulst, 2017). Data can also be used to advance the interests of one actor (e.g. gaining competitive advantage) at the expense of the collaboration (Mikhaylov et al., 2018). For example, the cost-savings potential of AI in resource management is slowly attracting IT companies and private water technology companies (Garrido-Baserba et al., 2020). To private companies, wastewater presents an "an untapped source of data-rich content about the citizenry" (Garrido-Baserba et al., 2020, p. 4700). Human biomarkers in wastewater can measure viral and bacterial infections, pharmaceuticals, personal care products, nutrition factors (e.g. obesity factors, sugar intake), legal and illicit drug use at neighborhood or community scales (see Figure 6.2) (Eggimman et al., 2017; Garrido-Baserba et al., 2020; Moy de Vitry et al., 2019). Analysis of flow speeds can also create indirect documentation on daily habits and behaviors of individuals (Giurco et al., 2010). The data on behavior and health can enable private companies to pursue targeted advertisements and can create bias by insurance companies or employers towards or against particular neighborhoods (Moy de Vitry et al., 2019). These risks to privacy may be higher as cities transition to small, decentralized systems, as biomarker data could easily be traced to individual or neighborhood-level sewer systems (Moy de Vitry et al., 2019).

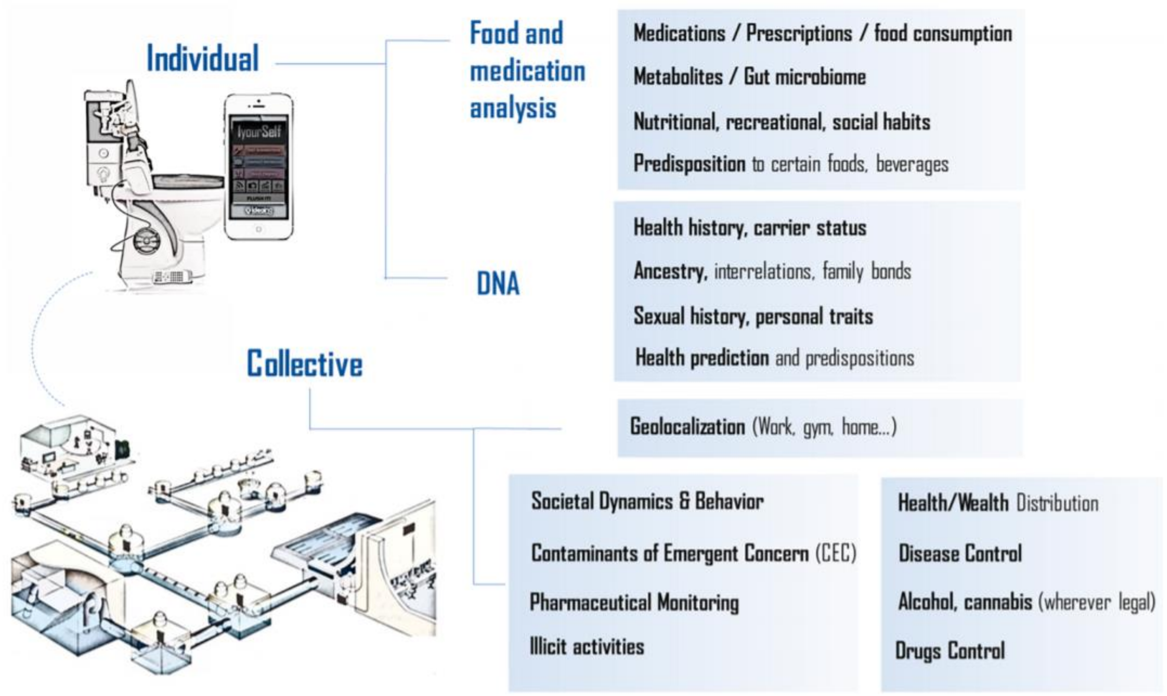

Figure 6.3 Individual and community-level data that can be identified through sewer mining and data analytics (Garrido-Baserba et al., 2020)

Establishing clear governance mechanisms and procedures for data sharing and use can allow actors to maintain control over the data and to minimize unforeseen uses and consequences (Klievink et al., 2018; Susha et al., 2017b; Susha & Gil-Garcia, 2019; Susha, 2020). Currently, there is a lack of data governance frameworks for data collaboratives (Berens, Mans, & Verhulst, 2016, cited in Susha et al., 2017b). Boundary spanners can facilitate the development of organizational procedures and norms around data stewardship (Perkmann & Schildt, 2015; Robin et al., 2016; Susha, 2020) and can build trust and rapport through mediation and translation services (Feldman & Ingram, 2009).

6.5 Conclusion

This chapter demonstrated that, when properly designed and implemented, public-private data collaboratives can increase operational efficiency and develop soft infrastructure approaches to water management through Big Data methods. The chapter also highlighted the importance of boundary spanning organizations in facilitating the uptake and development data collaboratives. Across the three cases, boundary spanning organizations connected public and private actors across previously isolated networks; established procedures for sharing data sets; ensured research questions aligned with available datasets; and mitigated data-related and financial risks by cleaning and aggregating datasets and providing implementation support of data tools. Diffusion of these collaborative methods will depend on the technical capacity of utilities, the embededness of water utilities within networks, and the level of interaction between producers and users of novel data tools interact. Finally, the chapter showcased that data-oriented PPPs face a unique set of challenges related to risk and privacy that must be addressed prior to entering into a data collaborative.

The outputs and outcomes of the cases reinforce the importance of developing a robust data-sharing infrastructure at the state-level. Presently, California’s water data sources are often incomplete, inconsistent, and difficult to access or use (Cantor et al., 2018). Moreover, state-level decision-making and technical activities are splintered across programs with independent legal mandates, funding sources, management styles, and norms (Lund, 2018; Romm et al., 2018). As a result, there is often a disconnect between ecological and social system resilience solutions (Hughes & Pincetl, 2014; Romm et al., 2018). Building resilience will require an effective combination of restricting institutions, infrastructure, and information (Hall et al., 2014). These “water models” will depend on the local hydrological conditions, economic context, and the past decisions of decision-makers in the local water sector (Pinter et al., 2019). Open data can identify gaps in the data and new applications of private sector datasets and expertise to the water sector. These data collaboratives can enable the development of local, regional, or even state-level tools for decision-making and can provide new insights into water use, efficiency, and management.

7.0 PROJECT IMPACTS

Chapter 4 summarized the current and future socio-technical challenges facing California's water sector and identified variations in the definitions of sustainability and resilience utilized by regulatory agencies and PPP project participants. Chapter 5 uncovered the endogenous and exogenous drivers of public-private partnerships: water managers were motivated to enter into PPPs to overcome funding constraints, increase efficiency, transfer knowledge and technology from the private sector, and increase technical capacity of water utilities. This chapter utilizes the frameworks of holistic sustainability and social-ecological system (SES) resilience to ***examine the socio-economic, institutional, and environmental outputs and outcomes of water sector PPP projects.*** PPP projects are evaluated in the context of (1) potential tradeoffs between ecological well-being, economic viability of projects, and social justice considerations and (2) to the extent that they contribute to SES resilience. Social justice considerations refer to both changes to water rates and opportunities for stakeholders that are traditionally outside of technocratic water regimes (citizens, non-government organizations) to provide "voice[32]" throughout the project lifetime.

Projects that are sustainable are those that maximize environmental and social benefits without compromising financial viability of the project or placing undue burden on marginalized populations. SES water resilience refers not only to the ability of socio-technical water systems to persist and adapt to changing circumstances, but also to their ability to transform when the situation becomes untenable (Eriksson et al., 2014). SES resilience approaches utilize diverse cross-sector strategies that enhance ecosystem function, rather than detract from it (Eriksson et

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[32] According to Hirschman (1970), citizens hold public service and resource providers accountable by engaging them in two ways: 1) making their views and needs known (voice) and 2) choosing whether to utilize or boycott a particular good or service (exit).

al., 2014; Falkenmark et al., 2019; Gonzales & Ajami, 2017; Mao et al., 2017; Romm et al., 2018). Moreover, an SES approach does not assume that change is a linear process (Davoudi et al., 2012). Rather than being able to withstand under rigid single-point-in-time conditions, infrastructure must be able to sense and respond in real-time to risk (Hayes, Desha, Burke, Gibbs, & Chester, 2019; Krueger, Borchardt, Jawitz, & Rao, 2020). In other words, systems must be designed to overcome failure rather than avoid it (Butler et al., 2017). Water systems must move away from a strictly hard infrastructure approach, as these strategies have less flexibility and a lengthier time lag in responding to change (Mao, Clark, Karpouzoglou, Dewulf, Buytaert, & Hannah, 2017), thus increasing system vulnerability to internal and external shocks (Krueger et al., 2020). The final element that is critical to achieving SES resilience is the use of tailored solutions that are sensitive to local contexts and incorporate the experiences and knowledge of diverse groups (Eriksson et al., 2014; CNRA et al., 2020). These local solutions must be supported by regional and state-level strategies that scale solutions, share knowledge and best practices, and set robust environmental standards (Krueger et al., 2020; CNRA et al., 2020; Rodina, 2019)

There is a rise in PPP literature that examines project resilience- and sustainability-oriented outputs and outcomes. Scholars have examined the impacts of PPPs on sustainability within the context of fulfilling Sustainable Development Goals (Berrone et al., 2019; Pattberg, Beirmann, Chan, & Mert, 2012; Pinz et al., 2017), agroforestry (Shapiro & Rosenquist, 2004), and critical infrastructure provision across sectors (Hueskes et al., 2017; Patil et al., 2016) and within the water sector (Johannessen et al., 2014). Public-private partnerships may be uniquely positioned to tackle sustainability challenges. Private funding of design, build, and infrastructure maintenance, along with cost-saving measures in operations and management allows governments to free up budgets (Tahir, 2007; Pessoa, 2010; Ameyaw & Chan, 2013) to assist both current and future generations (Pinz et al., 2017). Bundling of contracts[33] also encourages the private partner to consider costs across the entire life-cycle and to ensure that each phase of the project is completed with the highest standards for operation and maintenance (Douglass & Sykes, 2013; Grimsey & Lewis, 2004). Depending on the contractual arrangements, PPPs also transfer construction, financial, commercial, operating, and maintenance risks to those in the best position to handle it – the private sector (Tahir, 2007; Pessoa, 2010; Ameyaw & Chan, 2013; Beevers, 2016). The public sector, therefore, can dedicate additional resources in monitoring service quality and ensuring public welfare is maximized.

The same features of PPPs that can improve sustainability can also increase transaction costs and lead to an overall reduction in social and ecological welfare (Koppenjan & Enserink, 2009). One main challenge in managing PPPs is reconciling the differences in culture, priorities, and management approaches between the public and private partner (Koppenjan, 2015). While the public partner is responsible for ensuring the welfare of its constituents, the priority of the private partner is profit. Failure to effectively understand each partner’s limitations and tangible benefits can yield poor project design and implementation (Emerson & Nabatchi, 2015) that passes costs on to consumers (Shambaugh & Matthew, 2016). Without clear sustainability-oriented input and output requirements, the private partner has a low incentive to provide the first-best solutions and technology (Hueskes et al., 2017; Koppenjan, 2015; Patil et al., 2016; Wu, 2017). Moreover, while long-term time horizons incentivize a life-cycle approach to

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[33] In traditional procurement, the public government contracts each party for each step in the project life-cycle, which can result in project delays and cost overruns due to multiple procurement processes (Fridegotto, 2017). In a PPP, the private companies and investors forms a Special Project Vehicle (SPV), which bundles all procurement phases into one long-term contract (e.g. Design-Build-Finance-Operate-Transfer) with the public partner (Grimsey & Lewis, 2002; Makovsek & Moszoro, 2017).

infrastructure and service provision, the long contract period risks the "lock-in" effect[34] (Hodge & Greve, 2007), reducing the overall flexibility and resilience of management systems (Iossa & Martimort, 2015; Loxley, 2013; McLennan & Maclean, 2019; McQuaid & Scherrer, 2010; Ross & Yan, 2015). Unless clauses to update technology, project outputs, and partner rules and responsibilities are included in the contract, the project runs the risk of becoming obsolete (Koppenjan, 2015).

Examinations of resilience in PPP literature primarily centers on bolstering infrastructure resilience rather than system resilience (see Bloomgarden, Netto, Hempen, Baxter, & Felio, 2016; McLennan & Maclean, 2019; PwC Advisory LLC, 2017). Only one study considers the direct contribution of PPPs to city-level resilience. Through a literature review, Marana and colleagues (2018) identified five characteristics of PPPs that contribute to resilience. Partners must 1) coordinate with multiple levels of governance to scale solutions and minimize redundancy, 2) have access to real-time information and data, 3) develop institutional mechanisms for social learning, 4) include diverse stakeholders throughout all project stages to ensure projects align with the needs of communities, 5) provide equal access to information and opportunities for participation for all project participants.

Engineering resilience literature has focused on the role of PPPs in climate adaptation within the tourism industry (see Wong, de Lacy, & Jiang, 2012), urban development (Taylor & Harman, 2016; Storbjörk, Hjerpe, & Glaas, 2019), and disaster preparation and recovery (Chen, Chen, Vertinsky, Yumagulova, & Park, 2013). PPP infrastructure projects rarely account for climate-related risks (Sundarajan & Suriyagoda 2016). The ability to incorporate infrastructure

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[34] In the context of PPPs, the lock-in effect occurs when a project is "locked in" to a particular technology or service provision method with the contract structure. Incorporating a new technology in the P3 arrangement would require re-negotiation; depending on the relative bargaining power of partners, this re-negotiation could lead to project delays and or cost overruns (Hodge & Greve 2007; Iossa & Martimort 2015; Ross & Yan 2015).

resilience considerations (disaster and climate risk management) into the bid specifications, contract structure, and project design is dependent on the public partner capacity (McLennan & Maclean, 2019; PwC Advisory LLC, 2017) and national- and state-level policies (Taylor & Harman, 2016). Unfortunately, most resilience policies are still developing (McLennan & Maclean, 2019), and may lack clear implementation strategies or specifications (Taylor & Harman 2016).

Despite a growing body of practitioner and academic literature, there is low consensus on whether PPPs are an effective tool for sustainable development and resilience. It is imperative to clarify the role of PPPs in promoting water sector sustainability and social-ecological system resilience. The remainder of this chapter presents the outputs and outcomes of the seven infrastructure and three data-oriented PPP projects. As the Cadiz, HB Desalination, and Urban Runoff projects are still in the development phase, the benefits and potential adverse impacts of these projects are the ones anticipated by project partners and by community stakeholders (i.e. NGOs, opposition groups, etc.).

7.1 Project Benefits

Table 7.1 presents the socio-economic and environmental benefits of the 10 projects. Projects contribute to sustainability and resilience through the development and diversification of local supplies and increased efficiency of water management and resources related to water (e.g. energy). Knowledge transfer and the pooling of resources have also enabled projects to “pioneer” innovative technologies and methods.

	Developing Local Supplies (in Acre Feet per Year)	Water Reclamation and Re-use	Energy Efficiency	Reducing Water Loss	Stormwater & Run-off Management	Improved Water Quality	Development/ restoration of habitat	Knowledge Transfer	Cost-Savings	Innovation	Awards and Accolades
Gobernadora	1,250	X			X	X	X			X	4
Lake Mission Viejo	600	X								X	3
Energy Storage Project	--		X						X	X	2
Rialto	--			X		X			X		--
Cadiz	50,000										1
HB Desalination	56,000		X				X				--
Carlsbad Desalination	48,000 to 56,000		X			X	X			X	12
DataKind	--							X	X	X	2
2 Sigma	--			X				X	X		--
Urban Runoff Project	2,400	X			X	X		X			2

Table 7.1: Economic, Environmental, and Social Benefits for each project as identified through triangulation of interviews, shadowing, observation, and document analysis data.

Improving Water Sector and Ecological System Resilience

A key benefit of the PPPs is the opportunity to enhance local water supplies (#11; #15 - #17; #20; #21; Shadowing, 2/27/2019, 4/26/2019, 12/18/2019; Observation, 8/29/2019, 11/26/2019). Water stakeholders view the diversification of local supplies and the reduced reliance on imported water a critical step for bolstering sustainability and resilience in the water sector (#11; #15; #16; #18; #21; Observation, 8/30/2018, 8/29/2019; CNRA et al., 2016, 2020):

> having that reservoir of water at your doorstep is something that is so beneficial. We live in a virtual desert. We better make sure that we can take care of our needs. And I would rather be independent and self-reliant than have to depend on water coming from someplace else (#16).

Diversification of local supplies reduces the risk of interrupted water services during droughts, emergency interruptions, and regulatory curtailments (#11; #15 - #18; #21; CNRA et al., 2020; Gonzales & Ajami, 2017). Additionally, development of local water sources frees up MWD water for communities that currently lack the financial or technical capacity to reduce reliance on imported supplies (#11; #16). Both desalination plants, for example, are designed to produce as much as 56,000-acre feet a year, fulfilling roughly 18% of OCWD's and about 8 to 10% of SDCWA's total water needs (Wisckol, 2019). The facilities have been heralded as a "drought-proof solution" to water management (#17; Shadowing, 12/18/2019; Rogers, 2013; Weston, 2016a, 2016b), and have been described as "an insurance policy against the unrelenting effects of climate change" (Markus, 2014). The Carlsbad desalination plant has been recognized by the State Water Resources Control Board as "drought-resilient" (SDCWA, 2016), thus allowing SDCWA to reduce its conservation target from 20% to 13% during the 2015 Conservation Mandate.

Figure 7.1 A view of Lake Mission Viejo (Shadowing, 4/26/2019)

Even small increases in local water supplies can have a significant impact on sustainability and resilience at the county- or the city-level (#11). The LMV AWT Facility, for instance, provides the resolution to a 40-year controversy surrounding "unnecessary" potable water usage (Bourke et al., 2019). LMV is the first "fully sustainable" (City of Mission Viejo, 2017) and "drought-proof" man-made lake in California (Bourke et al., 2019), as it is the first recreational lake in the state to be filled with non-potable water (#11; SMWD, n.d.-c). The Facility will save more than 114 million gallons annually of drinking water for other users (City of Mission Viejo, 2017). From the partnership arrangement, the City of Mission Viejo has also been able to save $700,000 on water utility costs for irrigation.

Projects also allow water districts to reduce long-term costs of water provision and water management (#1 - #3; #7; #8; #14) and be “good environmental stewards” (#11) by minimizing non-revenue water loss (#1 - #3, #7, #8), reclaiming and re-using dryweather run-off (#1; #3; #5; #11 - #13; #20), managing multiple resources (#14), and transferring skills and new methodologies across partners (#1; #3 - #5; #21). A key element highlighted by project participants is that the PPPs are multi-use projects that increase both human and ecological system well-being (#1 - #8; #11- #14; #20). The Gobernadora project, for example, provides groundwater recharge; stream flow management; treatment of runoff; capture of excess flow water; downstream sedimentation management; and a “critical” wetland habitat for a variety of animal species such as frogs, fish, owls, waterfowl, foxes, hawks, mountain lions, and other animals. (#11-#13; #20; PACE, 2015). The establishment of a natural treatment system and inflatable dams has minimized the amount of concrete and human impact in the region (#11). The biodiversity of flora and fauna that has sprung up around the basin (see Figure 7.2) have “surpassed what people were anticipating” (#11). A representative from Clean Water Now, an environmental NGO, remarked that GMB is “a great project and one of the best I’ve ever seen […] I just see something that I didn't think I'd ever see in my lifetime. You know, seeing people able to mime [nature] to the point where it becomes its own habitat. And it's self-sustaining” (#13). Flow attenuation has also reduced the downstream impacts of runoff (#11; #13; #20). San Juan Creek “represents the second greatest flood threat in Orange County” (#20). At its peak (run off for a hundred year storm event, high confidence flows) the flow rate is 41,000 cubic feet per second. In the past, largescale storm events damaged water district infrastructure (SMWD, 2014) and caused “significant ecological erosion damage” along Gobernadora Creek and to GERA[35], the downstream ecological preserve (Zenger, 2015, para 5).

Figure 7.2: A view of Gobernadora multi-purpose basin and the Coto de Caza community. (SMWD, n.d.-a)

Leaders in the Field: Innovation through Partnership

Interview respondents also emphasized that the project partners are recognized internally and externally as “pioneers” in water provision and sustainability (#1 - #4; #6; #11; #12; #20; Shadowing, 4/26/2019; Bourke et al., 2019; Jensen, 2012). Respondents stressed that “people

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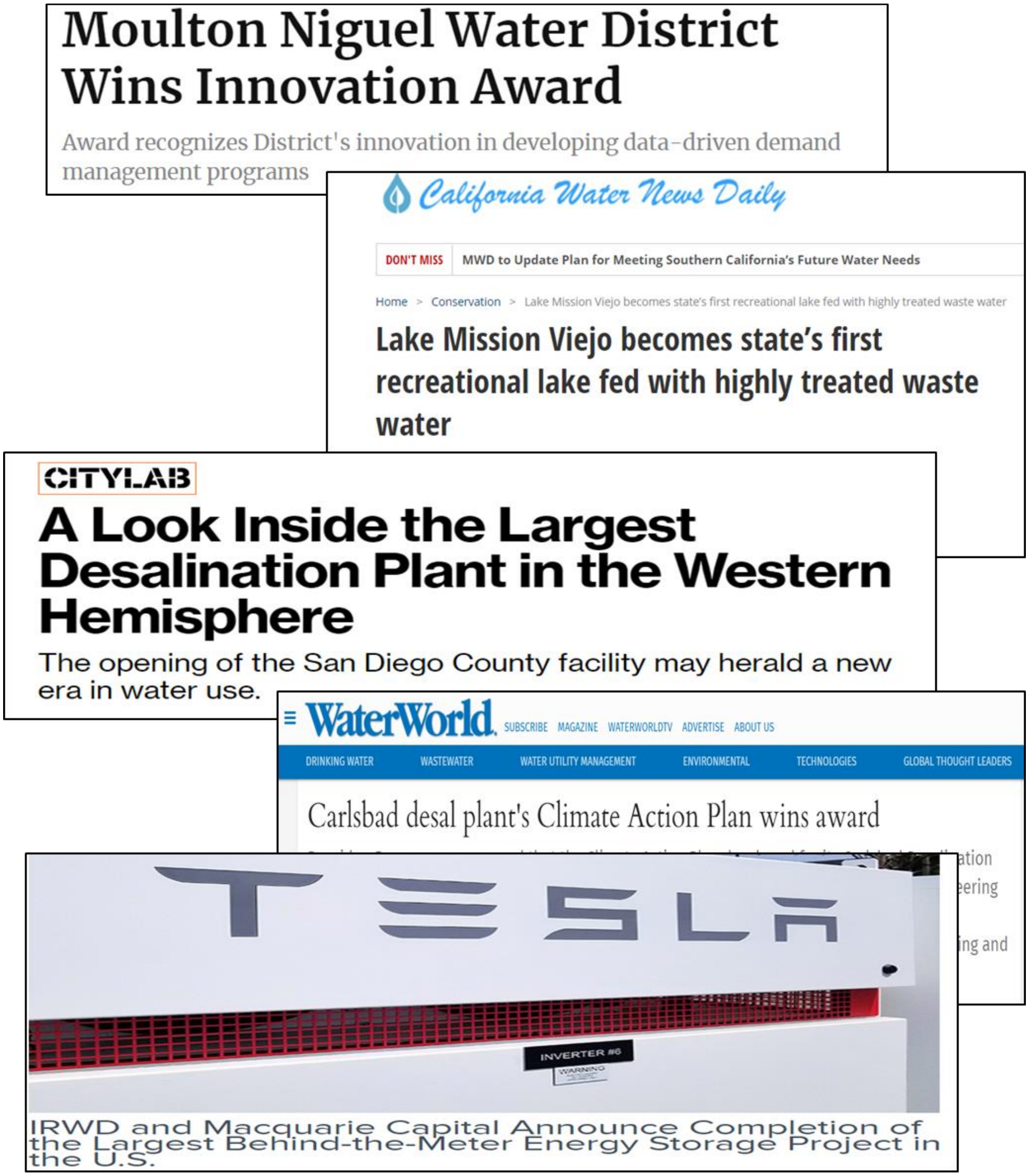
[35] Gobernadora Ecological Restoration Area (GERA) is a 105-acre area that has been restored from agricultural land into wetland and woodland (RMV, n.d.). The protected area was created in cooperation with the CA Department of Fish and Game, the US Fish and Wildlife Services, and the Army Corps of Engineers in 1994 as part of broader mitigation efforts for the Ranch.

aren't doing some of the stuff we [the project participants] do. No one around here has done a project like this (#11; see also #1 - #4; #12 #13). In fieldwork and in media articles (see Figure 7.3), PPP projects were often referred to “the first of their kind” – the largest desalination facility in the western hemisphere (#17; Shadowing, 12/18/2019; Bliss, 2015), the largest behind-the-meter energy storage system (#14; IRWD, 2017), the first recreational lake in the state of California to be filled with recycled water (#11; Bourke et al., 2019; SMWD, n.d.-c), and one of the first applications of Big Data Analytics to water management (#1 - #4; CA Water News Daily, 2017). Respondents and media coverage of the PPP projects also pointed to the “unique” and “innovative” partnership structure (#1-#4; #11; #12; #17; Bourke et al. 2019; Jensen et al., 2012). Project participants attributed the opportunity to pool resources and skills as a key contributor in producing these innovative technologies (#1 - #5; #16; #20; #21).

> That's why like partnering because it's the only way that we're going to learn as an industry. If we just talked to the same people all the time, then we're not learning anything. We're just recycling our knowledge and our experience. We need something new to challenge that, to question that, and to improve that (#4)

In total, the projects received 23 awards across regulatory agencies (e.g. CalEPA), water associations (e.g. WaterNow Alliance, Global Water Intelligence), and business associations (e.g. OC Business Council). Table A2 in the Appendix provides a summary of all awards and accolades for each project.



Moulton Niguel Water District Wins Innovation Award

Award recognizes District's innovation in developing data-driven demand management programs

California Water News Daily

DON'T MISS MWD to Update Plan for Meeting Southern California's Future Water Needs

Home > Conservation > Lake Mission Viejo becomes state's first recreational lake fed with highly treated waste water

Lake Mission Viejo becomes state's first recreational lake fed with highly treated waste water

CITYLAB

A Look Inside the Largest Desalination Plant in the Western Hemisphere

The opening of the San Diego County facility may herald a new era in water use.

WaterWorld

Carlsbad desal plant's Climate Action Plan wins award

IRWD and Macquarie Capital Announce Completion of the Largest Behind-the-Meter Energy Storage Project in the U.S.

Figure 7.3: Headlines from media articles that highlight the “pioneering” and “innovative” elements of the 10 PPP projects

Economic Benefits

Finally, public and private partners have also highlighted the economic benefits of partnerships. Infrastructure PPP projects stimulated the local economy (#17; #21; Cadiz, 2019a; Lambert, 2013) by providing tax revenue to cities (#16; #17; Cadiz, 2019a) and creating temporary and permanent local jobs during construction and operation of facilities (#17; #21; Cadiz, 2019a; Lambert, 2013). For the HB Desalination Facility, the city of Huntington Beach will receive roughly $106 to $290 million in financial benefits through the combination of new revenue and through cost-savings throughout the lifetime of the facility[36] (Poseidon, 2018). Project participants have also expressed that the PPPs have enabled public partners to free up resources for other critical infrastructure needs (#1; #4; #11; #21). According to the Mayor Ed Scott, Rialto was able to use $30 million in an upfront payment to invest in the redevelopment of Rialto airport (Table Rock Infrastructure, 2015). The City has already received $15 million in return investment, and has been able to add 2,800 permanent jobs, with another 5,650 added by the end of redevelopment. City officials argue that the project has been critical "to help put the budget back on sturdy footing after the wobbly years following the '08 – '09 recession" (Table Rock Infrastructure, 2015, para. 8).

7.2 Impacts to Ratepayers

Total project costs and distributional impacts vary between projects (see Table 7.2), and depend on the project design (#15; #16; Shadowing, 12/18/2019); opportunities for grants and low-interest loans (#11; #14; #15; #17; #21), project challenges (#11; #14 - #17; #20; #21; Shadowing, 2/27/2019, 3/15/2019, 4/26/2019); the return on investment on the private equity (#4; #11; #15 - #17; #19; #21); and the cost of water provision relative to the unit cost of imported water ($1,050 to $1,136) from Metropolitan Water District[37] (2019). The return on

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[36] The city of Huntington Beach will receive $3.9 million for the purchase of the city's property (Poseidon, 2018). Upon completion of the project, $2 million is placed in the general fund (#16). Every year, Poseidon will pay $950,000 in property tax to the general fund, $50,000 in utility tax, $200,000 in franchise fees for the piping infrastructure, $2.6 million to support local school districts (Poseidon, 2018). Finally, Huntington Beach has the right – but not the obligation – to obtain 3,360-acre-feet per year (about 12% of the city's overall water supply) at a 5% discount on the avoided cost of purchasing imported water (#17).

[37] For example, the unit cost of water for the Carlsbad desalination plant includes debt service charge, an equity return charge, fixed and variable operating costs, fixed and variable electricity costs (#21: WPASA, 2012).

investment is “commensurate with the risk that [the investors or private partner] is taking on” (#15; see also #11; #17; #19). Projects with high risks for development, construction, or operation will require a higher rate of return to secure investment (#11; #17; #18). For example, the agreement negotiated between SDCWA and Poseidon has a target internal rate of return of 9.38 to 9.45%, depending on the bond interest rate at closing (Reinhardt, 2012). At the time of financial close in 2012, SDCWA estimated that Poseidon could achieve an equity return of up to 13% (Rogers, 2014). The return to investment depends on Poseidon’s ability to manage the completion risk (design, permitting, and construction) and meet performance and water quality standards.

	Final Capital Cost (in millions)	**Cost Overrun (in millions)**	**Price per A/F**	**Changes to Water Rates ($)**	**Change to Water Rates (%)**
Gobernadora	$23.4	$7.86 to $9.08		low	low
Lake Mission Viejo AWT	$6.5	$1	$1,525	$0	0%
Energy Storage Project	Proprietary Information	Proprietary Information	--	$0	0%
Rialto	$177 total capital investment ($41 in capital costs)	Unknown	--	$43.04 to $72.78	68% to 115%
Cadiz	$225 to $275	--	$827 to $1,127	low	low
HB Desalination	$1,000	--	$1,791 to $2,141	$3 to $8.60	5% to 14.33%
Carlsbad Desalination	$1,000	$0	$2,125 to $2,368	$5	6.25%
DataKind	--	$0	--	$0	0%
2 Sigma	--	$0	--	potential for savings	--
Urban Runoff Project	$0.4	--	--	potential for savings	potential for savings

Table 7.2 Project Costs, Distributional Impacts, and Adverse Environmental Impacts

Price per A/F is the mutually-agreed upon price when the facility first became commercially operational. These water prices will increase every year due to changing input costs such as energy costs. Cost overruns are costs that were incurred prior to commercial operation. Changes to water rates represent the changes to average water rates of Tier 2 water users (water users that stay within the allotted monthly budget).

For nine of the projects, changes to water rates are roughly zero to eight dollars, representing a 0% to 14% increase in the average water rates within the public partner's jurisdiction. The highest infrastructure upgrades in Rialto, a city that has chronically under-invested in its water and wastewater system and has acquired one of the largest debts by a water provider in the country (Wharton, 2015). The PPP provides capital upgrades to the ageing water system as well as additional funding for debt refinancing and economic development (Table Rock, 2019) While the partnership has resulted in 30% cost-savings (roughly $500,000) for wastewater system operation, water rates have increased by 68% (Ivory, Protess, & Palmer, 2016). City officials have argued that the rates have been artificially lowered for roughly a decade and that rate changes to ensure the utility remains "competitive" (Table Rock Infrastructure, 2015, para 9).

Public water managers acknowledged that the distributional impacts of the projects are "not insignificant" (#11; #15; #16; #18; #21). Water managers also stressed that no particular group bears a disproportionate burden of project costs. Even when projects occur at a community, rather than a county-level, costs are distributed equally throughout water users[38] (#11; #15; #15; #21). Prior to entering into an agreement, water managers conduct analyses to ensure that decisions are cost-effective (#1; #4; #11; #15), as they need to "justify our costs to the ratepayers. [...] We can't afford to take risks with your money. We are a public agency." Projects were reviewed from a water portfolio standpoint across long time horizons (#11; #15; #16; #21).

> The way we have to look at things, it's not just for tomorrow, it's for many, many years down the road. It doesn't last forever, but it is kind of a forever project.

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[38] The exception to this is the LMV AWT Facility PPP. As the Lake will only benefit members of the LMV Association, the SMWD Board of Directors was adamant that project costs must be borne by the private partner, and not the district's water users (#11).

> Once you've got it in the ground... you've got a pipe leak, you fix the pipe. Pump fails, you replace the pumps. That's the way we try to look at it. And that's the difference between us and [the private partner]. We look at it from a business standpoint, but we're in the business of forever. (#11)

Public partners emphasized that utilities would be forced to raise rates in the future regardless of whether they entered into the PPP due to rising costs of electricity and the increased costs of imported water (#4; #11; #15; #16; #21; Weston, 2106b). The cost curves for capital-heavy projects such as desalination are projected to cross with the unit cost of imported water within the next 15 to 30 years (#11; #15; #16; #21; Clean Energy Capital, 2014; Finley, 2015; Wisckol, 2018). Investment in projects such as desalination or water recycling, thus, may reduce rate increases in the long-term.

Ultimately, respondents perceived the cost premium of the PPP projects as a tradeoff between affordability and reliability (#4; #11; #13; #15; #16; #21; Weston, 2016b). "A lot of times the game is basically ... how much would you pay? How much would you pay to make sure that your family, that when you go home at night, you're going to have water to cook food and wash dishes with? (#13). Respondents emphasized that the decision into entering a PPP is not a strict comparison between MWD and PPP water cost. Instead, decision-makers compared the unit cost of water ($/AF) to the project's ability to diversify water supplies (#4; #11; #15; #16), increase certainty of water provision in changing climate conditions (#11; #15; #16), ensure public safety (#4; #13), and to test and replicate technologies at other sites (#4; #11). While support for projects was not unanimous within the participating public organizations (#11; #15; #16; #18; #21; IRWD, 2014), public partners were willing to accept the increased cost of projects in order to meet the broader goals of their districts (#4; #11; #15; #16; #19; Lambert, 2013; Weston, 2016b):

> How much are you willing to pay extra? And what is the ultimate impact on the rate payers? Is it $1, $5, $10? And does that seem justifiable from our standpoint as an insurance premium on the off chance we lose the other supplies? Okay, so your water rate goes up. I'd sure pay for water if I didn't have any. **Because cheap water doesn't do you any good if you can't get it** [emphasis added]. So, if it's a matter of me being able to brush my teeth and take a drink of water versus paying $10 more on my water bill, I'll pay the $10 (#11).
>
> Any project that would help you reduce how much imported water you need, you want to think about. And that gets down to the nut of the whole project - it's going to be more expensive than imported water, but it's reducing the uncertainty you have by taking imported water. And **how much are you willing to pay to create more safety and more certainty with your water supply?** [emphasis added] (#15)

7.2 Opportunities for Voice

The state of California has several regulatory procedures in place to ensure that citizens have the opportunity to voice inputs on projects. The California Infrastructure Finance Act (IFA), the dominant PPP legislation in the state, requires public agencies to hold at least one public hearing prior to raising rates in relation to a PPP project (California Government Code Section 5956). Similarly, public participation is “a mandated and an essential component” of the California Environmental Quality Act (CEQA) (Title 14, CCR 15201). The public is able to review and comment on environmental CEQA documents and environmental permit drafts, participate in public hearings, and challenge decisions with legal action (DTSC, 2018). All infrastructure projects complied with the legal requirements for public participation during permitting and the EIR process. SDCWA, for example, conducted over 40 hours of public meetings to discuss the project (#21).

Case sites varied in the degree to which they provided additional opportunities for project feedback and NGO participation (see Table 7.3). NGOs participated either as project partners or contributed to the development and implementation of PPP projects by providing technical support or monitoring environmental impacts. NGO participation and engagement varied between projects. The NGO consultant for the HB Desalination project, for instance, stepped down from their position because the two organizations did not develop effective two-way communication or a mutual understanding of each other's perspectives (#13). According to the NGO participant, Poseidon "listened, but they didn't embrace one idea that I had" (#13).

	Community Engagement prior to Commercial Operation	**NGO Participation**	**Community Contention**	**Potential for Environmental Harm**	**Number of Legal Challenges filed**
Gobernadora	X	X (consultation + monitoring)	low		0
Lake Mission Viejo AWT	X	X (project support)	--		0
Energy Storage Project			--		0
Rialto	X		medium		
Cadiz			high	X	6
HB Desalination	X	X (consultation)	high	X	6
Carlsbad Desalination	X		high	X	13
DataKind		X (project partners + project support)	--	--	0
2 Sigma		X (project support)	--	--	0
Urban Runoff Project		X (project partners + project support)	--	--	0

Table 7.3 Opportunities for Stakeholder Inclusion and Degree of Community Contention

Community engagement includes all communication, outreach, and opportunities for voice on the project prior to project completion or commercial operation. These engagement opportunities go beyond the legal requirements for public notice and comment for projects for permitting, rate changes, and CEQA documents.

Community contention refers to the degree of news coverage or public statements from external organizations in opposition to the project. A low rating represents 1 to 2 negative articles, a medium rating is 3-5 and a high rating is 6 and greater articles. Projects with no rating received no negative coverage from media sources or external organizations.

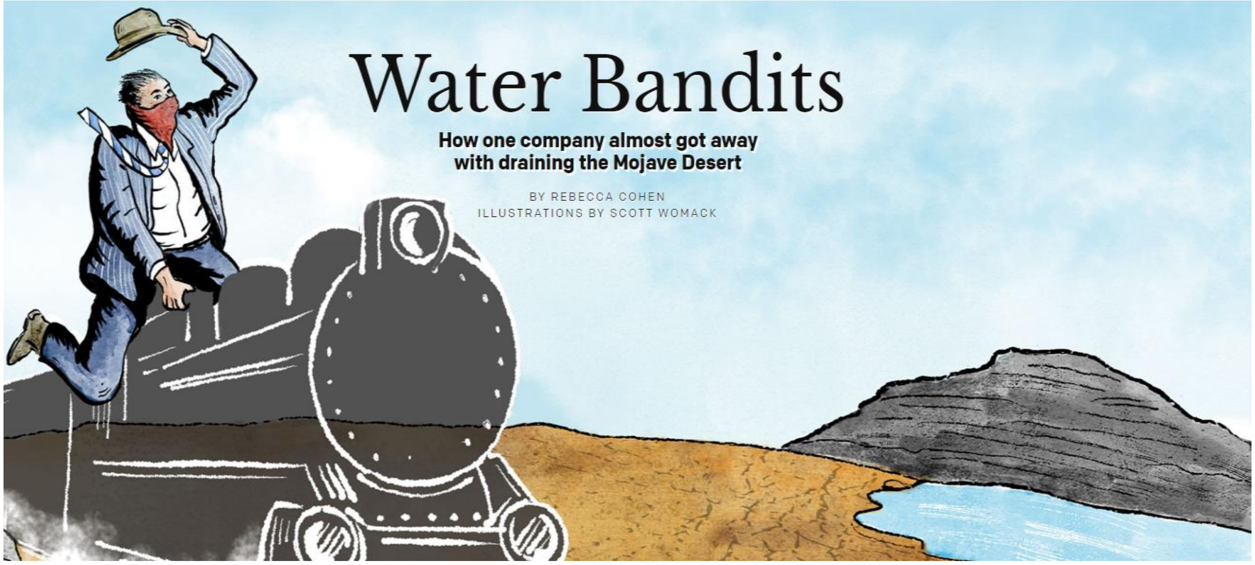
Finally, potential for environmental harm refers to adverse environmental impacts that have been identified by protectionist groups or independent research

Community engagement primarily focused on communicating information about the project and gaining community buy-in and trust (#11; #15 - #17; #21; see Chapter 9 for more information). Project participants were more likely to engage with the public when PPPs required rate increases or construction work off-site. Public and private partners participated in town halls, led information campaigns, met directly with community members and NGOs to discuss concerns regarding projects, and engaged with community leaders (#11 - #13; #15 - #17; see also Chapter 9). Public partners in the Gobernadora and the HB desalination project also provided opportunities for NGOs or citizens to provide direct feedback on project design or the PPP agreement. In the Gobernadora project, a member of an environmental NGO was brought on to review and comment on the CEQA documents and the project design. After discussions with the General Manager, the NGO was invited to stay on and to monitor environmental impacts during project implementation (#11; #13; Shadowing, 3/15/2019). In 2015, OCWD formed a public working group of citizens, agencies, and organizations to provide feedback on the Term Sheet between Poseidon and OCWD (#13; #15 - #17; OCWD, n.d). The revised term sheet provided greater clarity of project costs and the roles and responsibilities of partners, and provided additional opportunities for individuals to ensure that the project minimizes risks to ratepayers (#17). OCWD plans to incorporate a similar mechanism for feedback and review during the negotiation of the Purchase Agreement (#15).

Four projects did not engagement with the community during project design or implementation. Information on the IRWD Energy Storage Project and the data-oriented were publicized via media articles or featured in district materials after project completion (#1 - #3; #14; see IRWD, 2017; MNWD, 2017). Respondents argued that the fast nature of the projects limited opportunities to launch community engagement programs (#1; #3; #14).

Community Contention and Adverse Environmental Impacts

Citizens and NGO groups provided "voice" throughout the project lifetime through project opposition: NGOs and citizens organized protests, contested projects at public hearings, wrote op-ed media articles, and issued legal challenges to EIRs and environmental permits (#11; #15 - #17; #21). Three projects have faced high levels of community contention: the two desalination plants and the Cadiz PPP (see Table 7.3). While other projects have a balance of positive and negative op-eds, media coverage of Cadiz is predominantly negative, with environmental groups (NPCA, 2019) and political figures (Feinstein & Friedman, 2017; Rendon, 2018) arguing that the project will irreparably harm the Mojave Desert (see also Figure 7.4). Cadiz is proposing to extract 50,000 AFY of groundwater each year for 50 years. However, independent evaluations suggest that recharge rate for the aquifer is between 5,000 to 33,000 AFY (Ajami, 2012), with the US Geological Survey (2017) estimating that the recharge rate could be as low as 2,000 to 10,000 AFY.



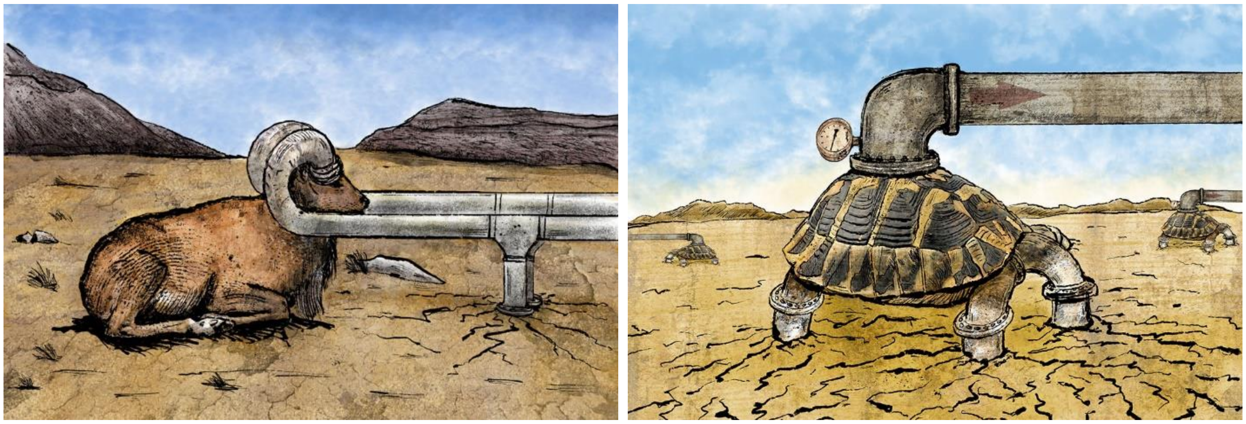


Figure 7.4 Illustrations by Scott Womack showcase the concerns over adverse environmental impacts to the Mojave Desert and the wildlife inhabiting it (Cohen, 2019).

The extent of the potential environmental impacts is currently still under debate. Two studies funded by the Mojave Desert Land Trust, an organization opposed to the project, claim that Cadiz will have adverse environmental impacts on the surrounding springs (see Zdon, Davisson, & Love, 2018; Zdon & Love, 2018). Yet, research funded by the Fenner Valley Authority has identified "numerous methodological errors in the opposition-funded papers" (CA Water News Daily, 2019, para. 2). Project participants argue that opposition to Cadiz "is all politics. There's no technical issues" (#11) and point to the EIR approval in 2012 as testament to the low impacts of the project. The EIR found that the project "will not harm desert flora or fauna, and the aquifer will remain 95% full after 50 years of operation" (FVWA, n.d.). Opponents of the project have countered that the project has only been able to pass early stages of permitting due to lobbying and political favoritism (Clarke, 2012; Stringfellow & Sizek, 2018) and have accused Cadiz of utilizing loopholes in regulations to avoid federal review of environmental impacts (Clarke, 2017).

To address concerns of adverse environmental impacts, public partners developed the Groundwater Monitoring, Management, and Mitigation Plan (2012) in conjunction with groundwater experts and San Bernardino public officials. The Management Plan serves as an early warning system to potential impacts to air quality, vegetation, local springs, groundwater aquifer levels (Management Plan, 2012) and establishes a maximum groundwater draw-down level to “ensure the appropriate and safe management of the groundwater basin” (SMWD, 2012b, p.2). Monthly monitoring reports on surface and groundwater water levels within the watershed will be sent to an agency-appointed technical review panel, who will then provide recommendations. San Bernardino County and SMWD will have the authority to enforce these recommendations or to halt withdrawals from the groundwater basin.

Concerns surrounding the Huntington Beach and the Carlsbad desalination plants have primarily focused on cost and project fit. Environmental NGOs have expressed that desalination should “be the last tool in the tool box, not the first” due to its distributional impacts, high energy intensity, and concerns of sea water withdrawal and brine discharge disrupting and damaging marine ecosystem function (OC Coastkeeper, n.d.; Surfrider, 2015). Interview respondents have countered that the desalination plants are as environmentally sensitive as possible (#15 - #17) – the plants are carbon neutral, the intake screens have been modified to reduce impacts to wildlife, and brine disposal adheres to California’s environmental regulations (#15 - #17; #21; Poseidon, 2020).

Respondents viewed cost as the primary source of opposition for desalination (#13; #15; #16; #18; #21). Due to the high cost of desalinated water, media articles have described the Carlsbad plant as “a pig that will try for years to find the right shade of lipstick” (Rogers, 2014, para. 10) and a form of “corporate welfare” (para, 28). The facility has been criticized for increasing the costs borne by ratepayers in an area that has some of the highest water rates in the country (Rivard, 2017a, 2017b; Fikes, 2015). Similar concerns have been raised for the HB desalination facility. A report by Municipal Water District of Orange County (2018) suggests that if the price of imported water rises at a slower rate than anticipated, the HB desalination project may end up costing ratepayers as much as $400 million dollars over the span of the project lifetime. Moreover, an independent evaluation by the UCLA Luskin Center found that the PPP would make drinking water for disadvantaged households in Orange County "moderately to severely less affordable" (Pierce et al., 2019, p. 2), with water bills for low-income households increasing from 2.5% to 3% of pre-tax income (Peirce et al., 2019). The study also predicts that individuals whose "those served by the county's small underperforming systems, whose lower-quality water might be improved through new desalinated supply, will not be served by the proposed agreement to purchase desalinated water," thus creating unequal benefits and harms to Human Right to Water Outcomes (Pierce et al., 2019, p.1).

Some agencies that purchase water from OCWD have publicly expressed concern about the increased unit cost of desalinated water (IRWD, 2018, 2014). In policy position memos and letters to OCWD, members of IRWD (2014) argued that "some retail agencies may receive greater benefit from ocean desalination than others" (IRWD, 2014, p. 2) and that the project should proceed "without forcing nonparticipating agencies to subside the project" (IRWD, 2018, p. 2). Other retailers may "not want to have any participation in a desalinated supply" due to the availability of more cost-effective alternatives (IRWD, 2018, p.2). IRWD (2018) also expressed concerns that desalinated water could lower the quality of water within the OC Groundwater Basin by increasing concentrations of total dissolved solids. The agreement as OCWD "exchanging reliance on MWD for decades of dependence on a private company at more than double the cost of water" (IRWD, 2018, p. 1).

Figure 7.5 show the public turn-out at hearings associated with the two desalination projects. Public and private respondents argue that the opposition to the desalination project comes from “a loud vocal minority” (#21; see also #15- #17). Surveys of OCWD and SDCWA water users suggest that the majority of the public supports desalination (#15-#17; #21). In 2019, a survey (N=1000) showed that 85% of OCWD’s supported constructing a desalination plant in Huntington Beach (Global Newswire, 2019). Meanwhile, surveys conducted in 2004 (N=710) and 2012 (N=816) showed 75% and 82% of respondents agreeing or strongly agreeing that desalination is important to meeting water supply reliability goals in San Diego (Rea & Parker Research, 2004, 2012).

Figure 7.5 Protesters and supporters at a California State Lands Commission meeting on permit approvals for the Huntington Beach Desalination plant (Zint, 2017)

7.5 Project Outcomes

Participation in the PPP projects has shifted values and norms in public water utilities. First, the project created a sense of pride amongst staff (#1 - #5; #11; #14). The innovative project designs have created a recognition amongst staff that "people aren't doing some of the stuff we do. No one around here has done a project like that" (#11). Increased staff pride and buy-in has "opened the door for more public-private partnerships" and other collaborative strategies to water management (#1; #3; #5; #11; #14). One respondent remarked that while staff at their water utility have "always liked to collaborate, [the PPP] reaffirmed that belief that you can't do things in a silo. You can't take a single-discipline approach to complex problems. You need to get different viewpoints" (#3). Members from public agencies had to adapt to working closely and collaboratively with members of the private sector (#14; #15; #21). The experiences created a new understanding of how different actors within the water sector operate. When asked about lessons learned from participation in PPPs, respondents reflected on skills gained in (1) utilizing, operating, and maintaining new water technologies and (2) negotiating future contracts and maintaining partnerships in ways that protected the public (#1- #5;#11; #14; #15; #16; #21).

Project participants argued that buy-in and affirmation of collaborative water strategies may scale beyond project participants through sharing of best practices with other utilities and agencies in the water sector (#1 - #5; #9 - #11). The successes of these initial PPP experiments can reduce barriers of entry for future projects (#5; Rogers, 2013). Respondents believed that these projects have “the potential to really open people’s eyes” to collaborative strategies.

> I think one of the great impacts this project could have is just demonstrating the benefits of - even though we may have different missions - […] when we work together, we can help our organizations carry out our missions and accomplish our objectives more effectively. (#5)

7.6 Discussion

This chapter examined the impacts of water sector public-private partnerships on sustainability and social-ecological resilience. Process-tracing of economic and environmental impacts suggests that PPP projects have the potential to enhance local water supply and improve water management. Moreover, the cases suggest that PPPs can be used to pilot projects that can be scaled or replicated at other sites, transfer knowledge and skills to other sectors, provide capital funding, and lead to innovative and multi-benefit projects. Participation in PPP projects ultimately created greater staff buy-in at public agencies in cross-sector and collaborative solutions to pressing water challenges.

The cases highlight the challenge of assessing projects costs and benefits across long time horizons. When a project is not financially viable or there is high uncertainty in future conditions, private partners are incentivized to pursue cost-cutting measures or shirk responsibilities, thus passing costs along to future ratepayers and potentially increasing risks to environmental systems or human health (Bond, 2010; Leighland, 2018; Loxley, 2013; Ng & Loosemore, 2007). For the 10 projects, uncertainty regarding future water demand and supply made it difficult to assess the unit cost of water. For instance, MWDOC's (2018) analysis of future water sources in Orange County ranked the Huntington Beach desalination facility as the worst option out of six potential projects due to the high unit cost of water and concerns the plant's water provision may exceed the County's future water demand. However, the County's probability of water shortages ranges from 3 to 35% between 2020 and 2050, and is dependent on climate change effects, future demand management, and investment decisions by Metropolitan Water District. Public partners believe that Met's rates will increase annually between three to six percent while MWD projects that rates will increase three percent every year over the next 30 years (#11; #15; #16). On average, MWD's water rates have increased 6.66% every year between 1969 and 2014 (Clean Energy Capital, 2014). At a 6% annual rate increase, the cost curve for desalinated water will cross with that of imported water by 2035. At a rate of 4%, the desalinated water becomes cheaper than imported water in 2048 (Wisckol, 2018), and at 3%, the cost curves will never cross (Clean Energy Capital, 2014). In the face of this uncertainty, strategic decision-makers examined both the economic impacts of projects as well as the PPP's capacity to achieve the utility's resilience and sustainability goals.

Economic Efficiency vs. Equity

When examining economic impacts of PPPs, it becomes clear that PPPs can indeed face a tension between economic efficiency (financial viability of the project) and equity (impacts to low-income water users) (Dellas, 2012; Koppenjan & Enserink, 2009; Koppenjan, 2015; Taylor & Harman, 2016). This tradeoff depends on the capacity of public and private actors, technology implemented, the risk premium associated with the project, the scale of the project, and project challenges. Participation in PPPs resulted in rate increases for three out of the six water utilities featured in this research (OCWD, SDCWA, and Rialto). The high unit cost of the desalination facilities can be explained by the complexity of the technology, shifting environmental regulations (see Chapter 8), and the large scale of the facilities. However, in the case of Rialto, the tradeoff between economic efficiency and sustainability was exacerbated by the high risk associated with the ageing infrastructure and financial insolvency of the utility. Rialto's poverty rate (17.9%) and median household income ($53,962) are below the average for California ($67,169 and 11.8%, respectively) and that of other case sites[39] (DataUSA, 2019). The city also has a high proportion of color: 73% of the population is Hispanic, 11.8% are African American, and 10.8% are white. Prior to entering into a PPP, Rialto was on the verge of filing for bankruptcy (Table Rock, 2019) and had been facing more than a decade of water quality and water provision challenges (Rosenblatt, 2007). A 2011 report released by the city projected that rates would increase roughly 31% if operation of the wastewater and water system remained under public operation (Langford, 2011). Yet in the PPP arrangement, the public partner committed to raising rates by 115% to ensure financial viability of the project. Due to rising concerns of water affordability, public officials have slowed rate increases to 68% by utilizing surplus reserves (Ivory et al., 2016; Table Rock, 2019).

The Rialto PPP has been heralded as a model of success in providing much-needed repairs to a region that is lacking the technical and financial capacity to do so on its own (Lambert, 2013; Table Rock Partners, 2015). However, the case highlights the challenges of infrastructure provision in chronically underfunded systems reveals how PPPs may "lock-in" public partners into contracts whose costs will be borne by consumers (Hodge & Greve, 2007;

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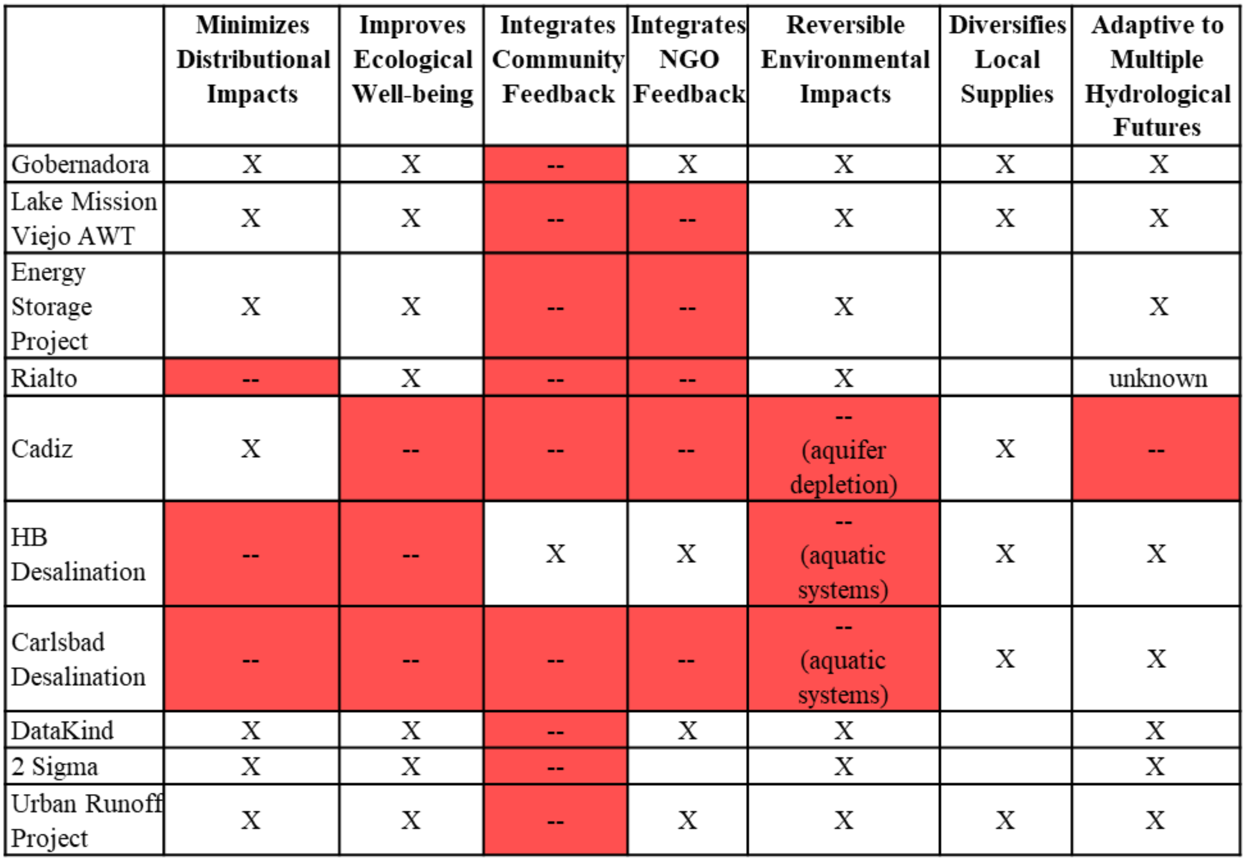
[39] In 2017, median household income and poverty rate in Orange County was $86,217 and 12.1%, respectively. Household income in San Diego County was $76,207 and the poverty rate is 13.3% (Data USA, 2019).

Hughes, 2017). Transferring operation, management, and maintenance risks to a private partner is challenging for ageing systems, as the cost risk is undefined and open-ended (Callahan, 2012). Financing the partnership was also “a challenge due to the city’s tenuous financial situation” (Hewes & Randolph, 2018, p. 17). Along with financing for infrastructure and O&M, private equity firms provided upfront financing to Rialto, a practice that was outlawed in France in 1993 due to concerns of corruption and biasing the decision-making process (see Lobina & Hall, 2007). Media reports suggest that these payments enabled Rialto to retire outstanding debt, thus strengthening the financial viability of the water utility in the long-term (Jensen, 2012; Table Rock Infrastructure, 2015). Yet, during public workshops surrounding the PPP proposal, residents expressed a desire to retain a publicly-managed water system and were concerned about accepting up-front financing, as this is a cost that would be ultimately borne by ratepayers throughout the contract life-time (Langford, 2011; Steinberg, 2011c). Opposition groups attempted to block the rate increase by filing a “protest” with the city under Proposition 218, but were unable to collect the number of signatures necessary (California City News, 2012). Lobina (2014) suggests that the Rialto PPP arrangement is actually a form of “hidden taxation” (p. 32) and “water privatization in practice, but not in name” (p. 2). Independent evaluations of the project suggest there is little evidence that Rialto would not have been able to find other sources of capital for their project needs and in many cases, this capital could have been obtained at a lower cost (Hughes, 2017; Lobina, 2014).

This tradeoff between equity and economic efficiency can serve as a barrier to PPP adoption in low-income areas. In developing countries, the high cost of connecting to water systems (Albaalate et al., 2013) can result in uneven patterns of economic development (Siemiatycki, 2011; Patil et al. 2016). When institutional and monitoring capacity of the government is low, the private partner will pursue activities that maximize profitability (Pusok, 2016), providing quality services to users in high value locations while limiting service access to low-income users (Graham & Marvin, 2001). PPP projects in low-income regions can be financially viable when users accept a shared, rather than an individual, water connection at a reduced water rate; are able to secure financing through micro-credit; or provide voluntary labor to offset costs of the water system (i.e. laying their own piping, serving as a monitoring system for leaks) (Dellas, 2012). This potential for exclusion from the water system suggests that PPPs may not be a tool to combat water-related poverty (Dellas, 2012) unless public partners and non-government organizations are willing to subsidize critical maintenance or expansion of networks in low-income regions (Leighland, 2018; Nizkorodov, 2017).

PPP Contributions to SES Resilience and Holistic Sustainability

Table 7.4 summarizes the contributions of the infrastructure and data-oriented projects to holistic sustainability and SES resilience. PPPs undertaken in the study include hard (infrastructure-oriented) and soft (decision-making, operational efficiency, and behavior oriented) approaches to water management that have enabled water districts to diversify water portfolios, increase efficiency, and consider linkages between multiple resources (e.g. water-energy nexus). Bringing multiple parties and types of knowledge together increases likelihood of creating multi-use projects such as the Gobernadora Multi-Purpose Basin or the Urban Runoff Project.



	Minimizes Distributional Impacts	Improves Ecological Well-being	Integrates Community Feedback	Integrates NGO Feedback	Reversible Environmental Impacts	Diversifies Local Supplies	Adaptive to Multiple Hydrological Futures
Gobernadora	X	X	--	X	X	X	X
Lake Mission Viejo AWT	X	X	--	--	X	X	X
Energy Storage Project	X	X	--	--	X		X
Rialto	--	X	--	--	X		unknown
Cadiz	X	--	--	--	-- (aquifer depletion)	X	--
HB Desalination	--	--	X	X	-- (aquatic systems)	X	X
Carlsbad Desalination	--	--	--	--	-- (aquatic systems)	X	X
DataKind	X	X	--	X	X		X
2 Sigma	X	X	--		X		X
Urban Runoff Project	X	X	--	X	X	X	X

Table 7.4 Contributions of the 10 PPPs to Holistic Sustainability and Social Ecological System Resilience. Projects that are both sustainable and align with SES resilience minimize distributional impacts, include diverse stakeholders in project design, and contribute to ecological system well-being (e.g. improving resource efficiency, improving habitats, reducing downstream impacts). Projects that contribute to SES water resilience provide locally tailored solutions that diversify water supplies through both hard and soft water management strategies, improve resource efficiency, and are able to adapt to multiple hydrological futures.

Projects vary in their degree of flexible design and perceived adverse environmental impacts. The data-oriented PPPs, Energy Storage Project, and the water recycling and reclamation projects (Gobernadora, LMV AWT facility) represents water solutions that contribute to ecological well-being and improve water system reliability. Thus, these projects represent cases of both sustainable and SES resilient water management strategies. The Cadiz water project, on the other hand, represents an engineering resilience – rather than an SES resilience - approach to water management. The groundwater aquifer in the Mojave bolsters local water supplies and reduces the risk of interruptions from imported water, thus increasing water system resilience. Cadiz Inc. (2019) claims that over the spans of its lifetime, the project will conserve 500 billions of gallons of fresh water that would otherwise be lost to evaporation or salt contamination. However, the gap between estimated aquifer recharge (2,000 to 33,000 AFY) and extraction (50,000 AFY) has raised concerns among scientists, civic society, and decision-makers that the PPP will irreversibly harm the Mojave Desert ecosystem (Ajami, 2012; Feinstein & Friedman, 2017; NPCA, 2019; USGS, 2017). Public partners have strived to minimize environmental degradation through the establishment of an independent team for groundwater monitoring (SMWD, 2012b). The PPP is the result of an unsolicited proposal (USP) in which Cadiz Inc. and its investors bear the costs of project development. The USP, thus, has created an alternative maladaptive path for the seven utilities participating in the PPP. The case aligns with SES resilience literature, which suggests that engineering resilience solutions can cause tradeoffs between system reliability and sustainability (Chelleri, Waters, Olzabal, & Minucci, 2015; Dewulf et al., 2019; Foudi, 2014; Kythreotis & Bristow, 2016).

Similar concerns have been raised among practitioners and scholars on whether desalination is a resilient and sustainable solution of water supply. On the one hand, desalination contributes to diversity of water portfolios (Gonzales & Ajami, 2017) and provides drought-resilient water supplies (Rivard, 2016; Tahir, Baloch, & Ali, 2020; Weston 2016a, 2016b). Yet, the high unit cost of water, high energy footprint, and uncertainty of impacts to aquatic ecosystems has raised concerns that the technology is a maladaptive solution to sustainable long-term management and climate change adaptation (Barnett & O’Neill, 2010; Greenberg, 2014). To reduce environmental impacts, both desalination facilities have pursued voluntarily carbon neutrality and are installing the best available technology that aligns with the current (2015) environmental legislation on intake and brine disposal (#15 - #17; Poseidon, n.d.). The extent of impacts to ecosystems is currently unknown, and will require careful long-term monitoring of the marine environment surrounding both plants.

The adverse environmental impacts of the cases highlight the importance of pursuing water management strategies that promote system-level, rather than organization-level, resilience (Cedergren, Johansson, & Hassel, 2018). Focusing on the benefits to individual organizations and cities can create tradeoffs across geographical and temporal scales (Dewulf et al., 2019) and lead to the adoption of maladaptive technologies (Barnett & O'Neill) that weaken system sustainability and resilience in the long-term. To transition to sustainable water pathways, Foudi (2014) argues that engineering resilience approaches must be complemented with long-term social-ecological resilience. Engineering solutions provide a buffer capacity for acute shocks (e.g. droughts). However, without SES resilience approaches, adaptive management, and IWRM, water stakeholders will not develop the necessary long-term adaptive capacity to withstand chronic shocks (e.g. climate change) (Barnett & O'Neill, 2015; Foudi, 2014; Hall et al., 2014). Transitioning to a SES resilient water system will require a balance of hard and soft infrastructure approaches[40] that sustainably utilize ecosystems and their services (Eriksson et al., 2014; Lawson et al., 2010; Mao et al., 2017).

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[40] Hard and soft infrastructure approaches are insufficient on their own in achieving sustainability and SES resilience, and must be carefully balanced (Chelleri, Schetze, & Salvati, 2015; Mitchell et al., 2017). For example, replacing imported from Northern California on the coast of Southern California would require water agencies to build a 50,000 MGD desalination facility every four miles along the cost (Jeff Kightlinger in an interview for the Sacramento, 2016). Similarly, a strictly demand-management approach would not be sustainable (Mitchell et al., 2017). Demand hardening occurs when water use is already efficient and there is a high cost in pursuing additional water conservation measures (Dilling et al., 2019). In cases of demand hardening, development, population growth, or drought can rapidly shift the balance between water supply and demand, creating inflexible conditions of vulnerability. Conservation efforts must be accompanied by storage or exchange arrangements to water supplies for emergency or drought conditions (Mitchell et al., 2017). Presently, demand hardening has not been a challenge encountered in California's urban water sector. However, as droughts become more frequent and severe, the local sector and state regulators must take precautions to maintain system resiliency.

Public Voice in PPP Projects

Past examinations of PPPs found that public or stakeholder “voice” is most common in the operational phase, where citizens will actively oppose a project if their direct interests or rights are encroached upon (Chen, Hubbard, & Liao, 2013). Voice is least common during the planning stage, where there is limited information on the project. Consultation with citizens is often limited to “willingness-to-pay” surveys to gauge acceptable prices for service provision, and does not provide opportunities for voice in the planning and procurement stage of the project. This research also found that community engagement that went beyond legally mandated requirements for environmental permitting, CEQA, or rate changes was primarily focused on gaining buy-in and project acceptance, rather than soliciting direct feedback. Only two projects – Gobernadora and the HB Desalination PPP – provided opportunities for civic society members to provide input on project design or negotiated legal documents.

Similar approaches towards public inclusion can be seen in academic literature. Despite a growing recognition that inclusion of diverse stakeholders in decision-making and project design can bolster sustainability and SES resilience (Dewulf et al., 2019; Eriksson et al., 2014; Krueger et al., 2020; Mao et al., 2017), the majority of scholars still frame resilience as a task for conventional actors in the water sector (governments and water managers). A literature review of 144 peer-reviewed water resilience studies found that 62% of scholars viewed resilience as the sole responsibility of water managers while 33% attributed responsibility to governments or water-related institutions (Rodina, 2019). Only 12% of papers indicated that responsibility of achieving resilience should be shared by multiple stakeholders. Public participation and stakeholder engagement, thus, is seen as ways to gain buy-in of strategies developed by technocrats. Limiting opportunities for diverse participating reduces the opportunities to co-produce knowledge on the complex linkages between social and ecological systems (Pahl Wostl, 2008; Pahl-Wostl et al., 2007) and creates barriers in shifting community behavior. Yet, sustainable water management - in environmental, economic, and social terms - can only be successful if knowledge gaps that deal with uncertainties are closed (Pahl-Wostl et al., 2007)

7.7 Conclusion

This chapter revealed that PPPs in California's water sector have allowed project participants to make significant gains by diversifying water supplies, promoting technology and water management innovation and efficiency, and overcoming technical and financial limitations. The cases indicate that PPPs can contribute to both engineering and SES resilience through hard and soft water management strategies. The chapter also ultimately highlights that contributions to resilience do not automatically contribute to sustainability, but can instead cause tradeoffs between reliability and long-term ecological well-being (Chelleri, Waters, Olazabal, & Minucci, 2015; Johannsen & Wamsler, 2017; Roostaie et al., 2019). Transitioning to pathways that are resilient and sustainable will ultimately require a stronger emphasis on flexible, collaborative projects that can anticipate and overcome short- and long-term tradeoffs between ecological and social systems. Adaptive management strategies that monitor real-time changes to ecosystems and human well-being and utilize this information to amend institutions and management strategies will be critical in "bouncing forward" rather than "bouncing backward."

8.0 PPP PROCESS: RISK ALLOCATION and PROJECT CHALLENGES

The previous chapter summarized the key socio-economic, environmental, and institutional outputs and outcomes of 10 PPP projects. This chapter ***explores the unique challenges of PPP project development and implementation in California's water sector***. As past examinations of infrastructure PPPs suggest that inefficient risk allocation is a key driver of cost overruns, project delays, and heightened costs to ratepayers (Ameyaw & Chan, 2015; Carpintero & Peterson, 2016; Delmon, 2009; Ng & Loosemore, 2007), this chapter also examines the distribution of risks partners***. What risks are transferred to private partners, and how does this allocation impact project outputs and outcomes?***

While practitioners and scholars have examined challenges of individual projects (see Hewes & Randolph, 2018), no studies in California have compared across multiple cases. Only a handful of studies have examined barriers to water PPP adoption in the US. In 2008, the Environmental Financial Advisory Board identified gaps in PPP enabling legislation, challenges in securing grant funding, public opposition, and low political will as the key barriers to water and wastewater PPPs in the US. A 2019 survey of American Water Works Association members identified stakeholder skepticism over the costs and benefits of a PPP, fears of privatization/shifting technical control to a third party, and a lack of internal or external support for the partnership as the main reasons water managers were reluctant or unable to adopt a PPP structure for infrastructure provision (AWWA & EY, 2019). More than 50% of survey respondents felt that they lacked the financial, legal expertise to evaluate, structure, procure, or negotiate PPP projects. Respondents from smaller utilities were more likely to have a weak level of understanding of PPPs. When coupled with low internal and political support, this knowledge gap can discourage public water managers from pursuing a PPP approach.

Risks can be classified under general risks and project risks (Ng & Loosemore, 2007). Project risks are specific to the project and include design, permitting, construction, and environmental (see Table 8.1). General risks are risks that are related to the regulatory and macro-economic environment and include revenue, financial, political, public risk, reputational risk, and force majeure. In theory, risks should be borne by the partner who is best able to manage the risk at the lowest cost to the project (Delmon, 2009; Grimsey & Lewis, 2002, 2004; Hovy, 2015). A risk-taking party must be able to foresee and assess relevant risk factors (i.e. a change in water demand or supply) and bear the full costs and the impact of risk (minimize third party impacts) (Ameyaw and Chan, 2016). Risk allocation, therefore, should be based on partners' level of commitments, contingency mechanisms, degree of uncertainty, and prior experience in collaborative projects (Jin & Doloi, 2008). Risk-allocation is also the direct result of the bargaining process between participating parties (Chung et al., 2010). When bargaining power of institutions is weak, risk is transferred predominantly to the public sector (Bloomfield, 2006).

Surveys of public and private partners reveal that risk allocation is perceived to be efficient when financing, design, construction, and operational risks are transferred to the private partner (Ameyaw & Chan, 2013; Ke, Wang, & Chan, 2010). There is disagreement on who is best suited to manage demand and public perception risks (Li, Akintoye, Edwards, & Hardcastle, 2005). On the one hand, the public sector may be best suited to bear those risks, as they are often responsible for factors that might influence long-term demand (rate-setting, demand management practices, etc.) (Quiggin, 2006) and can directly manage concerns through the Environmental Impact Assessment process (Chung et al., 2010). Conversely, inefficient transfer of demand and political resistance risk to the public partner can result in significant cost overruns that are borne by tax- and ratepayers[3] (Ng & Loosemore, 2007).

Risk Type	**Description**
Design and Permitting	Inadequate investigation of geotechnical constraints, delays in the design process, and ambiguities and inconsistencies in design that require design changes.
Construction	Cost overruns and delays due to faulty construction techniques and implementation challenges.
Environmental	Adverse environmental impacts and hazards such as droughts, floods, landslides, fires, and earthquakes.
Revenue	Factors that affect revenue such as changes in demand, taxation, and the prices of inputs.
Financial	Price and costs increases, financiers withdrawing, changes in interest rates, or from poorly designed financial structures.
Political	Changes in legislation and/or political interference. This is a key concern to the private sector, particularly in developing countries where political stability is low.
Public Perception/ Reputational	Arises when the government's public accountability is in question. The extent to which the media is supportive of a PPP project and public perceptions influence the reputational risk to the public partner. Reputational risk also impacts the private partner’s perception of credibility, and can thus influence its evaluation of political/regulatory risks.
Public/ Compliance	The government's duty to ensure that the facilities are constructed in accordance with legislation
Force Majeure	Unforeseen risks that are outside of the control of both parties such as war, calamities, and acts of God

Table 8.1: Project-specific and general risks of PPPs. (Carter et al., 2017; Chung, Heshner, & Rose, 2010; Grimsey & Lewis, 2002, 2004; Guasch et al., 2007; Ng & Loosemore, 2007; Shen, Platten, & Deng, 2006)

Efficient risk allocation has been identified as a critical success factor for public-private partnerships (Ameyaw & Chan, 2014; Chen & Doloi, 2008; Osei-Kyei & Chan, 2015, 2016; Li et al., 2005; Pinz et al., 2017). However, risk allocation between public and private partners is challenging (Delmon, 2009; Hovy, 2015) and is often inefficient (Ng & Loosemore, 2007). Inefficient risk allocation can lead to expensive contract renegotiation or project failure (Delmon, 2009). Risk allocation impacts the willingness of financiers to invest in a PPP project (Burke & Demirag, 2017), and if improperly managed, can reduce innovation and environmental benefits of projects (Makovsek & Moszoro, 2017; Taylor & Harman, 2016). Moreover, risks that are inefficiently or unclearly assigned will be transferred back to the other party with higher risk premiums, which can yield higher project costs than those for traditional procurement projects (Leighland, 2018; Makovsek & Moszoro, 2017). In Chile, for example, 147 renegotiations in 50 PPP contracts resulted in an additional $2.8 billion in project costs.

Ultimately, there are gaps in understanding of not only the impacts of PPPs, but also the efficient allocation of risks between partners. Only a handful of studies have examined risk transfer in the water sector (see Ameyaw & Chan, 2015; Carpintero & Peterson, 2016; Choi, Chung, & Lee, 2010; Grismsey & Lewis, 2002; Shrestha, Chan, Aibinu, & Chen, 2017) and sustainability PPPs (see Dellas, 2012; Taylor & Harman, 2016). However, scholars suggest that risk sharing and risk transfer between public and private partners is more important in the water than any other sector (Albalate, Bel, & Geddes, 2013). Water infrastructure projects face large sunk costs, long repayment periods, and low rates of return (Albalate et al., 2013; Ameyaw & Chan, 2013, 2015; Korayem & Ogunalana, 2019). Moreover, as the majority of infrastructure is located underground, the condition of the water system is difficult to assess, creating additional risks to private partners (Ameyaw & Chan, 2015). Anticipated revenue can also be impacted due to decreased demand from regulatory and behavioral changes. This research addresses this literature gap by examining the distribution of risks between partners of water sector PPP projects. The chapter also examines how this risk allocation hindered or assisted project partners in overcoming technical, regulatory, and socio-economic project challenges.

8.1 Distribution of Risks between Partners

Through risk sharing and pooling of resources, PPPs provide public water agencies with the opportunity to achieve outcomes that they would be unwilling to pursue or unable to achieve on their own. Table 8.2 summarizes risks and obligations borne by private and public partners in the seven infrastructure PPP cases. With the exception of the Gobernadora and Lake Mission Viejo, private partners bear the responsibility for finance, design, construction, operation, maintenance, and water provision of water projects (WPASA, 2012; GMB IA, 2014; IRWD-DRES Portfolio, 2018; OCWD & Poseidon, 2018). Public partners serve as the lead agencies on the Environmental Impact Report process, hold public hearings throughout the CEQA process (#11; #15; #16; #17), and, in some cases, accept the demand risk for the project by purchasing a mutually agreed upon volume of water (#17; #21). At the end of contract periods, the public partner has the “right but not the obligation to” purchase the facilities or technology from the private partner (WPASA, 2012; OCWD & Poseidon, 2018). Regulatory risk, force majeure risk, and other risks beyond the control of the private partner were shared between partners or were borne by the public partner (#21; GMB IA, 2014; IRWD- DRES Portfolio, 2018; OCWD & Poseidon, 2018; WPASA, 2012).

	External Financing	**Capital Costs**	**Site Evaluation**	**Land Acquisition**	**Permitting**	**Design**	**Gaining Public Support**	**Construction**	**Operation**	**Maintenance**	**Ownership**	**Compliance w/CEQA**	**Regulatory Risk**	**Demand Risk**	**Force Majeure**	**Performance**
Gobernadora	🟩	🟩	🟦	🟨	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟩	🟦	🟩	
Lake Mission Viejo	🟩	🟦	🟦	🟦	🟦	🟦	🟨	🟦	🟦	🟦	🟦	🟦	🟨	🟨	🟩	X
Energy Storage Project	🟨	🟨	🟨	🟦	🟨	🟨	--	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	X
Rialto	🟨	🟨	🟨	🟦	🟦	🟨	🟦	🟨	🟨	🟨	🟨	🟦	🟩	🟦	🟩	
Cadiz	🟨	🟨	🟨	🟨	🟩	🟨	🟨	🟨	🟦	🟦	🟨	🟦	🟨	🟦	--	
HB Desalination	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟦	🟩	X
Carlsbad Desalination	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟦	🟩	X

Table 8.2: Risk Sharing of Infrastructure PPPs. Table 8.2 identifies the party that bears the responsibility for each step in the project life-time, as outlined in formal agreements between

partners (SMWD/Cadiz MOU, 2011; GMPB IA, 2014; IRWD DRES, 2014; Table Rock, 2019; OCWD & Poseidon, 2018; WPASA, 2012). Yellow represents risks borne by private partners, blue represents risks borne by public partners, and green indicates that both parties have formally agreed to share the risks for the project.

These risks represent the risk allocation at the start of the contract duration. Risks may shift throughout the project lifetime. For instance, in the Rialto Contract, O&M and maintenance risk are transferred to the private partner during the first five years of the agreement, but is shared between partners throughout the remainder of the contract duration (Callahan, 2012).

Risks and obligations of data-oriented partnerships are divided more evenly among partners than in infrastructure PPPs (see Table 8.3). While the public partner provides the initial project scope (#1-#3; #6- #8), public and private partners jointly refine a research question that can be answered through available data and determine input variables to include in the model (#6 - #8). Private partners then develop the model and provide implementation support for water district staff (#2; #6 - #8). Public water officials bear the sole responsibility of collecting data, sharing anonymous and aggregated data with a third-party (#4), and utilizing the model and the results as tools for decision-making (#1; #3). Data-related risks to privacy and data quality are mitigated by the California Data Collaborative, an NGO that provides data sharing and implementation support to water utilities (see Chapter 6).

	Securing Financing	**Data Collection**	**Data Clean-up**	**Developing Project Focus**	**Model Implementation**	**Model Design**	**Model Development**	**Implementing Policy Response**
DataKind	🟨	🟦	🟦	🟩	🟦	🟩	🟨	🟦
2 Sigma	🟨	🟦	🟦	🟩	🟦	🟩	🟨	🟦
Urban Runoff Project	🟦	🟦	🟦	🟦	🟦	🟩	🟨	🟩

Table 8.3: Risk Sharing of Data-Oriented PPPs. Table 8.3 identifies the party that bears the responsibility for each step in the project life-time, as summarized in interviews and formal agreements between partners (Urban Runoff MOU, 2018). Yellow represents private partners, blue represents public partners, and green indicates that both parties have formally agreed to share the risks for the project.

8.2 A “Unique Opportunity” through Risk Transfer and Risk Sharing

Both public and private participants highlighted the risk-averse nature of public water agencies (#1; #3; #11; #14; Observation, 8/30/2018, 8/29/2019). According to one district staff member, “government is often a later adapter” because “it’s not our money. It’s your money, and we don’t waste that” (Observation, 8/30/2018). Technology is “adopted slowly, and only after extensive pilot testing” (Observation, 8/29/19). “What's nice about the PPP is where the private side is willing and able to take some of those concerns [of constructing and operating facilities] away. [….] We're not in the business of taking risks. We want to serve our customers and that's what our purpose is” (#14).

Four of the seven infrastructure projects included performance guarantees in the contract structure[41]. Under a performance-based contract, public partners are not obligated to pay the private partner until the project is delivered and meets specified performance criteria (#11; #15 - #17; #21; Shadowing, 12/18/2019). This risk distribution presents a “unique opportunity” (#15) as it allows public water managers to pursue projects with innovative methods and technologies with “private investment dollars rather than spending ratepayers’ funds on infrastructure” (SMWD, 2012c, p.1; see also #11; #14; #17; #18; #21) in the early stages of the project. Poseidon, for example, has spent $50 to $60 million on the Huntington Beach Desalination Facility over the last 20 years (#15) and is not anticipated to be operational until 2025 (#17). Similarly, the Carlsbad desalination plant took “over 15 years and $75 million in private investment just to get to the construction milestone” (#17). According to a public partner, “that's

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[41] For instance, in the Energy Storage Project, IRWD receives a minimum guaranteed cost-savings amount regardless of AMS’s performance; all additional cost-savings are shared between partners (IRWD-DRES Portfolio, 2018). According to a public water manager, this arrangements ensures that “there’s really no risk at that point to IRWD” (#14).

where having a private company that can speculate and put all of that money at risk and maybe not get any return is beneficial. That would be really hard for a public agency to do.” (#15).

> If you look at the permit [process].... [shakes head]…. Oh gosh, what they have to go through. I just keep thinking, "I'm glad it's not me [laughs]." No. I would rather **them** spend all the money and all the time and everything. No public entity could go through all that (#16, emphasized by respondent)

Private partners are motivated to enter public-private partnerships and to take on these risks due to opportunities for long-term profit (#14; #17), the opportunity to pilot technologies (#14), comply with regulatory demands (#11 - #13), or fulfill contract obligations to third parties (#14). Private partners seek out public partners with high financial (#17) and technical capacity (#1; #3; #4; #17). A primary motivation for private partners in entering into PPP agreements is the public partner’s willingness to bear the demand risk: “private equity in our experience is looking for not so much higher returns, but certainty and longer returns. A 30 year water purchase agreement is attractive to them because they're looking at this as a long-term investment” (#17). To increase certainty of returns, private partners factor in costs of industry-wide inputs such as electricity into the unit cost of water provision (#11; #15; #17; #21; SMWD/Cadiz MOU, 2011; OCWD & Poseidon, 2018; WPASA, 2012).

Ultimately, in a PPP, the public sector can draw on the expertise of the private sector (#1; and reduce risks of new technologies and methods (#1; #11; #16; #18; #21). “That [risk transfer] was a foundational aspect of moving forward with a P3. I mean, we have never designed or built or operated [that kind of facility]” (#21). There are instances, however, in which a private partner is unwilling or unable to accept a project risk. South Coast Water District (SCWD), for example, is in the process of securing permits for a 5 Million Gallon per Day (MGD) desalination that will utilize slant-well technology. The method is expected to reduce impacts to aquatic environments, but has never been implemented commercially at a desalination facility (#17; #18). While

Poseidon proposed entering into a public-private partnership with SCWD in 2016 (Alderton, 2016), technology utilized at a pilot level would pose as a high operational risk.

> Because Poseidon ultimately assumes the risk of operations and the customer has no obligation to pay for water unless the company delivers it, Poseidon is very sensitive to making sure that they're using best industry practices and proven technology. […] That doesn't mean that they couldn't figure out a way to partner with someone like SCWD, who's using a newer technology. It's just… how would you mitigate that financial risk? […] Probably some [risk] premiums built in because you still have to pay the debt. (#17)

Had SCWD partnered with Poseidon, water users would face bill increases of roughly $22.09 per month (Alderton, 2017). SCWD recently voted to reject a partnership with Poseidon in constructing the Doheny desalination plant. District officials estimate that a publicly owned and operated plant would increase the water bills of average Tier 2 customers $7.08 a month.

8.3 Project Challenges

Process-tracing revealed technical, social, and regulatory challenges in project design, development, and implementation. Institutional and regulatory challenges (evolving environmental regulations, complex permitting process, and low collaboration between regulatory agencies and project developers) were perceived to be the biggest barrier to PPPs development and implementation. Respondents also viewed public opposition and the difficulties of negotiating "the best deal" as unique challenges faced by PPP projects.

Evolving State Regulations

One of the main challenges partners have encountered has been compliance with "strict" (#15) and evolving state regulations (#11; #12; #17). "California is going through a significant evolution in water," with the state government preparing new regulations regarding water efficiency and use (#13; see also #1; #3; #11; #15; #16). Four of the seven infrastructure PPP projects – Cadiz, Gobernadora, HB and Carlsbad desalination - experienced delays and increased project costs due to shifting regulatory demands during project design and construction (#11; #12; #15 - #17; Shadowing, 2/27/2019, 12/18/2019). For instance, the Bureau of Land Management approved the pipeline scope and right-of-way for the Cadiz project in 2009, and then reversed the decision in 2015 (Cadiz, 2019). In 2017, under Trump's new administration; the agency withdrew the 2015 decision and granted the project permission to begin construction (BLM, 2017). Similarly, Poseidon experienced two large changes throughout both desalination plant's lifetimes, which has increased cost by "millions of millions of dollars" (#17). In 2010, the State Water Resources Control Board (SWRCB) enacted a phase out of once-through cooling power plants to minimize adverse environmental impacts to aquatic systems (CA Energy Commission, 2019), which "fundamentally changed the design of [the desalination] facilities. And then in 2015, the SWRCB passed unique [intake and discharge] regulations for desal facilities, which again, required both of our plants to be redesigned" (#17).

Complex Permitting Process

Costs and project delays have also resulted from the complex permitting process (#11; #12; #16; #17; #20; Shadowing, 2/27/2019) and mitigation measures (#11; #12; #15; #17; #20). According to a public partner, "the permitting is difficult. California places a high priority on the environment" (#15). The "complex web of federal and state requirements leaves unclear which agency has the final authority over whether a desalination project in California may move forward," resulting in a long and arduous permitting process (Ocasio, 2015, p. 467):

> Each one of those [regulatory] entities have their own separate authorizing statutes and policies and regulations. And so we will find ourselves doing almost the identical analysis over and over and then getting different conditions placed on our project. So it's not just the cost to mitigate, it's the cost to site, design, and operate our facility, and then mitigate for any unavoidable impacts (#17).

Securing permitting requires "an understanding" of the process and necessary clearances; a public or private agency can "fail for a lack of getting permits or permits with reasonable mitigation measures" (#20). In some cases, approval of one permit is conditionally provided on the grounds of securing permits from other agencies (Ocasio, 2015; Ulibarri, Cain, & Ajami, 2017). Moreover, requirements of agencies may be mutually exclusive. "Trying to appease [all sides] can be quite a juggling act" (#11; see also Ulibarri et al., 2017). To one respondent, "*the greatest risk [of a project] is not in the operation of the plant - although there is some risks there - or even in the construction of the plant. It's really in the development, at least that's in our experience* (#17).

For example, a desalination plant requires a "multitude of state and local agencies" to provide approvals for construction and operation (#15 - #17; Ocasio, 2015). Along with meeting federal requirements for the protection of fisheries and endangered species, a desalination facility would require compliance with the Porter-Cologne Water Quality Control Act[42], California Safe Drinking Water Act, California Coastal Act (CCA), and the California Environmental Quality Act (CEQA) (Ocasio, 2015). To build and operate a plant in California, a project developer would need to complete an Environmental Impact Report, receive coastal development permits through the Coastal Commission, and receive approval from the State Water Board for NPDES permit for brine discharge. Between 2006 and 2016, the Carlsbad desalination facility secured six local land use permits for project development, habitat management, and coastal development plans; 20 permits and plans from the SDCWA; and additional state and federal-level permits for

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[42] The Porter-Cologne Act requires a coastal industrial installation to use the "best available site, design, technology, and mitigation measures feasible to minimize the intake and mortality of all forms of marine life." Surfrider has legally challenged permits issued for the Carlsbad plant by the State Lands Commission and the Coastal Commission for the intake system (Tracy, 2011).

public health, water quality, energy minimization, GHG emissions, erosion projections (Ocasio, 2015).

Another example is the Gobernadora project, which underwent seven years of revisions to the basin design (#12; #20) to comply with regulations of multiple public agencies. During the design process, storm erosion of Gobernadora Creek brought three additional acre-feet of the territory under federal jurisdiction, requiring partners to re-design the project for a smaller basin size (#12; Shadowing, 2/27/2019). Per the recommendation of the Division of Dams and Safety, the design had to be altered again to avoid federal oversight of the dam structure (#11; #12; #20; Shadowing, 2/27/2019). Finally, the County of Orange, which had concerns about liquefaction and stream bank erosion, required multiple rounds of revision and the establishment of a monitoring plan for the embankment and engineered structure prior to approving the project (#12). Delays in the design and the permitting process almost led to the loss of $7.5 million in grant funding for the project (#11). Despite these challenges, partners on the Gobernadora project believe that they “got lucky” during the permitting process, as plans for the basin were already included in the Ranch Plan[43] (Shadowing, 3/15/2019). Had the basin undergone permitting on its own, the process would have been more time-intensive (#20; Shadowing, 3/15/2019).

Multiple requirements for project approvals across various regulatory agencies may threaten the financial viability of a project (#11; #15 - #17; #20). For instance, to secure discharge permits from the Santa Ana Regional Water Quality Board, Poseidon would have to

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[43] The Ranch Plan Planned Community Project is a development project that will add a total of 14,000 dwelling units along roughly 23,000 acres of space (Orange County Board of Supervisors, 2004). The plan includes a blueprint for long-term conservation, management, and mitigation of urban-runoff (#11; #12; #20). One of the requirements was for RMV to build and maintain a storm water mitigation facility in Gobernadora Canyon to control flooding and concentrated urban storm runoff (County of Orange, 2012). The process of receiving land use entitlements and EIR approval took 12 years (#20). “It was a phenomenal amount of study of biology, habitat, stream course, river hydrology and geomorphology that really took a long time” (#20).

"assume the responsibility" for the restoration of the Bolsa Chica wetlands at "no financial cap" (#17). The expected annual cost of dredging the wetlands is approximately $1.3 million, with an additional $25,000 to $35,000 per year required for inlet rehabilitation (WRA, 2019). "And that's just for [one agency]. We haven't even gotten to the Coastal Commission" (#17). Approval from the Coastal Commission (CCC) is contingent on perceptive impacts of the plant's intake facility. The CCC's preference to utilize a subsurface intake has raised concerns that the requirements would "kill the project with ballooning costs" (Boxall, 2016, para 37). An independent advisor group convened by the CCC estimates that adopting this technology would increase capital costs from $852-$899 to $1.936-$2.347 billion, increasing the estimated unit cost of water from $1,914 to more than $3,450 per AF (Concur, 2015). The advisory panel concluded that a sub-surface intake option is "not economically viable at the Huntington Beach location within a reasonable time frame" (Concur, 2015, p.18).

Low Collaboration between Public Agencies and Regulators

Fieldwork revealed an "antagonistic relationship" and "a great deal of dislike and resentment" between state- and regional-level regulatory agencies and public water agencies (#13; see also #11; Observation, 3/15/2019; 8/29/2019). According to a leader of a state regulatory agency, "historically, there have been tension between [regulatory] agencies themselves, and between regulatory agencies and stakeholders (such as water districts)" (Observation, 8/29/2019). Collaboration between regulators and public water agencies is low to provide water infrastructure projects. One respondent argued that the antagonistic relationship leads to delays in the permitting process:

> The project itself, when you look at it at face value, it's a terrific project. It helps the environment. It mitigates some of the impacts of urban development. It provides us with more water. It seemed to be a win-win-win. But somehow when the individual agencies look at it - or individuals within the agencies - A couple of

> them would see it as something horrible and that we're trying to pull a fast one. (#11)

Public agencies perceive regulators as impeding local-level opportunities for water diversification. Solutions are top-down, rather than from the bottom-up (#11; Observation #1; Observation, 3/15/2019; Observation, 8/29/19). Many respondents pointed to the Conservation Mandate (2015) as a signal that science-based, tailored solutions are needed to address local water issues (#1 - #5; #9; #11; #20; Observation, 3/15/2019; Observation, 8/29/19). During a meeting where two agencies shared best practices and challenges of collaborative water projects, one participant stated that "if we solve water problems with water people rather than bureaucrats, then we are one step ahead of the game. If we keep Sacramento out of it, it will provide more solutions. [...] They want to throw money at the problem, but will not address any of the local issues" (Observation, 3/15/2019).

Low collaboration between project developers and regulatory agencies can exacerbate permitting and regulatory challenges of PPPs. Recently, the Huntington Beach desalination plant has encountered another permitting hurdle that may further increase mitigation costs. In August, 2020, the Regional Water Quality Board required to increase wetland restoration from 52 to 84 acres, stating that the current mitigation efforts are insufficient (Wisckol, 2020). Members of the Regional water expressed frustration with Poseidon for failing to collaborate on a complete mitigation plan for the HB desalination facility (Pho, 2020). Poseidon staff have countered completing a mitigation plan depends on the approvals across various local agencies. Poseidon also highlighted that shifting regulatory requirements also make it difficult to complete a thorough plan. "We can't advance it because the earth under our feet keeps shifting" (Pho, 2020, para 13).

Opposition to Projects

While interview participants stressed that their projects were a “win-win” (#1; #2; #4; #16; #20 Bourke et al., 2019) and considered them to be successful (#1 - #8; #11 - #17; #20-#21), projects have faced various degrees of opposition by the public and non-governmental organizations. This opposition has resulted in delays in project approval or permitting (#11; #15 - #17; #21; “Chronology”, n.d.; Rogers, 2014). In the case of the Carlsbad Desalination plant, nine lawsuits and five administrative permit appeals by environmentalist organizations between 2006 and 2011 delayed construction until December 2012 (“Chronology”, n.d.).

Technical challenges can sometimes increase public perception of risk, thus further fueling public opposition to projects. Critics of the two PPP desalination plants frequently point to the start-up issues of the Carlsbad facility (see Surfside, 2015; Rivard, 2017b). The plant faced regulatory challenges, algal blooms, and a 10 day shutdown period to repair a water tank (Rivard, 2017b). Respondents stressed, however, that these technical challenges are typical of all large-scale water infrastructure, regardless of the procurement type (#11 - #15; #21; Shadowing, 3/15/2019). There is a “learning curve” to designing and operating new technology. One water manager dismissed these concerns, stating that their department carefully reviews the annual operation report of the plant. With a plant of that scale, “you're going to have startup issues. Nothing, that I would consider a major flaw or make me think, "Hey, they don't know what you're doing (#15). In fact, the success of the plant’s operating has actually boosted the Water Authority’s credit rating to AAA (SDCWA, 2019b). Respondents also perceived the high unit costs of water, the fear of private sector participation in water management and supply, and an opposition to industrialization/development as sources of PPP project opposition.

High Costs and the Fear of Private Sector Participation in Resource Management

Water has historically been provided at a low cost (#5; #11; Observation, 8/29/19). Despite public support for diversification and the development of local resources (#13; #15; #19; #21; Global Newswire, 2019; SDCWA, 2004, 2016e) there is high resistance to raising water rates (#13; #15; #19; #21). The salience of future drought conditions, however, may slowly reduce opposition to rate increases and shift public expectations of affordability. A recent survey of 1,063 adults residing in the San Diego County revealed that roughly 63% of residents would be willing to pay $5 more to increase reliability and enhance local control over water supplies (True North Research, 2019). The level of support has grown since 2014, when only 33% of individuals surveyed (N=500) would support rate increase to meet the County’s water needs (Probe Research Inc., 2014). Respondents expressed that this support may be symbolic (#13; #18), and that rate increase still pose a significant challenge. Most people in Orange County say "yes, I would pay more to have safe healthy, sustainable water supplies." They raise their hand: "Yeah, I'm for that. Trying to get someone to drop their hand from, "yes" to writing a check, that's the longest three feet in the world” (#13; see also #15; #18).

In the case of PPPs, opposition to increased water rates is exacerbated by the perception that private companies are “privatizing a public resource” (#13; see also Rogers, 2014; Saari, 2016; Wisckol, 2018). A concern is that inclusion of a private partner would “have profit built into the cost, which ultimately gets passed on to the customer” (Wisckol, 2018, para 27). One respondent stressed that under water PPPs, “people's resources are being capitalized. Literally capitalized, you know, for money, for greed” (#13) and that private companies are profiting off the public partner’s anxiety of interrupted water services: “‘Oh yeah, you're going to take our water because you're going to **need** it [emphasized by respondent].’ You know, they’re going to cram this down people's throat.” (#13). For instance, a group opposing Poseidon argued that desalination “should be a public project. We don’t need a private company to come in here from the East Coast and tell us how much water we need” (Saari, 2018, para 16). Opposition groups view utility services as “a basic human need [that] should never be subject to the whims of private profiteering. This is especially true of our water systems, which are essential to a thriving economy and to life itself” (Langford, 2011 para 2.). The PPP in Rialto, for instance, faced opposition from residents due to concerns that unnecessary costs would be borne by ratepayers (Langford, 2011; Steinberg, 2011c). An op-ed called the proposed agreement a “bad deal for Rialto” (Langford, 2011, para 3) that would cause “consumer rates to soar” (para 4). Ratepayers would be forced to “to subsidize this company’s profits, over and above the costs for basic operation of the city’s water system, not to mention lucrative compensation packages for top executives” (Langford, 2011, para 7).

The issue of a profit structure built into public resource provision is one that public managers struggled with when weighing the decision to enter into a PPP agreement:

> What's the right amount of profit that a private company should make off the public? I don't know how you get to that. I mean, what's an acceptable return? Say they want an 8% return on capital annually. As a member of the public, are you okay with that? Somebody puts in a million. Should they make 80 grand a year? […] It’s not easy. (#19)

Similarly, members of the Board of Directors at one public agency questioned the decision to enter into a PPP and “the validity of a project - as a private company, is there profiteering that is taking place for a commodity that we need as an essential portion of life? (#11). Private partners, on the other hand, argued that the return on investment is low and that the project is meant to benefit the public (#17).

> No one is getting rich off of this […]. All the private sector is doing is getting a return on their investment for taking water that you can't consume and making it consumable. Potable water. That's what they’re getting their return on. All the water is appropriated for public use. The private partner don't control the water.

> They don't own the water. They can't hold back the water. They can't sell water to anyone else. All the water has to go to the public partner. So the public are the ones controlling the water, not a private entity. (#17)

The "No Project Mentality"

In interviews, respondents from both public and private organizations emphasized that environmental opposition groups could be divided into two groups: those that have genuine concerns about the adverse environmental impacts, and those with a "no project mentality" (#11; #13; #15; #16).

> They call themselves environmentalist. I don't think they are. I think they're actually 'no-growthers.' And that's what it comes down to. If you have water, you can build and sustain projects. If you don't, you can't. The people who want no more growth… the fastest way to stop that is to cut off any projects that will produce water. (#16)

One opposition group, for example, argues that the provision of water will lead to "irresponsible development" by "inducing the growth of housing and population" (R4RD, n.d.; see also #13). Interview respondents have expressed frustration that this "rigid" and "binary" mentality (#13; see also #11; #16) makes it difficult to address concerns of opposing parties. "They don't want to listen. There are a number of people that [think] 'you're doing it, so it has to be bad'" (#11). One Board of Directors member has "sat down and talked to people until they're blue in the face and I'm blue in the face. Their perception is not going to change" (#16; see #11; #15; #17; #21).

Projects have also been opposed due to concerns over industrialization of residential areas (#11; #15-#17; Shadowing 4/26/2019). One opposition group has pushed for "no more industrial projects" in Huntington Beach (#16) to minimize the "burden on that part of the neighborhood" (#15). The area already contains an industrial facilities by Boeing, a toxic waste site (ASCON), and a water sanitation district plant (#15; #16). Public partners have responded that the facility "will be tucked behind the power plant. You really won't see it, it's such a low profile." In fact, one of the reasons for the selection of both the HB and the Carlsbad desalination facilities is that by being co-located with the power station, they are already occupying industrial land (#15; #16; #21; Shadowing, 12/18/2019;). Similarly, despite the project's emphasis on habitat restoration, residents surrounding the Gobernadora Basin were concerned that the structure would "be this horrible eyesore or this big concrete monolith" (#11). The start of construction required additional community engagement to gain public trust and to assure residents that property values would not decrease. Similar concerns were raised for the Lake Mission Viejo facility (Shadowing, 4/26/2019). SMWD District had to ensure that a screen of trees and brush would be in place to minimize visibility of the facility to the surrounding residential community.

Public and private partners have been able to assuage some of these concerns through engagement and educational outreach (#11; #13; #15; #16). When opposition groups are "not opposed to any and all projects," but are "opposed to projects that will have a demonstrable negative impact," partners can develop opportunities for collaboration with stakeholders (#11; #13). The best practices of community buy-in will be explored in greater detail in Chapter 9.

Getting the Best Deal

While a PPP arrangement can reduce economic risks to public partners in the early stages of the project, public partners noted that the profit-oriented nature of the private sector can expose the public partner to new types of risk (#3; #4; #11; #13; #14; #19). The private partner is "worried about the bottom line. They want to see a return on their investment" (#14).

> I don't believe for a minute any of these people are altruistic**.** We say, "nah, you're in it for the money." Don't kid yourselves. […] They don't have as big a desire to worry about the water. **Their main interest isn't our main interest**. […] There are definitely competing interests in that realm (#11)

Given the private partner's desire to "minimize risk and increase return on the dollar" (#19), public partners strive to "get the best deal possible" that "returns maximum benefits to the public" (#16; #19). A project must "focus on the people, the public that we [the water districts] serve" (#4).

However, "the hard part when you're a government entity and you're doing a P3 is to get a fair deal because there's pitfalls every step of the way. And it is difficult. (#19). One public partner respondent stated that negotiation is "challenging" and "very labor intensive. […] A lot of blood, sweat and tears went into that document [the contract agreement]" (#21). One challenge is that public agencies vary in their experience and technical capacity of partnering with a private partner (#11; #19; #21):

> As we do these public-private partnerships, we're relatively new to it. I can tell you that I feel pressure. I can tell you that the [private companies] that we sit across the table from are more experienced than we are, because we don't do this all the time. We're government. (#19)

Public partners may also feel pressured to accept deals that are not in their best interests due to lobbying pressures from private companies (#19; Boxall, 2016; Zenger, 2015). According to media sources, Poseidon has spent more $1.6 million lobbying and campaign contributions (Boxall, 2016). Additional challenges in negotiation are information asymmetry and uncertainty of future conditions (#4; #11; #15; #16; #19). Public and private sector actors differ in their degree of transparency (#4; #19; #21). "Private companies are by their nature not transparent," which can cause "a fundamental clash" (#21) any time a private and a public sector agency work together (#4; #21). While public agencies must reveal past agreements and transactions, the private sector is not obligated to do so (#19), making it difficult to assess "how good our [PPP] deal is compared to a true private sector deal. Because in the private sector, they don't reveal that information. They just don't" (#19). As a result,

> It's hard to know if you've negotiated a good deal or a bad deal. […] It's messy. […] You jump in, if you have the courage to do it. And nobody can tell you. I can't look you in the eye and tell you that 20 years from now, we're going to look

> back on it and say, "You negotiated a fantastic deal." […].It’s hard to predict the future. (#19)

Public partners are cognizant of the economic risks to public agencies and water users when entering into a PPP agreements (#3; #4; #11; #15; #19). During interviews and observations, participants raised examples of failed PPPs (Observation, 8/29/2019; Shadowing, 4/26/2019), where private companies would “gouge” and exploit public agencies (#11; #13; #18; #19), particularly districts with low technical capacity (#11). Respondents also expressed concerns over private partners failing to meet the performance standards of the agreement (#3; Observation, 8/29/2019). When projects are owned and operated by “a utility and there's a different sense of response as well as accountability. It's pretty hard to hold a corporation accountable with the way capitalism works, at least the way it works today” (#13). These concerns about divergent priorities are also raised by critics of PPPs (see above section and Chapter 7 discussion on project voice) and in independent evaluations of projects (see figure 8.1).

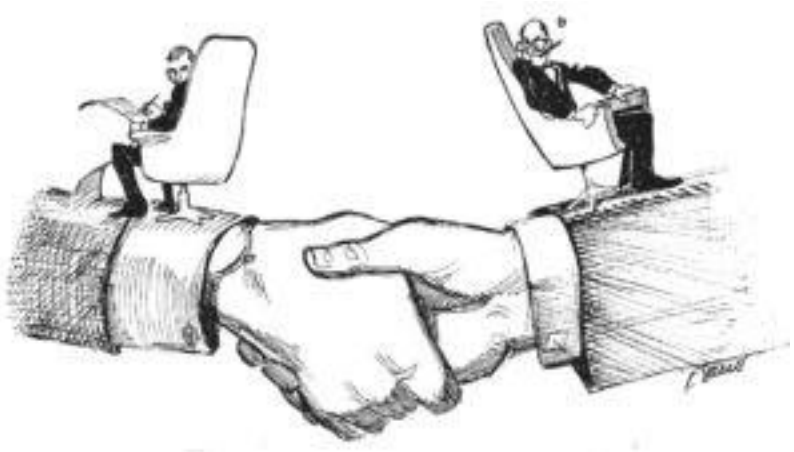

Figure 8.1 Illustration accompanying a 5 year-impact assessment of the Rialto PPP project (Table Rock Infrastructure, n.d.)

Despite these challenges of negotiation, public participants were willing to “jump in” and accept the risks of managing a relationship with diverging priorities. One respondent even referred to the private partners “a necessary evil” that enables the district to achieve their goals (#11). Ultimately, the diverging priorities between public and private partners requires a public water agency to

> be smart and not get caught asleep. That if an unscrupulous private entity was out there, that we don't sign an agreement. […] That's probably one of the biggest risks is you signed a bad agreement and now you're locked in. (#11)

8.4 Discussion

Public and private partners perceived the allocation of risks to be efficient. By transferring design, permitting, construction, operation, and maintenance risk to the private sector, public water districts felt they were able to minimize risk to ratepayers during the project development and implementation stage. Conversely, the long-term contract nature and the public partner’s absorption of demand risk created opportunities for the private partner to gain returns on investment. This risk allocation enabled the public sector to enter into projects that they would be unable to or unwilling to pursue on their own. Public and private partners encountered four challenges that contributed to increased unit costs of water and project delays: the complex nature of the permitting process, evolving environmental regulations, public opposition, and the challenge of “getting the best deal” for the public in the face of diverging priorities, information asymmetry, and power asymmetries.

This research highlights the challenges of long-term collaborations in dynamic environments (Demirel, Leendertse, Volker, & Hertogh, 2016). PPPs can shift and evolve due to changing regulatory, macro-economic, or ecological conditions or through the interactions of stakeholders. The presence of numerous internal and external stakeholders increases the complexity of the PPP development throughout the project lifetime. Politicians and regulatory agencies provide the final approvals of projects and enact or update legislature. Policy-maker can influence a price structure (i.e. tolls) of the PPP or can introduce competing projects. Water sector PPPs in particular face high regulatory risk due to the government's traditionally heavy involvement in managing water systems (Korayem & Ogunlana, 2019). Projects can also shift due to evolution of technology or the development of new best practices (Demirel et al., 2016). Finally, large-scale stressors such as climate change alter input or output costs or shift priorities of policy-makers away from the initial PPP goal. Thus, project changes and/or adjustments are inevitable at every stage of the project lifetime (Hwan & Low, 2012, cited in Demirel et al., 2016).

Environmental shocks and shifts can increase project costs[44] (Pessoa, 2010) or lead to project failure. For example, in 2008, the city of San Juan Capistrano was forced to take over operations of the Groundwater Recovery Plant after a series of internal and external challenges. The city entered into a 20-year, $20 million dollar contract with Southwest Water Company (SWWC) to construct and operate a groundwater facility that would provide 100% of the city's total water needs in the winter and 50% of the city's needs in the summer (Capistrano Dispatch, 2011). The $25 million plant was financed through AAA bonds and was named the "Plant of the Year" by the Southern California Chapter of the American Public Works Association (Water Online, 2005). The project was considered the "model of water self-reliance" and "of governmental efficiency in a public-private partnership" (Capistrano Dispatch, 2011, para 3). Yet, in 2008, city official became "disappointed" when plant began producing discolored water (OC Register, 2008). While the issues were corrected by SWWC, the city also discovered MBTE in the groundwater due to contamination from a Chevron gasoline spill (OC Register, 2008). With the plant operating at half-capacity, both partners agreed that the water operated "would

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[44] For instance, an audit of five DBFM PPP projects in the Netherlands uncovered 157 unplanned changes to the contract that resulted in cost overruns of 61 million euros (Algemene Rekenkamer, 2013).

just away from the deal" and the city would take over operations (Capistrano Dispatch, 2011, para. 8). In 2014, the city owed more than $40 million dollars in debt for the plant, and has slowly strived to resume operations of the facility (Cuniff, 2014).

Water users and civic society can also contribute to project delays or changes. The opposition of stakeholder groups to water sector PPPs due to concerns of resource exploitation and privatization have been well-documented by practitioners and academics (Bond, 2010; Hall, Lobina, & de la Motte, 2005; Loxley, 2013). Some of these concerns are tied to the ability to the capacity of the public sector. A quantitative examination of public attitudes and perceptions in the U.S. reveals that while 54% of surveyed individuals believed that PPPs could provide benefits to their community, only 28% of respondents agreed that the public sector had the sufficient skills and experience to manage a PPP contract (Boyer & Van Slyke, 2018). Support of a PPP will be higher when respondents have high trust in the government entity participating in the partnership and when the respondents are well-informed about PPPs[45]. Thus, information dissemination surrounding a PPP should include not only the potential benefits of a private partner's involvement, but also the abilities of the public sector in managing the partnership. Yet, in controversial projects, some public partners allocated community-buy in as a responsibility of the private sector. One respondent argued that it was "it was really up to the [private partner] to sell the project" (#16) while another stated that "we do want to keep this water flowing. But we're not running out taking bullets for [the private partner]" (#11). Future PPP projects, especially those with higher unit costs of water or high private sector involvement will require additional public partner participation in community engagement and buy-in. Along with clearly

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[45] Boyer & Van Syke (2018) consider a respondent well-informed on a PPP when he or she can correctly identify a PPP that is in development within their state of residence. Respondents are most informed regarding transportation and water infrastructure services (roughly 89% could identify a PPP project in development for these two sectors)

presenting project benefits relative to alternative water management strategies, the public agency will ultimately have to prove that it is indeed capable of "getting the best deal." Transparency, the development of robust state- and county-level PPP institutions, and opportunities for the public to participate in projects can over time lead to broader acceptance of private sector participation in the water sector (Beevers, 2016; Chen et al., 2013; El-Gohary et al., 2006; Hall et al., 2005).

A key theme that runs throughout project barriers is regulating and mitigating the potential environmental impacts of water sector projects. The cases suggest that maximizing ecological well-being requires significant intervention on behalf of the public partner (Koppenjan 2015; Patil et al. 2016; Hueskes et al. 2015) or the broader regulatory regime (Taylor & Harman, 2016). California has the strictest environmental regulation in the United States (Ulibarri et al., 2017). The state's permitting process requires infrastructure projects to evaluate any potential harms that may emerge from an infrastructure project and to mitigate any impacts with environmentally beneficial offsets or changes in the design structure. For the case studies, conditions for securing permits have led to the establishment of the Groundwater Management, Monitoring, and Mitigation Plan (2012) for Cadiz, an Energy Minimization and Greenhouse Gas Reduction Plan for Carlsbad (2008) and Huntington Beach (2017) desalination plants, and restoration of ecologically vulnerable areas such as the Gobernadora Ecological Restoration Area and the Bolsa Chica Wetlands.

This intervention by the state may be necessary to ensure ecological well-being of projects, as water managers interpret sustainability to be reliability and financial health of water utilities (#4; #11; #13). From the perspective of one NGO member, environmental sensitivity is predominantly driven by regulatory oversight (#13). Indeed, when asked about environmental considerations in project design, one public water manager stated that the water utility is "going to rely on the state agencies to take care of the environmental issues. The regulatory agencies have the experts and the experience to minimize any type of environmental impacts" (#15). Past examinations of PPP procurement processes have found that decision-makers provide little weight to ecological and social justice measures when weighing award criteria for private partner bids (Hueskes et al., 2017; Zheng & Tiong, 2010). Moreover, in uncertain technical conditions, such as the ones with Doheny's slant well technology, private companies have a low willingness to pay for innovative technology and will incorporate the best available infrastructure (even if it a second-best solution) to minimize risk (Koppenjan & Enserink 2009; Koppenjan 2015; Taylor & Harman, 2016).

While the state's regulatory framework minimizes environmental impacts, considerations of sustainability may exacerbate the tradeoff between economic efficiency and equity. Mitigation measures across multiple permits can render projects no longer financially viable (Ulibarri et al., 2017). Moreover, interview respondents identified the complex permitting process and evolving environmental regulations as the dominant drivers of increased projects costs and delays (see also Hewes & Randolph, 2018). Acquiring permits for construction and operation of facilities requires approval from multiple local- , state-, and federal- level agencies. There is no overarching agency to make decisions over environmental impacts (Howard, 2015; Ocasio, 2015; Ulibarri et al, 2017). Instead, project developers must submit permits to a number of agencies, each with their own sets of procedures, forms, and timelines (Ulibarri et al., 2017). This fragmented permitting process creates inefficiency in the review process, perpetuates a focus on narrow concerns rather than holistic evaluation of environmental impacts, and raises transaction costs for applicants (Howard, 2015; Ocasio, 2015; Rabe, 1995; Ulibarri et al., 2017).

Interview respondents also emphasized that the permitting process provides opportunities for opponents to contest the project, thus further delaying projects through lawsuits and litigations (#11; #17; #15; Dayton, 2016; Finley, 2015). For instance, in the early 2000s, anticipated project costs of the Carlsbad desalination plant was $270 million (Fikes, 2015). Changes in the design, lawsuits, the permitting process, and rising energy costs drove the project cost up to $300 million then $530, and finally $1 billion. Meanwhile, in Israel, a desalination plant that produces three time as much water as the Carlsbad facility cost $500 million to reach commercial operation (Finley, 2015).

PPPs may be uniquely challenged in receiving permitting approvals. The PPPs featured in this research were often large-scale, multi-use projects that utilized new technology or methods for water management. Studies suggest that large-scale, complex, or innovative projects will result in a longer permitting process (Ulibarri et al., 2017). In conditions of high public opposition or scrutiny, as is often the case in water sector PPPs (see Hall et al., 2005), regulatory agencies may be reluctant to take "a political stance" by approving a project. Moreover, permits proposed by businesses – rather than public agencies – are more likely to experience delays. A review of 285 Clean Water Act Section 404 permit applications found that state agencies were 124% more likely to receive a decision while federal agencies were 158% more likely to receive a decision than a business (Ulibarri & Tao, 2019). Similarly, Carpintero and Peterson's (2016) examination of 131 PPP wastewater treatment plants in Aragon, Spain revealed that transferring permitting risks solely to the private partner led to delays in project implementation and cost overruns. Yet, for the majority of case sites, permitting and public support risks were allocated to the private partner. Reducing distributional impacts to ratepayers in a strict regulatory climate may require the public partner to be more heavily involved in public outreach campaigns and the permitting process. Public support, project approval, and permitting risks must be allocated on a case-by-case basis (Li et al., 2005).

A complex permitting process has led to the delay in the provision of critical infrastructure services all over the US (Howard, 2015). It is imperative to identify ways to increase efficiency of the permitting process without compromising environmental protection (Ulibarri & Tao, 2019). Overcoming permitting challenges will require centralizing decision-making and providing strict, clear timelines for project review and approval (Howard, 2015). Increasing collaboration and communication between regulatory agencies and project developers in early stages of the permitting process can also assist in reducing delays and clarify expectations of regulators (Ulibarri et al., 2017). Reform will be challenging, as it will require altering a regulatory regime with long-engrained practices (Rabe, 1995).

8.5 Conclusion

This chapter identified the socio-economic, regulatory, and relational challenges of developing and implementing water sector PPPs in California. To a certain extent, regulatory and social challenges are related to the chosen technology/ method of water supply. For example, publicly-led desalination projects have also come under significant civic society opposition and have encountered regulatory hurdles in permitting and the CEQA process (Fears, 2015; Shrodes, 2019). The West Basin’s EIR for a 20 MGD desalination facility is estimated to cost $60 to $80 million (Shrodes, 2019). PPPs, thus, present a unique opportunity to shift risks from ratepayers and the public sector in the early stages of the projects. However, this research reveals that the private sector participation in infrastructure provision and the emphasis on generating economic value from the project (e.g. return on investment) can amplify barriers to project development by bringing greater regulatory or public scrutiny. Risks, therefore, must be assigned on a case-by-case basis (Ng & Loosemore, 2007), and must account for the resources and capacity of partners, regulatory structures and broader political climate, and the dominant social values and beliefs of the public.

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9.0 LESSONS LEARNED and BEST PRACTICES

The previous chapter examined barriers of water sector PPPs development and implementation. This chapter, therefore, examines the lessons learned and factors critical to project success of the first water of water sector PPPs. Due to path dependent legacies of institutions and infrastructures (Jooste et al., 2011; Matos-Castaño et al., 2014; Mu et al., 2011; Skelcher, 2010), best practices for PPPs must be tailored to the political, technical, socio-economic context of a region. This chapter examines the experiences and perceptions of project participants in sustaining public-private partnerships and overcoming the barriers of project opposition, evolving regulations, permitting complexity, and diverging priorities between partners. These lessons learned can assist water managers in the future PPP development within the state of California, and can contribute to the development of a responsive and robust institutional framework (Matos-Castaño et al., 2014).

Past empirical studies have examined best practices of PPPs by identifying Critical Success Factors (CSFs). CSFs are internal or exogenous social, economic, political, or project-related characteristics that must be present and/or acknowledged by public managers in order to maximize the likelihood of project success. CSFs must be upheld at all phases of the project (Jefferies et al., 2002), but are particularly crucial in the developmental phase (Li et al. 2005). Scholars have examined CSFs using a variety of empirical methods, including single case studies (see Chen, 2009; Jamali, 2004; Jefferies et al., 2002; Osei-Kyei & Chan, 2016), literature reviews (see Osei-Lyei & Chan, 2015; Pinz et al., 2017) and surveys of practitioners, BOT companies, and academics (see Ameyaw & Chan, 2014; Osei-Kyei & Chan, 2015; Tiong, 1996; Zhang, 2005).

A literature review of 24 peer-reviewed studies of infrastructure PPPs revealed a total of 32 CSFs (for a complete summary of CSFs identified by each author and the selection process for the literature review, see Table A3 in the Appendix). Economic, technical, political, and social CSFs identified by more than 20% of scholars are presented in Table 9.1 below.

CSF	Frequency	Description
Expertise of Consortium	16 (66.67%)	Private partner must be technically and economically competent
Stable Political Support/Climate	15 (62.5%)	Political climate must be stable, with the public partner actively supporting the project by maximizing input and output legitimacy (Verhoest et al., 2015)
Efficient Risk Allocation	14 (58.33%)	Risks must be allocated to partners that are best able to fully absorb potential costs or shocks without transferring the impacts to citizens
Strong Legislation and Regulatory Systems	12 (50%)	Regulatory and judicial framework must (i) provide mechanisms of deterrence while simultaneously (ii) promoting innovation, (iii) limiting barriers to entry, (iv) incorporating affected parties in PPP policy-formation, and (v) formally articulating the role of the PPP in resource provision (Verhoest et al., 2015)
Robust Procurement Process	11 (45.83%)	Procurement process must (i) promote competition between potential bidders, (ii) incorporating legal, partnership management, and project delay costs into the Value for Money calculation, (iii) and weigh project quality as well as VfM in award criteria (Ameyaw & Chan, 2014).
Sound Financial Package	11 (45.83%)	Project requires a sound revenue stream to ensure viability. Project should include an appropriate combination of financing sources, efficient payment structure, debt financing that minimizes risk, and mechanisms to address fluctuations in interest and exchange rates (Zhang, 2005)
Public Engagement/ Support	10 (41.67%)	Dissemination of information on the project and management structure, as well as opportunities for citizens to voice concerns can increase overall public support, decreasing the risk of large-scale non-payment.
Appropriate Project Identification	8 (33.33%)	Projects must be suitable to PPP structure (high profitability, opportunities for bundling, stable demand for resource, technical feasibility) (Zhang 2005).
Stable Economic Conditions	7 (29.17%)	Macro-economic conditions (inflation rates, unemployment, GDP growth, exchange rates, and interest rates) must remain stable and market conditions must be low-risk throughout the project lifetime (Ose-Kyei & Chan, 2015).
Available Financial Market	5 (20.83%)	Easily accessible financial markets provide incentive for private partner financing and participation in public-private partnerships (Li et al., 2005).

Table 9.1 Critical Success Factors (CSFs) of infrastructure PPPs projects identified by at least 20% of all authors across 24 peer-reviewed publications. Macro- and micro-economic CSFs

are in red, CSFs related to institutional frameworks or arrangements are in blue, social CSF are in green, and technical factors are in yellow.

Economic factors were most frequently identified in the literature review (37.5% of all identified CSFs were focused on macro- or micro-economic factors), aligning with findings that suggest that satisfying project profitability is the primary concern of project managers (Koppenjan 2015; Pinz et al., 2017). Project financial viability has even been proposed as a precursor to satisfying the three dimensions of sustainability (Pinz et al., 2017). This emphasis on economic efficiency is not surprising, as there is limited incentive for the private sector to enter into a partnership if there is no opportunity to gain profits. Environmental factors, on the other hand, received a low consideration, with only Tiong (1996) and Zhang *et al.* (2013) referencing the importance of environmental impact assessment in relation to technological limitations and public support constraints.

Institutional frameworks and arrangements may carry the greatest weight in determining project success. Institutional capacity impacts the procurement process and the strength of the private partner (Ameyaw & Chan, 2014), the degree of confidence-building with the private partner and stakeholders (Feldman, 2017), the tariff structure (Shi et al., 2016), and macro-economic investment conditions (Iossa & Martimort, 2015; Li et al., 2005). In fact, a comparison of CSFs between Ghana and Hong Kong identified a favorable legal and regulatory framework as one of the most important factors in determining project success for both developed and developing countries (Osei-Kyei & Chan, 2017).

Studies also suggest that there may be significant differences between CSFs in developed and developing countries (Osei-Kyei & Chan, 2017). Given the high reliance on international investment in infrastructure improvement, PPP practitioners and experts Ghana placed a greater emphasis on socio-political and economic factors - appropriate project identification, robust procurement process, high public partner support for the project, and stable and favorable economic conditions – than those in Hong Kong. Experts in Hong Kong, on the other hand, prioritized collaborative elements (shared authority, clear partner objectives and obligations, etc.).

Fieldwork and document analysis events uncovered a total of 27 CSFs (see Table AX for a full list of CSFs identified in interviews, observations, and shadowing events). The most commonly identified CSFs - project fit (41%), partner fit (27%), the identification of mutual benefits and project goals (44%), robust contract structure (24%), and inclusion of stakeholders throughout the project lifetime (34%) – are explored in detail below.

9.1 Project Fit – Project Cost, Socio-Technical Constraints

Public and private respondents stressed the importance of selecting a project that is worth the investment of time and resources to both parties (#1; #4; #5; #9; #14; Shadowing 2/27/2019). For the public partner, the project must ultimately benefit ratepayers (#1; #4; #11; #14 - #16), while the private partner must have opportunities to receive a return on investment (#1; #3; #4; #11; #14; #15 - #17). The project must be financially viable (#5; #11; #14; #17; Shadowing, 2/27/2019, 4/26/2019); if capital costs are too high and there are no opportunities for parties to break even in the foreseeable future, then the project is not worth pursuing (Shadowing, 2/27/2019).

Ensuring financial viability requires considerations of potential political opposition to the project (#4; #11; #12), as well as technical conditions such as geophysical constraints on a project site (#11; # 12; Shadowing 2/27/2019, 3/15/2019; 4/26/2019), cost of technologies implemented (#5; Shadowing, 12/18/2019), and existing infrastructure (#11; #15; #16; Shadowing 2/27/2019, 3/15/2019; 4/26/2019, 12/18/2019). Both desalination plants and the Urban Runoff project were able to increase cost-effectiveness through technological advancements. Desalination in particular has been a historically expensive and energy intensive process. A key breakthrough in the industry has been an improvement in the membrane technology. Over the last few years, the lifespan of the membranes utilized in the reverse osmosis process has increased from 3-5 years to a range of 7-9 years. This breakthrough has led to a "big difference in cost" for maintenance of the facility (Shadowing, 12/18/2019).

An element heavily emphasized by project participants was the importance of selecting appropriate sites for facilities (#11; #15 - #17; #21; Shadowing, 2/272019, 4/26/2019, 12/18/2019; Bourke et al., 2019; Fikes, 2015). Poseidon identified the AES and Encina power plants as potential locations for desalination in the late 1990s. The locations were industrial site[46] and already included an intake-outtake cooling system (Shadowing, 12/18/2019; Fikes, 2015). Co-locating the intake and brine distribution system with the power plant and being in close proximity to an electric grid would significantly reduce overall project costs (#21). Moreover, the long-term operation of the power plants has led to a "wealth of data on the marine environment" (Shadowing, 12/18/2019), thus potentially streamlining the environmental impact report process. Both sites were also in close proximity to the regional distribution system. The Huntington Beach location, for example, already includes distribution system infrastructure from a previously constructed desalination plant, Water Factory 21 (#16).

Finally, ensuring financial viability requires public and private partners proactively seeking alternative funding sources (#11; #15; #17; #20; #21) "from a wide variety of contributors (public and private). Because without it, you can't deliver the project" (#20). Six of the projects – GMB, HB desalination, the LMV AWT Facility, and all three data-oriented partnerships – were able to secure funding that reduced the financial burden to the public.

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[46] Respondents emphasized that it is more challenging to receive permitting approvals on "pristine" land rather than an industrial location (#20; Shadowing, 12/18/2019).

Partners encouraged anyone interested in pursuing a PPP to “think outside the box” (#11) and to begin consideration of funding sources as quickly as possible (#11; #17), as funding opportunities may become available through discussions with policy-makers[47] (#11), rebate programs (#3; #5; #15; #16), and state-level funding for regional programs (#11) and propositions (#12). Projects that clearly showcase multiple environmental and social benefits and directly quantify impacts (#12; Observation, 3/15/2019) will have the greatest likelihood of success in securing additional funding. One participant, however, remarked that the grant programs and bond measures in the state have not fully “caught up with public- private partnerships. We were unable to get grant funding that we would have otherwise been eligible for because the staff in Sacramento determined that the bond language does not allow for PPPs” (#20).

Conducting Independent Evaluations of Potential Impacts

Due to diverging interests between public and private actors, respondents emphasized the importance of conducting independent evaluations of project fit and impacts (#1; #2; #11; #15) as well as learning from the experiences of similar PPP projects (#4; #11; #15; #16; #21) prior to proceeding with a PPP. A poorly structured PPP agreement or a project with high adverse impacts threatens the reputation of the water district (#4; #11; #16; #19). Public water managers must, therefore, conduct their own independent analysis of socio-economic and environmental impacts.” We don't want a whitewashing of it. You've got to look at it so it passes muster to the outside, but it's got to pass muster with what we think is going on” (#11).

> Do the research. Find out really what the process is and what really is going on. Don't just have somebody come and sell a project to you and be off on your merry way. Really dig down and try to find out what the real facts are. Don't be afraid to […] find out negative

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[47] For one project, the partners “would have never thought that a city was going to be interested in […] providing some funds. It was only through a chance meeting, with an offhanded comment made to the Mayor that was almost a challenge.... They came up with the money for it.”

> facts or negative things about the project. You can learn a lot from that and you can also make the project a lot better. (#16)

One challenge noted by public partners is that they “don't know how to jump in” to a PPP (#5). A PPP is “something new. So, you want to be real careful” (#16). Learning from individuals who has past experience on similar PPP projects can minimize risks to the public partner (#4; #11; #15; #16; #21) and can clarify the PPP process. One public partner remarked, “luckily, […] we didn’t go first. It was probably more risky and dangerous for the [early adopters of PPPs] to go first on something like this. So they've kind of opened a door and showing everybody how it can be done” (#16). Talking with individuals who have been through “good, the bad, or the indifferent” experiences (#11) can allow water managers to get a sense of “what to expect, what this [a PPP] really is. […] To me, that is the soundest way to approach this because you don't know what you don't know” (#4). Studying experiences from others can also ensure that “you don't make the same mistakes” (#16). Public water managers have carefully reviewed annual performance reports of facilities to ensure the methodology is appropriate for meeting the water needs of their district (#16) and have hired financial, technical, and legal consultants that have participated in similar PPP projects to assist in contract review and negotiation (#16; #21). One public partner viewed this step as “indispensable,” as the team “had been there before and understood the issues (legal, technical, financial). We couldn't have done it without that team of support that we had” (#21). In the case of the Carlsbad desalination facility, for example, reviewing Poseidon’s experiences in Tampa, Florida led to the public partner adding in contract stipulations regarding design review rights and facility performance testing.

9.2 Partner Fit

Along with ensuring project viability, partners emphasized the importance of partners of selecting a partner complementary skills, resources, and needs (#1; #2; #5; #11; #14 - #17; #20; #21).

Complementary Skills and Resources

Public and private actors seek out participants that can further the goals of the project (#1; #2; #5; #17; #20). In the case of the Urban Run-Off project, for example, MNWD was able to merge its expertise of managing a water supply and wastewater collection system with the County of Orange's expertise on the stormwater runoff and the broader municipal storm drain system (#5). These two perspectives enabled a holistic understanding of run-off in wet and dry conditions, and established a mutual project need. One respondent likened PPPs to a marriage, in which the private sector's "tenacity" and the "ability to deliver projects as fast as possible" is combined with the public sector's knowledge of the complexity of government rules and regulations (#20). By blending the two skill sets together, you are "getting the best of both worlds" and "you can really create some amazing projects" (#20).

Participating actors must take into account the technical capacity of potential partners. Public agencies seek out a private partner that is willing to bear development risks (#11; #15; #16; #20; #21) and provide opportunities for knowledge transfer (#1-#5), especially if the project involves technology that the water district has low experience in (#15; #16; #21). In seeking a public agency partner, the private company looks for "an experienced and sophisticated public agency interested and capable (i.e., financial and technical wherewithal) of partnering on the development of public serving infrastructure. Typically, such public agencies are "responsible for building and operating public facilities and benefit from shifting financial expense and risk"

(#17). Public partners must also be “agile” and “pro-active” in mobilizing resources (#5; #9) to match the fast pace of the private sector (#20).

If private partners are developing a facility or an algorithm, the public partner must have the technical wherewithal to utilize the technology (#1; #2; #11; Shadowing, 4/26/2019). Failure to take into account the technical capacity of a public partner is a “waste of resources” (Shadowing, 4/26/2019). “You put in a treatment system that's extremely expensive to operate, potentially complex. You hand it over to people that don't have any idea on how to run that. Bad idea, it's destined for failure” (#11; see also #1). A public partners’ low technical capacity provides a disincentive to the private partner, as getting a project off the ground and implemented will require additional resources and time (#1; #11; #17). Limitations of technical capacity can be overcome by providing training to the public partner (#5; #7; #8; #11) or mutually agreeing to deliver solutions that align with the skills of O&M staff (Shadowing, 4/26/2019).

Ideal partners for projects may emerge as the design develops. For the Gobernadora project, for example, preliminary designs of the basin made clear that an additional public agency – the County of Orange – would be needed to oversee the flood management portion of the project (#11; #12; #20). Similarly, Poseidon identified the city of Huntington Beach as a viable location for a desalination plant in the late 1990s, approached the City in 2003, but did not identify a public partner until 2010. According to one respondent, “Orange County is an example that illustrates the importance of having a partner that has the wherewithal to be in a P3” (#17). Rather than having one regional water authority, there are two agencies (MWDOC and OCWD) with two separate statutory charges managing water provision for retailers. A regional facility requires a regional partner (#17 #21). The distribution of water to a high number of multiple public agency partners could be "cumbersome and difficult" (#17; see also #21). After many years of engagement, OCWD "stepped forward" to partner with Poseidon, entering into an MOU with the private project developer in 2010 (#16; #17). Despite being a groundwater manager, the skills, resources, and goals of OCWD are considered complementary to Poseidon's. The water utility

> has got a AAA credit rating. […] They've got plans in place that identify as a matter of policy, their goal to develop local supplies and to reduce the amount of imported water into their service territory. So it fits. They have a philosophy that fits. They have a financial structure that fits. They've got the kind of technical expertise to evaluate the project because they understand [the technology]." (#17; see also #15; #16)

Complementary Needs – Identifying Mutual Benefits and Goals

The most important factor of success identified by participants is that partners must understand each other's needs and establish mutually agreed upon goals (#4; #5; #7 - #9; #11; #12; #14; #20; #21; Shadowing, 4/26/2019). Parties must all see a clear need for the project (#11). Having a clear purpose and mission is "paramount" (#4) as the partner's objectives may differ (#4; #5; #11; #17; #19; #21; Shadowing, 3/15/2019). To establish mutual goals, public agencies must first start by thinking about "what [they] are trying to achieve in water" (#17); think through "some of your biggest challenges and prioritize them based on where you think the private partner can add the most value and move your mission forward" (#7; #8). These individual needs and expectations must be clearly articulated, as it will allow for the selection of a private partner with complementary skills and needs upfront (#14; #19; Shadowing, 4/26/2019).

Mutual goals incentivize partners to maintain long-term commitment to the project (#5; #11; Shadowing, 4/26/2019). Projects must have a "value for both parties" (Shadowing, 3/15/2019, 4/26/2019). "If the partnership is built or initiated or founded on working together to solve a challenge that you have in common, that forms a strong foundation for you to build on. Because no matter what happens, you can always come back to that common need" (#5). If a partner does not have a long-term stake in the project outcomes, they "never suffer the repercussions of something being wrong" and will only "want it to succeed until the day they can sign off on the performance guarantees, and then you may never see them again" (#11)

For the Gobernadora PPP, participants described the early stages of the project as a "difficult start [with] a lot of internal challenges. Because when we started, we didn't have to work together. The relationships were kind of cladded on and they evolved over time. […] We didn't have money. We barely had a concept and we had partners that were reluctant to come together" (#20). Negotiation "took a while to come to fruition" (#11). The partners established a system of bi-weekly meetings to agree on partner roles and obligations throughout the project lifetime (#12). The conversations were held over the course several years (#11; #12; #20). "A couple of times the process was put on hold" due to diverging concerns of public and private actors: the "private investors were worried about how much they are going to have to invest, while the public partners were worried about what are they going to have to maintain" (#20). Consolidating the roles and responsibilities of the County of Orange proved challenging as the other partners perceived that the County's goals were "mutually exclusive" from the initial project purpose (#11; #20). Interview respondents believed that OC Public Works wanted to set the design criteria for the flood attenuation basin, but did not want to own or maintain the basin (#11; #20). OC Parks also wanted to include trails and a bridge by the upper dam. However, the public agency lacked the funds to pay for the project. Respondents perceived that County ultimate hoped the costs would be borne by the other partners (#11). According to a public partner, the project stalled again when the private partner's need for the project decreased.

> We were on the verge of losing our grant funding because people in the past didn't start the project, because the [private partner] didn't need things. Their development slowed down because the economy slowed down. The grant was awarded about when the housing market tapered off in 2008/2009[…] so no one wanted to spend any money building this stuff. So they sat on it, and sat on it. (#11)

While the project is considered to be a successful PPP by respondents and external agencies (#11 - #13; #20; ASCE, 2019b; OCBC, 2015; PACE, 2015), the case highlights how shifts in partner priorities can reduce project momentum. In fact, had Rancho Mission Viejo not provided additional funding to cover cost overruns, the project "probably would have stopped. […] Because while it was good for SMWD to capture that water, it wasn't something that they had to do. The Ranch needed to do it" to meet mitigation compliance for future development (#11; see also #13).

Respondents from public and private organizations also note that a clear, mutually agreed upon goal can speed up the negotiation process (#17; #21) and can make it easier to allocate risks (#17). When both parties are "locked in and motivated to try to come to a deal," it becomes "a true partnership in terms of negotiation. They obviously were negotiating hard on behalf of their side and we were negotiating hard, but we all had the end goal in mind" (#21). Parties must all see a clear need for the project (#11). In other words, there must be "value for both parties" to maintain project momentum (Shadowing, 3/15/2019). "If the partnership is built or initiated or founded on working together to solve a challenge that you have in common, that forms a strong foundation for you to build on. Because no matter what happens, you can always come back to that common need" (#5).

Agreeing on and committing to mutual goals requires trust between partners (#11; #13; #20; #21). The partnership is an "interactive process" and "should be a constant collaboration" (#2). Interview respondents emphasized the importance of routine and consistent communication to develop rapport between participating actors (#13), refine the project purpose (#1; #6 - #8; #14), define partner roles (#12; #14), and ensure consistent motivation of private partners (#1; #6).

> That's where it comes down to - is that there's a lot of trust. You have to work together and you cannot fail the expectations of your partners. And you have to constantly listen to what it is that they're after. While you might have your own goals and you understand what those are, you really do have to listen to them and understand what they're after. (#20)

9.3 Robust Contract Structure

Once participants have identified a viable project and a partner with complementary skills, resources, and values, they enter into negotiation. A robust contract is critical in minimizing distributional impacts to ratepayers throughout the project life-time (#3; #11; #14; #17; #21).

To ensure partners have a clear understanding of mutually agreed upon outputs and outcomes, the contract must explicitly state partner goals, detail the obligations and roles of each party, and outline the project scope (#11; #14; #21; Observation, 3/15/2019). One public partner respondent likened their first PPP experience to a

> giant group project, and it's not always a clear line of who is supposed to do what. […] For example, if I were to say, "You need to go paint a house." Well, what does that mean? Do I need to go hire someone? Do I need to hire someone to do the prep and then someone else to do the paint? None of that is specified. I'm still going to paint the house, but how am I actually doing it? […] The more uncertainty that can be ruled out, and the more expectations that can be spelled out in the beginning, can bode well for the project and coordination down the line (#14).

Contracts must also establish quantifiable performance-based metrics and incentives to ensure partners do not shirk responsibilities (#3; #14; #17; #21; Observation, 3/15/2019) and are "incentivized to manage and operate [the facility] efficiently" (#14). Including these stipulations ensures that the private partner "will serve in the best interest of the public entity" (#3).

Performance standards must be consistent throughout the project lifetime. Per the Water Purchasing Agreement, for example, Poseidon must "meet all the same water delivery specifications in year 29 as [they] did in year one. So maybe it's an older facility, but it's still operating at the contracted capacity and performance" (#17; see also WPASA, 2012). Under the performance-based guarantee, the water authority has no obligation to purchase the water until it 1) meets all specified water quality standards, and 2) passes the point of delivery (see Figure 9.1) (Shadowing, 12/18/2019). If clauses surrounding maintenance are not included in the contract, "that's false savings. Otherwise, they're not putting any capital investment back into that plant because there's nothing in it for them" (#11).

Figure 9.1 Point of delivery for the Carlsbad Desalination Facility. Each contract that focused on water provision included a point of delivery, after which the entity operating the facility no longer holds responsibility over water quality and use. In the figure above, the narrow black pipe is the "point of delivery" for the Carlsbad desalination facility. By the time it reaches the black pipe, water must meet all performance standards outlined in the contract (Shadowing, 12/18/2019).

Respondents recommend including flexibility in the system by dividing the contracts into phases (#11; Observation, 3/15/2019). For each PPP project, water districts signed non-binding

Term Sheets or MOUs with private partners prior to “locking in” to purchase agreements. Term sheets include a preliminary distribution of risks and obligations between partners, but allow the public water districts to re-evaluate the value for money of the project once final project costs are clearer. In formal agreements, partners also had multiple opportunities to review the project status and terminate the project if it was not meeting expectations (IA, 2012; GMB IA 2014; WPASA, 2012). For instance, in the Gobernadora contract between SMWD, Rancho Mission Viejo, and the County of Orange, parties must approve the final design plans and secure all permits prior to the construction of the project (IA, 2012). If regulatory jurisdictions require modification prior to issuing permits, parties shall meet and confer whether these changes can be made. Partners were not obligated to proceed with the implementation of the project if the proposed changes could not be “reasonably accommodated […]” (IA, 2012, p.10). If project cost increases occur, parties shall discuss strategies for minimizing cost and identifying additional revenue sources. “In the event that the Parties cannot identify/locate potential revenue sources to satisfy increased costs, SMWD may […] choose to discontinue all work on the Project and the Agreement will be terminated” (IA, 2012, p.14). Similar opportunities to re-evaluate project costs and partner commitments were included in the Lake Mission Viejo contract:

> Prior to proceeding with the construction of the Infrastructure, SMWD and LMVA will mutually agree in writing upon the final capital cost of the Infrastructure, the amount of capital that will be financed and financing charge; and other costs (such as permitting or defending any legal action) described in the project […]. If the parties cannot agree on the final amount of such items and the proper allocation between the parties of any extraordinary or other costs which have not been allocated by this Agreement, then either party will have the right to terminate this Agreement upon thirty (30) days written notice to the other party (SMWD & LMVA, 2016).

This flexibility allowed public partners to have “off ramps before incurring additional costs (#11). “Because we had to have a stop gap, that ‘this is how much we're spending here folks.’

We're not in a position where we can spend more than that because we do have to justify it to our rate payers (#11).

Contracts must also "provide clear clauses […] regarding what to do in contingencies" (#11; see also #14; #21). For example, negotiations and the contract structure of the Carlsbad desalination plant included how the water was going to move through the SDCWA's water system, operational protocols, specific water quality requirements, plant shutdown procedures and conditions, and procedures for facility transfer at the end of the contract term (#21; WPASA, 2012). These stipulations shield the public partners from risk in the case of cost overruns. Public partners should

> Take the rose colored glasses off and [think about] what's going to happen when things aren't really pretty. Get everything down that you can think of in the agreement. Because when things - which they inevitably do - don't go quite as well (if not horribly bad), that keeps everybody in the game and keeps things clear as far as delineation. Write it down because everybody's friends at the beginning, and they may not be at the end (#11).

One respondent from a public water utility believed that these contingencies were one of the most important lessons learned from entering into a PPP (#21).

> We thought that there were a lot of things that were being covered in the contract that we would likely never experience. And what we found is that in the first four years of this contract, we've had to deal with lots of issues that fortunately were covered in the contract. [laughs] So it's been interesting. It was nothing that we hadn't thought of. We just didn't think that they were going to come up so quickly. (#21)

Respondents cautioned that the inclusion and negotiation of these contingencies can significantly increase the duration of negotiation (#5; #11; #14; #21). Both parties must dedicate time and resources to develop the contract and the technical details of plant operation. The city of Rialto, for example, took around three years to form a partnership with Table Rock and Ulico. The process was described as "quite a tortured path" by participants due to the "dozens of financial and legal issues” unearthed during contract formation and negotiation (Jensen, 2012, para 13). Across multiple cases, hiring legal expertise was viewed as instrumental in streamlining negotiation (#21; Callahan, 2012; Hughes, 2017).

9.4 Incorporating End-users and Affected Stakeholders throughout the Project Lifetime

To reduce project opposition and to ensure that projects are tailored to meet the needs of end-users, three groups of stakeholders must be included in the early stages of the project lifetime: operations technicians within public water utilities, members of the affected community, and non-governmental organizations (#6 - #9; #11; #13; #14; #16; Shadowing, 4/26/2019; Observation, 3/15/2019).

Operation and decision-making in public agencies can be silo-ed (#1; #9), leading to a fragmented understanding of the project scope. Moreover, those in management positions have a different perspective than those operating on the ground. (#7 - #9; #11). Thus, public and partners emphasized the importance of including individuals from across different departments and levels of hierarchy in the early stage of project development technology (#6 - #9; #11; #14; Observation, 3/15/2019). One key group that must be present in early discussions are operation technicians and engineers (#11; #14; Shadowing, 3/15/2019; Observation, 3/15/2019). O&M staff are those that will “make the design work” (#11). If operators lack the technical capacity or the willingness to utilize a particular technology, the project will not operate effectively (Shadowing, 4/26/2019). Excluding the perspective of end-users can lead to cost overruns. In the case of IRWD’s Energy Storage Project, failure to include engineers in the agreement process led to uncertainty in where the storage batteries will be built (#14). This omission created a “cost risk” to each party, as site selection and installation required evaluation of soil conditions, contracting of geotechnical engineers, and site modifications, ultimately driving up project costs (Shadowing, 2/27/2019).

Exclusion of end-users can also result in the development of tools or facilities that meet “hypothetical” rather than “actual needs” (#9). “Sometimes you can design that you think is going to be useful, but it's just parallel to the actual, decision point” (#9). End-user need was stressed heavily by private partner and NGO respondents of data-oriented PPPs. There is a tendency in the data for social good world to produce “solutions in a vacuum. They are built for [users], and not with. (#7; #8). There is frequently a gap in communication and knowledge between those with the technical experience to develop Machine Learning solutions and those that understand the nuances of water management systems (#1; #2; #6 - #9). Yet, “when you are not in the water industry, you don't know the other side. You understand data and the modeling very well but not how the operations work, how the distribution works, how our treatment plants work here” (#2). Private partners emphasized the public partners are “the domain experts” (#6-#9). For example, when developing an effective forecasting tool for recycled water demand, the individuals who must be included in the design phase are those that determine when to utilize potable make-up water in the recycled water system. To build an effective mode, you need to “get the tool in front of them [the operators]. Learn about what sorts of information they are currently using to make that decision on whether or not to pull the lever. How can you fit this tool that you're creating into the sources of information that they're already receiving so that it works? (#9). Communication in the early stages of model development allows the collaboration to be “a learning experience for everyone” (#7; #8), and can lead to the development of tools that are “user friendly” (Observation, 8/29/19) and maximize scalability and program impact (#6 - #9):

> When we're thinking of solutions, particularly in the technology and data space, so often solutions and research is done more or less in a vacuum. The more people you can get at the table who are impacted, the more you can tailor those solutions to a specific or a diverse audience. Stakeholders can be in multiple different sectors at any given time and bringing them all together is the only way we're actually going to make lasting impact and do it responsibly (#7; #8)

Gaining Community Buy-in and Support

Respondents at public water agencies highlighted that "there's an increasing public awareness about water. There's a different mindset" in which members of the community want to be involved in the decision-making process. (#13; see also #1; #3; #4; #11; Observation, 8/30/2019). In the past, water utilities "all flew under the radar. The best meeting is when no one shows up" (#4; #13). Respondents argued that this kind of approach is now viewed as "old school" (#4; #11; #13).

Districts are starting to realize that "the most important thing is you've got to have is trust. Trust of your community. If you don't have that .... You're in a hard place," as it becomes difficult to implement new policies and ensure compliance on water conservation strategies (#4; see also #1; #3; #11; #13; #16).

> In the district, I think we've turned a corner from what most public agencies used to do. It used to be: tell them as little as possible, build it, and then deal with it. This project included, we did a lot of outreach. And we do that pretty much on all our projects now, to let the public know what's going on, try to get their input and if at all possible accommodate it. Because oftentimes it's not a big thing (#11)

Gaining community trust and buy-in requires transparency (#1; #4; #11; #21; Observation, 8/29/19) and extensive public outreach in the early stages of a project (#11; #12; #16; #17; Shadowing 3/15/2019, 4/26/2019). To reach as many members as the community as possible, outreach must be conducted through a diverse mediums – public board meetings, town halls and stakeholder meetings, social media posts, bill inserts, newspaper articles, educational videos, district-run blogs, public tours, and public events such as water festivals (#1;#3; #11; #15 - #18).

Engaging with community and civic leaders such as block leaders of HOAs, PTA groups, and city council members can also assist in disseminating critical project information and increasing community buy-in. Materials written in non-technical language can allow project partners to demonstrate project benefits and to assuage concerns about perceived project risks (#11).

Members of public water agencies highlighted that those opposing a particular project – either in public meetings or through op-eds, media articles, and correspondences –often cited incorrect information in their arguments (#11; #16; #19). “We have hundreds of people come out, mostly speaking against it. But the information they have is usually so wrong. And it's hard to engage and explain…” (#16). Another respondent referred to the misinformation as a “whisper chain” or as a “game of telephone – by the time it gets back around to you, it’s not the same project” (#11). Transparent and direct communication in the early stages of the project can reduce misinformation surrounding the project and, thus, can reduce project opposition (#11; #16). Members of SMWD addressed concerns regarding the Gobernadora project by leading town hall meetings, showing the plan designs to concerned citizens, and providing information regarding the construction schedule on the district website (#11; #12; Shadowing, 3/15/2019). These actions assuaged citizen concerns that the project will have no negative impacts on the surrounding community.

Across the 10 case sites, the most successful public engagement effort for the LMV AWT Facility project. The Lake Association conducted extensive outreach efforts. Over the span of a year, LMVA provided newsletters, mailings, and other correspondences to all homes in the city and homeowners association (Bourke et al., 2019). Delegates representing the 81 neighborhoods within the LMVA voted unanimously to switch to the Advanced Treated Water system (Shadowing, 4/26/2019; SMWD n.d.-c), with 82% of votes cast in approval of a partnership arrangement with SMWD (SMWD, n.d.-c). The high level of community support was considered a critical component of the project’s success. As the risk of gaining community buy-in was transferred to LMVA, SMWD was able to direct its resources and energy on project development.

NGOs as Bridges

NGOs participated in various stages of five of the ten PPP projects, either directly as project partners (the Urban Runoff Project, DataKind) or as actors supporting the development and implementation of facilities and algorithms. The inclusion of NGOs in project development can reduce project opposition (#11). One member of a public agency stressed that it is imperative to

> talk to the NGOs, try to find out and figure out what are people opposed to and address those issues early on. And if you find that they could be insurmountable, how do you do something different? Is there a way that you need to look at it differently in order to move it forward? (#11)

NGOs can also serve as “bridges” by connecting members of public agencies with individuals who can facilitate project development. In the case of all three data-oriented PPPs, the California Data Collaborative facilitated connections between MNWD and those that are involved in data for social good programs (#1 - #4; #9; #10). For the Gobernadora project, an NGO served as “an intermediary” between regulators and water districts, ultimately reducing barriers to permitting and providing an avenue to overcome antagonistic relationships between regulatory agencies and water utilities (#11; #13; Shadowing, 3/15/2019).

> I can call a lot of different agencies [EPA, Fish and Game, US Fish and Wildlife] and get appointments that public agencies not only can't get, but they would be uncomfortable with. […] I can get in the door and talk to them. […] Because they see their relationship as a hostile or adversarial. I don't. (#13)

Clean Water Now was initially brought on in the early stages of project development to review the CEQA documents and to provide recommendations on the project design (#13). The NGO stayed on to serve as an independent monitor of construction impacts (#11 - #13) and provided routine updates to state regulators on the development of the project (#13). The early stages of collaboration were described as “awkward” due to perceived differences in values between the NGO and the District (#13). The NGO member highlighted that this was a period where employees were vary of his presence and showed distrust at his suggestions (#13). For the NGO member, the period was also ‘an adjustment’ to the bureaucratic nature of district operations and management. The collaboration was able to evolve into a long-term relationship due to both party’s ability to “listen” and to develop mutual understanding of each other’s goals and values (#11; #13). This was one of the first instances for SMWD to include NGOs in water infrastructure projects (#11). The relationship has ultimately changed district practices in regards to community engagement: “we're trying to bring them [the NGOs] along on all our projects now, especially anything that's involving an environmental issue at the very beginning of the project to hear their issues or concerns” (#11).

In interviews, respondents highlighted that this kind of close relationship between an NGO and a water utility is unique (#11; #13). According to one respondent, other NGOs view the collaboration as an “inappropriate relationship” and perceive it as a form of abandoning or compromising their values (#13). “But I don't know how to explain why the other people that I work with.... Maybe some of them do things like this, but they don't want to talk about it because there's a repugnance like, ‘you don't work with public agencies’” (#13). Yet, members of the district and the NGO described the relationship as “mutually beneficial” (#11; #13). The NGO provides public support for projects that it perceives to be environmentally beneficial (#11; #13). For example, the NGO member attended city council meetings to support the Lake Mission Viejo AWT Facility. In turn, the relationship allows the NGO to instill environmental sensitivity into projects such as the GMB (#13).

> Somebody's going to have to bite the bullet and be willing to go in there and sit down with these people. And hammer out these things because without it there'll be nothing out there. There'll just be houses and that isn't going to work. […] Development's going to happen. So what can I get for the environment? There's never a win-win. Development is always lose- lose. The environment, loses, the developer loses (#13).

9.5 Leadership

The final factor identified by project participants as critical to project success is leadership. (#1 - #5; #9; #11; #13; #15; #20). The management style and values of those in leadership positions at water utilities – general managers (GMs), members of the Board of Directors, and project managers –shape the broader district culture and norms of low-level and mid-level employees (#1- #5; #9; #13).). When describing elements that make the partnership effective, respondents highlighted that complementary public partners have "a progressive and innovative philosophy from the top-down that starts all the way with their general manager and extends throughout their organization. They [the GMs] really kind of set the tone for that" (#5). General Managers have been described as "agents of change" (#1), where the cycling in of a new GM can "change the atmosphere, literally, the environment of a utility" (#13). Impactful leaders were seen as innovative, "out of the box," "big picture" thinkers that redefined how utilities viewed and managed resources, engaged with stakeholders, and interacted with ratepayers (#4; #5; #9; #11; #13; Bartlett, n.d., para 3

The Board of Directors is the final determinant on whether or not a district can proceed with the project. One respondent stressed that adoption of a riskier technology ultimately

> depends on the board. […] There's some Boards that would just say, "I don't want to bother with it. I don't want to have to raise my rates. I don't want to have people come into my board meeting yelling at me." And our Board said, "no, we're going to do it because water is so important." And so the Board did it. (#15; see also #4)

Project leaders and GMs, thus, must understand how to convey perceived benefits of project to stakeholders and decision-makers in accessible language (#4). The Board of Directors can also shape the directions of projects by establishing district priorities (#11; #13; #15). OCWD's pursuit of new local water supplies including seawater desalination, "is based on policies adopted by the Board of Directors" (#17). New members were elected into OCWD's Board of Directors in 2010 (#16). At the request of the new board (#15), OCWD entered into an MOU and a Confidentiality Agreement in March, 2010 to share information with Poseidon Resources on the project (OCWD, n.d.). Similarly, SMWD's efforts to increase local water supplies through traditional procurement and PPPs are driven by the Board's decision to reduce dependence on imported water (#11; Bartlett, n.d.).

Leadership is crucial in maintaining momentum during partnership formation and negotiation. To forge new partnerships and connections, "it takes a certain personality type […]. I don't want to say 'bold,' but in a sense it is. 'To boldly go where no one has before.' It is kind of an exploration, a journey." (#13). Respondents discussed a "human" and a "technical element in project development (#4; #13; #21). "Without leadership that's willing to compromise, listen, sometimes apologize, it's very difficult to launch a project" (#21). Leadership can also reduce barriers to PPP adoption by creating safe spaces for experimentation within water districts (#1 - #4; #9; #13). In both infrastructure and data-oriented PPPs, public water managers and members of the Board of Directors "empowered individuals to take risks or try projects that have not been necessarily done before" (#9; see also #1- #4; #11; #13; #15; #16), thus allowing staff members to "go out and seek out opportunities instead of waiting for them" (Observation, 8/29/19). One individual in a leadership position expressed that their contribution in developing a PPP was

> not in the technical work itself, but in taking that chance to do something that's unfamiliar, not only to me or this agency, but to the industry. And there is some risk involved in that, for sure. People don't like to be on the bleeding edge of anything or the leading front on anything because you get some bumps and bruises. And clearly on this one, we were out there. (#4)

9.6 Discussion

This chapter synthesized recommendations and best practices identified through fieldwork and document analysis. Water managers have strived to minimize socio-economic impacts of projects by ensuring appropriate project fit, selecting private partners with complementary goals and needs, utilizing a flexible yet robust contract structure, and including NGOs, the general public, and technical experts in the early stages of project development. Finally, leadership within water districts enables PPP formation by promoting spaces conducive to experimentation and innovation and by facilitating confidence-building and contract negotiation.

A key finding of this research is that public and private participants in California PPP projects placed a stronger emphasis on collaborative elements of partnerships, rather than macro-economic and political conditions. These findings align with the work Osei-Kyei & Chan (2017), and confirm that political barriers to PPP formation and market entry are lower in developed economies rather than developing ones. The most frequently identified CSFs in the literature were the technical expertise of the consortium, stable political support, appropriate risk allocation, and a strong regulatory system (see Table A3). Meanwhile, project participants in California PPPs most frequently identified the importance of establishing mutual goals and benefits, project fit, leadership, and partner fit as the most important factors guiding project success (see Table A4).

These findings ultimately reveal that building partnerships and participating in community engagement requires significant investment of resources, time, and necessary skills. There is a “human” element to partnerships that has been secondary in practitioner and academic literature of PPP CSFs. A successful project requires the establishment of mutual goals and expectations, as well as a shared understanding of what committing to a PPP (rather than traditional procurement) entails (Emerson & Nabatchi, 2015; Jamali, 2004; Jefferies, 2006). Establishing these expectations in the early stages of collaboration maximizes the likelihood of partner commitment to the project, increases project efficiency and product delivery quality, and limits opportunistic behavior of both partners (Ameyaw & Chan 2014, Jamali 2004; Jefferies, 2006; Jeffares et al., 2010). This research confirms that consolidating the needs of partners can be challenging (Koppenjan, 2015; Valente, 2010) and requires support from organizational leaders, technical experts, and stakeholders (#11; #12; #21; Shadowing, 3/15/2019).

While respondents would often point to the presence of leaders as a critical factor in enabling PPP adoption and maintaining project momentum, only one study has identified leadership as a CSF (Tiong 1996). Leadership can play a critical role in sustaining momentum of collaborative institutions (Gerlak & Hekkila, 2007; Forrer et al., 2010), especially in complex or large-scale resource settings where it may be difficult to establish or maintain trust among actors due to diverging values and interests (Raymond, 2006). There are two types of leadership positions that can influence PPP outcomes: project champions and boundary spanners/conveners (Cools, Slagmulder, & Van de Abbeele, 2011; Noble & Jones, 2006). Project champions are senior managers or politicians established leaders in their organization – they recognize the need for a PPP, initiate the initial project, and provide public and organizational support for the partnership (Noble & Jones, 2006). Champions also serve as the “public face” of projects, and can assist in building a supportive regulatory environment (Cools et al., 2011; Hewes & Randolph, 2018; Noble & Jones, 2006). They may chair formal meetings in the early partnership stages, and seek to bring cohesion in group dialogues by consolidating all identified goals and values in “one voice” (Noble & Jones, 2006). It is “rare for major projects to survive without them” (Florizone & Carter, 2013, p. 2).

In both infrastructure and data-oriented PPPs, respondents frequently spoke about the role of General Managers or the Board of Directors in identifying project need, assessing the political feasibility of projects, creating spaces that facilitate risk-taking and collaboration, and sharing stories of success with stakeholders in the water sector to promote scalability and replicability (#1 - #5; #9; #11; #13; #15 - #17). It is worth noting that identifying a need for a partner and a project fit can be challenging. For instance, in a survey of AWWA members, 70% percent of respondents identified few or no projects that could be suitable as potential P3s (AWWA & EY, 2019). Moreover, individuals with a low understanding of PPPs are more likely to identify no projects as suitable for PPPs. Thus, a successful project champion (General Managers, Board of Directors) must be able to recognize and act on windows of opportunity (Florizone & Carter, 2013; Meijerink & Huitema, 2010).

Meanwhile, boundary spanners are involved in the day-to-day machinations of projects during project development, negotiation, and implementation (Noble & Jones, 2006). Across the 10 cases, project leaders worked with partners – communicating often weekly – to generate mutually agreed upon goals, designs, outputs, and implementation strategies (#1; #2; #14; #21). Boundary spanners are the ones that assess partner fit based on the vision of the project champion and ensure that the partnership arrangement minimizes political and reputational risk (Noble & Jones, 2006). This step plays a key role in determining project outputs: the selection of a partner that is a poor technical, social, or political fit can result in decreased service or product quality, increased likelihood of contract renegotiation, and high transaction costs (Liu et al. 2014). Early meetings between public and private boundary spanners are critical, as they provide opportunities to build rapport and to bridge cultural differences between actors. While CSF literature focuses on the technical capacity of the private partner (see Ameyaw & Chan, 2015;

Meng et al., 2011; Osei-Kyei & Chan, 2015, 2016; Tistsifli & Kanakoudis, 2008), respondents in the California cases "sized up" public and private sector partners based on their technical capacity as well as their complementary needs, skills, and mutual philosophies. This broad assessment of partner fit aligns with Noble and Jones (2006) findings, who argue that partnership formation and project development requires a "chemistry" between partners that goes beyond economic or technical need. If boundary spanners cannot see the value of the partnership, they will be reluctant to maintain project momentum.

To aid collaboration, successful champions and boundary spanners must be sensitive to the cultural differences and values between partners parties (Som, Omar, Ismail, & Alias, 2020), build a shared narrative of the project (Farrelly & Brown, 2011), hold project participants accountable for meeting agreed-upon goals within the time frame (Forrer et al., 2010), and build trust between project participants (Som et al., 2020). Leaders can also assemble networks that have different "way[s] of knowing" water (see Ingram & Lejano 2009). Recruiting a dedicated team of relevant stakeholders to develop and to manage the project is particularly important when public agencies have low experience with PPPs (Hewes & Randolph, 2018). Assembled individuals pool diverse technical knowledge and expertise to create sustainability-oriented or resilient solutions within the institutional and social context (Farrelly & Brown, 2011; Meijerink & Huitema, 2010), thus allowing projects to overcome the constraints of existing norms, regulations, and practices of the water sector (Hewes & Randolph, 2018).

The importance of "bringing the right parties around the table" (Corrigan et al., 2005, p. 20; see also #7 - #9) has been frequently highlighted in 4P (public-private-people-partnership) literature (Ahmed & Ali, 2006; EPA, 2015; Kumaraswamy, Zou, & Zhang, 2015; Marana, Labaka, & Sarriegi, 2018). Engaging with a diverse group of stakeholders - end users, relevant

NGOs, professionals, community representatives, academics, and the media - can enable the establishment of a mutual agenda that moves beyond economic considerations to a more holistic focus of sustainable development (Kumaraswamy et al., 2015). Thus, participatory PPPs can bridge the diverging values and priorities of public and private parties, increase input and output legitimacy of the project, and ensure the project aligns directly with community needs (Dellas, 2011; Kumaraswamy et al., 2015; Marana et al., 2018; Mert & Dellas, 2012).

The inclusion of citizens in PPP decisions throughout the project lifetime can also strengthen public support for the PPP (Beevers, 2016; Hall et al., 2005). The role of public support and community buy-in has been well-documented in PPP literature (see Beevers, 2016; Chen et al., 2013; El-Gohary et al., 2006; Hall et al., 2005). Community buy-in is low when the public is either unaware of the concept of a PPP, does not have a sufficient understanding of how it works, or is denied access to details of a consortium's PPP proposal (El-Gohary et al.. 2006). Gaining community buy-in reduces the risk non-payment of bills (Loxley, 2013) and public pressure on policymakers to cancel the project, and thus decreasing risk premiums for financing arrangements (Hall et al., 2005). In California, projects that faced high opposition by the public and protectionist groups – Cadiz Water Project and the Huntington Beach and Carlsbad Desalination Projects– were delayed due to costly litigation and permitting challenges. Additional opportunities to include the community in project development may have reduced project costs and delays throughout the project lifetime.

NGOs may play a key role in the successful adoption of PPPs that promote sustainability and resilience by serving as independent sources of monitoring (see Ahmed & Ali, 2006) and by creating "bridges" between project partners, the community, and regulatory agencies. In the GMB case, for example, an NGO provided a voice of community support for projects that he believes are beneficial to state legislators, the media, and other NGOs, thus increasing project legitimacy and community buy-in. Independent monitoring of project design and implementation can also ensure private partners do not incur environmental harms through cost-savings (Koppenjan, 2015). While inclusion of affected stakeholders may increase project start-up costs, informal and formal opportunities for public “voice” allow project managers to course correct distributional or environmental impacts throughout the project lifetime, thus increasing project effectiveness and system resilience in the long-run (Kumaraswamy et al., 2015).

The “soft” relationship mechanisms outlined above establish norms of flexibility, solidarity, and information exchange in PPPs, which can lead to development of trust and confidence between partners and enable effective community engagement (Benítez-Ávila, Hartmann, Dewulf, & Henseler, 2018; Kumaraswamy et al., 2015). Meanwhile, contracts serve as a codified agreement on how these partners will work together throughout the project duration (Noble & Jones, 2006). Due to the long-term nature of PPPs, contracts are typically incomplete (Kumaraswamy et al., 2015; Leighland, 2018). Effective contracts will provide solutions to potential partnership pitfalls and specify processes to resolve unforeseeable outcomes (Kumaraswamy et al., 2015). The ability to formulate these clauses is dependent on stakeholders’ capacity to anticipate project-specific contingencies and to understand the broader socio-technical constraints of the sector (Demirel et al., 2016). As was frequently emphasized by project participants, the development of a robust project and contract negotiation can be a long-term process. Contract negotiation in the infrastructure cases sometimes took years. These transaction costs can serve as a barrier of PPP adoption (Leighland, 2018). In fact, PPP preparation costs are higher than those under a traditional public procurement (De Schepper, Haeqendonck, and Dooms 2015) as they often include the legal, financial, and technical costs of procurement, contract negotiation, and the development of “upstream” policies that support project implementation (Leighland, 2018). The time and resources required to develop and negotiate a project are often not included in a cost-benefit analysis, resulting in over-estimates of the monetary benefits of a PPP (Ho & Tsui, 2009). To build robust contracts and partnerships, public agencies interested in entering into a PPP must allocate a budget that leaves room for legal fees, transaction costs, unexpected project delays (Bloomfield 2006; Koppenjan, 2015)

The high investment of time and resource to create a complete contract element was viewed by project participants as a necessary tradeoff to prevent adverse environmental and socio-economic impacts. For all 10 projects, respondents perceived the contract structure as sufficient and effective for minimizing costs to ratepayers. An example of an incomplete contract structure, however, can be seen in another case – the recycling plant PPP in Santa Paula, California. The city council of Santa Paula had to recently regain control of a recycling plant by purchasing it back from its partners Alinda Capital (project financer) and PERC Water (project developer and operator) due to rising water costs and water quality concerns (Water Industry News, n.d.). In 2007, the Regional Water Quality Control Board sued the City of Santa Paula to implement necessary water quality improvements by constructing a new waste-water treatment facility by September 2010 (Ventura County Grand Jury, 2013). After reviewing bids, city officials voted to proceed with the Design-Build-Finance-Operate bid with PERC, believing that the private partner would be the most efficient, technologically advanced, and cost-effective option for ratepayers: the contract allowed for savings in roughly $18 million in capital costs and $1.8 million in annual operating costs. Moreover, the design resulted in a 25% increase in capacity, 70% reduction in the facility’s footprint, and a 30% reduction in energy consumption (PERC Water, n.d.). The plant received multiple awards, including Water Deal of the Year (2009) and Plant of the Year (PERC Water, 2015, n.d.)

Public and private partners encountered friction early on in the partnership on account of ambiguous performance standards. The plant did not address the historically high levels of chlorides in the wastewater (Ventura County Grand Jury, 2013). As a result, in 2014, the City filed a dispute with PERC Water over its failure to meet the RWQCB's water quality requirements, which include ensuring that chlorides do not exceed 100 mg per liter. Meanwhile, the private partner and an independent evaluation of the PPP contend that this requirement was "never specified" in the bidding requirements or the contract (Scheibe, 2013; Ventura County Grand Jury, 2013). The plant's design had never been intended to remove chloride (Scheibe, 2013). City officials responded that PERC staff "were supposed to be the experts" and "now the city is left to deal with this issue" (Scheibe, 2013). In 2015, the City pursued a "unique opportunity" to purchase back its wastewater treatment system due to historically low public bond rates (Ventura County Grand Jury, 2013, p.1). The partners also agreed to settle the court dispute with a $5 million reduction in the buy-out price (Scheibe, 2013).

The Santa Paula PPP contract structure created an undue cost burden for consumers. While the $62 million facility was 100% financed and constructed by the private partners, the city purchased the wastewater recycling plant for $70.8 million (Ivory et al., 2016). The City also had to pay a $940,000 break fee to replace PERC with another operator in a new O&M contract. During the duration of the partnership, the city was forced to double its sewage rates to maintain the monthly service fee to the private consortium (Ivory et al., 2016), resulting in the second highest sewer rates in Ventura County (Boyd-Barrett, 2015). Buying back the plant reduced sewer bills by $28 to $37 per month (Boyd-Barrett, 2015). The plant has also experienced two spills in 2015 and 2018, leading to criticisms that the officials purchased "a lemon" (Hamlin, 2018). Proposed solutions to address the chloride contamination will require an additional $11 to

$15 million in capital costs (Rock & Saunier, 2019). Yet, according to the financer, the project was ultimately a “profitable venture for Alinda” (Water Industry News, n.d., para 8). The example highlights the importance of including clear performance-based metrics in the bidding process and/or initial discussions of unsolicited proposals (Koppenjan, 2015; Leighland, 2018).

Public agencies can also ensure partner fit and project fit by pursuing “incremental partnerships.” Recently introduced as a PPP strategy, “incremental partnerships” can allow the government agency to “call off” or stop projects that are unproductive. This is particularly useful for smaller projects that are sensitive to local conditions or projects that are facing high uncertainty of supply/demand in the future (Leighland, 2018). This structure can be seen in the infrastructure PPP cases in California. For each project, partners reduced distributional impacts from evolving state regulations by providing “off ramps” and opportunities to re-negotiate the contract. To yield resilient projects, PPPs must include a feedback link between monitoring and decision-making to respond to changing circumstances (Demirel et al., 2016). This proactive, rather than reactive, approach can reduce cost-overruns throughout the project lifetime, yield a more efficient risk allocation, and ensure long-term commitment to the project (Cruz & Marques, 2013; Demirel et al., 2016; Fridegotto, 2017; House, 2016).

By situating case study data within a literature review of PPP CSFs and management practices, this chapter has developed a framework of how to 1) adaptively manage PPPs, 2) develop trust and rapport among partners, and 3) ensure that projects reflect community needs, thus increasing the likelihood of community buy-in (see Figure 9.2) This chapter identified the formal (flexible and robust contract structure) and informal mechanisms (strong leadership, engagement with stakeholders, trust) necessary to develop and manage successful public-private partnerships.

Figure 9.2 Framework for Effective PPP Development and Management

A key contribution to the literature is the emphasis on the informal/"soft" elements of partnership development. While these informal mechanisms can play a critical role in ensuring that projects identify and achieve resilience and sustainability-oriented goals (Kumaraswamy et al., 2015; Marana et al., 2018), they have received low attention in PPP literature. Identifying successful "soft" elements can aid practitioners in closing the high cultural distance between public and private sector participants (see Noble & Jones, 2006). The chapter also identified linkages and interdependencies between formal and informal mechanisms. Formal mechanisms enable relationship building by providing a blue-print for behavior; negotiated roles and responsibilities allow project partners to find common ground when confronted with diverse perspectives on how to address problems and misunderstandings (Benítez-Ávila et al., 2018). Conversely, inclusion of relevant stakeholders and effective, two-way communication between actors that builds rapport and trust can allow for greater flexibility of contracts, adaptability and responsiveness of project managers to changing needs, and increase overall commitment to meeting project outputs (Benítez-Ávila et al., 2018; Demirel et al., 2016; House, 2016; Kumaraswamy et al., 2015; Marana et al., 2018). Thus, public agencies entering into PPPs must be sure to devote sufficient resources and time to informal mechanisms of project development and implementation.

10.0 CONCLUSION

Traditional approaches to environmental regulation and management have fallen short in addressing complex environmental problems (Bhan, 2013). In decentralized and fragmented systems, agencies develop technical knowledge within their mandated area (Lach et al., 2005). While this specialization enables tailored localized responses, fragmentation limits effectiveness of addressing challenges that cross sectors and political boundaries (Emerson & Nabatchi, 2015; Rittel & Webber 1973). Risk-aversion, low incentives for innovation, inefficiency, and jurisdictional and resource constraints ultimately preclude public entities from overcoming "wicked" problems[48] (Head & Alford, 2015; Pinz et al., 2017). Unfortunately, the number of "wicked problems" is increasing (Head 2008, cited in Emerson & Nabatchi, 2015) while public governance resources to address these issues are becoming more scarce (Nabatchi, Goerdel, & Peffer, 2011).

Historically, the water sector has traditionally utilized an engineering resilience approach and has focused on "end of the pipe" approaches rather than holistic policies that prevent and adaptively manage environmental and social challenges (Feldman, 2018; Le'Maitre). The approaches have ultimately increased vulnerability of California's water systems to acute and chronic shocks and perturbations (Chelleri, Waters, et al., 2015; Holling, 1986; Le Maitre & O'Farrell, 2008). The present day water socio-technical system and governance mechanisms are challenged in meeting present-day and future water needs (Hundley, 2001; Hanak et al., 2011; Mount et al., 2018; Zetland, 2009). In light of these challenges, there is a need to pursue cross-boundary and cross-sector solutions. When effective, collaborations across sectors can enhance

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[48] "Wicked" problems are problems that are difficult or nearly-impossible to solve due to complex interdependencies, incomplete and contradictory information, and high consequences to implemented solutions (Rittel & Weber, 1973).

the understanding of the causes of "wicked" problems (Head & Alford, 2015), improve effectiveness of policy responses (Andrews & Entwistle, 2010), create institutions with greater flexibility (Cornick & Innes 2003, cited in Ulibarri 2015b) and resilience (Booher & Innes 2010, Goldstein 2012, cited in Ulibarri 2015b), and develop multi-resource management schemes that reflect the diverse needs of affected individuals (Ulibarri 2015a).

This research, thus, examined the role of public-private partnership in achieving water management that is sustainable and contributes to social-ecological system resilience. Semi-structured interviews, observations, shadowing, and document analysis of seven infrastructure and three data-oriented PPPs in California uncovered 1) factors that enabled PPP adoption, 2) the environmental, socio-economic, and institutional outputs and outcomes of projects, 3) barriers to PPP adoption and development, and 4) best practices of managing partnerships and minimizing distributional impacts. The findings of the research contribute not only to PPP empirical literature on critical success factors and project impacts, but also clarify debates in sustainability, resilience, and new institutionalism literature. A summary of key themes and the theoretical and practical contributions of the research is presented below.

Opportunities and Constraints in the Water Sector

New institutionalism posits that the built environment, formal (regulations) and informal (entrenched norms, value, and ways of doing things) institutions, and public expectations of safe, reliable, and affordable drinking water have constrained available pathways for water management and contributed to sector-wide inertia and risk aversion (Baehler & Bidden, 2018; Barnett et al., 2015; Brown & Farrelly, 2011; Kiparsky et al., 2013; Lach et al., 2005; Rayner et al., 2005). This research confirmed that water utilities are indeed constrained by public expectations, and that these expectations shape water managers' interpretations of sustainability and resilience. While regulatory agencies prioritized a social-ecological system approach, water utilities primarily interpreted resilience and sustainability within the context of reliability (continuous water service at all costs).

This research also highlights the importance of leadership in shaping district culture and creating institutionalized entrenchment (see Brown et al., 2011). Respondents often spoke about General Managers and members of the Board as "agents of change" who "set the tone" for the organization's philosophy. At Moulton Niguel Water District, for example, there is an expectation of "safety, trust, clarity, consistency, and accountability" (Robinson, 2019, para. 4).

> Those are the things that you do day to day. Every level of interaction, from meter reader to the General Manager to the Board members, we instill that in our organization. Culture of service, integrity, respect, all of that. It becomes our way of working and living when we're here (#4)

Leaders are the ones that establish organizational goals and identify the need for additional projects (Noble & Jones, 2006); for water utilities included in this study, these goals are dependent on political context and current socio-economic (e.g. rate of development) and hydrological conditions (climate change). The influence of district culture becomes apparent when comparing the water management between Moulton Niguel and Santa Margarita. The districts are located within a few miles of each other, are 100% reliant on imported water for potable use, and each serve a population of 170,000. Yet, since 2010 MNWD has prioritized a soft water management strategy while SMWD has focused on developing a diverse portfolio of local supplies.

As suggested by respondents, leadership, as well as organizational structure and culture, can play a crucial role in orienting project objectives towards social and ecological dimensions of sustainability (Silvius & Schnipper 2012; Emerson & Nabatchi 2013; Margerum & Robinson 2015). However, when leaders employs a supply-oriented, engineering resilience approach to water management, leadership can contribute to maladaptive solutions that increase system vulnerabilities in the long-run (Chelleri, Waters, et al., 2015; Holling, 1986; Le Maitre & O'Farrell, 2008). These differences organizational culture ultimately underscore the importance of 1) developing tailored, local solutions to water management challenges that 2) align with a mutual understanding of attributes of sustainable and social-ecologically resilient systems (Eriksson et al., 2014; Gonzales & Ajami, 2017; Lawson et al., 2020; Rodina, 2019).

Recognizing and Acting on Windows of Opportunity

This research also contributes to new institutionalism theory by clarifying the debate on drivers of institutional change. While rational-choice scholars and early historical institutionalist posit that change is the result of exogenous shocks (see Harding, 1982; Mahoney, 2000; Ostrom, 1990,), sociological and discursive institutionalists argue that individual actors can also introduce new governance structures, norms, or values that create alternative pathways for institutions (see Powell & DiMaggio, 1991; Schmidt, 2008, 2009, 2010). Despite the mixed results of PPPs throughout the globe (Leighton, 2018), public utilities were able to overcome risk-aversion and adopt an innovative collaborative mechanism through a combination of endogenous and exogenous drivers.

PPP uptake was driven in two waves (see Figure 10.1). The main PPP legislation in California, the Infrastructure Finance Act, was enacted in 1996 and provided a flexible regulatory regime for PPP adoption. The IFA created the legal window of opportunity for private partners, with Poseidon, Cadiz, and Rancho Mission Viejo beginning site evaluations for the PPP projects as early as 1998. The efforts of private partners were buoyed by the supporting political environment during the Schwarzenegger administration (2003 – 2011) and regulatory requirements: in three cases, regulations regarding the management of water-related resources (energy, land-use) mobilized private companies into seeking out public partners.

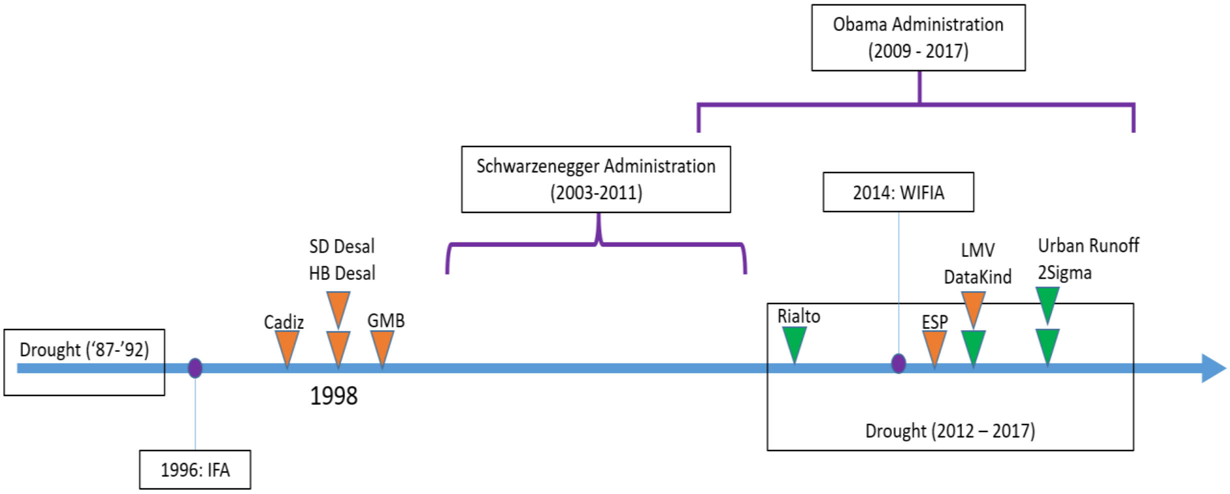

Fig 10.1 Timeline of PPP Initiation/Uptake. The timeline illustrates the point in which public or private partners first initiated projects (e.g. evaluating project fit, identifying potential partners). Orange indicators represents unsolicited proposals. The timeline includes PPP-enabling regulations and supportive PPP political environments as well as major exogenous shocks such as droughts.

Strategic decision-makers at water utilities were motivated to enter into PPPs to overcome funding limitations, bolster technical capacity through knowledge or technology transfer, and to cost-effectiveness and efficiency. Furthermore, the risk allocation structure of PPP projects provided a "unique opportunity" to pursue new types of water projects. By shifting risks of development, operation, and maintenance to private partners, water utilities were able dedicate resources to other critical infrastructure needs and to reduce risks to ratepayers in early stages of the projects. Legitimization of PPPs at the state-level and leaders within public water utilizes created safe spaces for experimentation and innovation. These endogenous and exogenous factors contributed to the first wave of PPP projects (1998 – 2011).

Climate change and droughts (1987 - 1992, 2012 – 2017) served as focusing events for water stakeholders, and further contributed to the recognition that PPPs may be a viable tool in achieving water sector goals. Drought has frequently been identified in the literature as a driver of change (Kiparsky et al., 2013; Pinter et al., 2019) that can resuscitate arguments of supply-driven hard infrastructure approaches (Marshall & Alexandra, 2016). However, drought can also create a new way of thinking and problem solving (Dilling et al., 2019) and lead to innovative governance structures and technological improvements (Pinter et al., 2019). In California, the recent drought led to a rise of sustainability and resilience discourse, which created the demand for strategies that diversify water sources and bolster local supplies; forge connections across sectors, geographical boundaries (e.g. watersheds), and political scales; and utilize real-time data to create tailored and robust policy responses.

The discourse represents a shift in values away from a traditional supply-oriented and hard engineering approach to water management. There is a growing recognition among scientists and practitioners that present-day institutions and governance mechanisms are maladaptive to facing acute (natural disasters) and chronic (unsustainable resource use, climate change) stressors (Johannessen & Wamsler, 2017; Pahl-Wostl, 2008). The sustainability and resilience discourse allowed water stakeholders to re-evaluate present day institutions and water management practices and to introduce new agendas to build adaptive capacity to large-scale shocks and stressors (see Schmidt 2008, 2009, 2010). The 2012 to 2017 drought, thus, contributed to the development of four new PPP projects (LMV and the three data-oriented projects) and created additional momentum for the first wave of PPPs.

The origins of PPPs in California's water sector highlight the unique role of unsolicited proposals (USPs) in developing alternative water system pathways. USPs can introduce new strategies or technologies that public entities did not consider or were unable to implement on their own (PPP Knowledge Lab, 2019). Both OCWD and SDCWA had independently evaluated desalination as a strategy for diversifying their water portfolios prior to partnership formation (see Chapter 5). Poseidon’s USPs, thus, enabled the regional wholesalers to implement technologies ahead of schedule and to minimize risks to ratepayers during project development. Two USPs (Cadiz and the Energy Storage Project), on the other hand, created an alternative water path for water utilities. In interviews, public sector respondents remarked that they may not have pursued these water management strategies without the USP. The rise in USPs have created concerns that corporations will come up with more “reckless” water supply proposals (Cohen, 2019, para 42) to meet the growing demand for local water supplies. It will be imperative to maintain a strict regulatory climate to minimize adverse environmental impacts of potentially maladaptive alternative water management strategies. In all six USPs, public partners took steps to ensure that these unsolicited proposals minimized distributional impacts, including learning about the experiences of other PPP participants, consultations with stakeholders during the Environmental Impact Report process, and evaluation of impacts and value for money calculations. These steps align with best practices outlined by scholars (see Osei-Kyei, Chan, Dansoh, & Ofrori-Kuragu, 2010) and practitioners (see Carter et al., 2017).

PPP Impacts on Sustainability and Resilience

The cases showcase the diverse range of possible contributions of PPPs to the water sector, from informal soft-infrastructure approaches to regional hard infrastructure water supply strategies. Evaluation of socio-economic, environmental, and impacts of cases revealed that PPPs can contribute to both engineering and SES resilience. When carefully managed and designed, projects also have the potential to contribute to holistic sustainability: the data-oriented projects and local-level reclamation and recycling projects (Gobernadora, Lake Mission Viejo AWT Facility, and the Energy Storage project) are economically viable, minimize distributional impacts, and contribute to ecological well-being.

Economic Efficiency vs. Equity

Examination of economic and environmental impacts of PPPs identified two tradeoffs. First, the study confirms that PPPs face a tradeoff between economic efficiency and equity (Dellas, 2012; Koppenjan, 2015; Koppenjan & Enserink, 2009; Taylor & Harman, 2016). Rate increases of projects ranged from $0 and $72.18, representing roughly a 0% to 115% change in water rates (see Table 7.2). The unit cost of water, and thus, the extent of rate increases, was dependent on project challenges, risk premiums, contract structure, the complexity of technology implemented, and project scale. Process tracing revealed three mechanisms – technical and financial capacity of the public partner, shifting environmental regulatory constraints, and environmental permitting – that can exacerbate the tradeoff between economic efficiency and equity.

Public sector respondents stressed the challenge of "getting the best deal" for the public in the face of diverging priorities between public and private actors, information asymmetries, and limited experience in negotiating PPP contracts. A key contribution of this study to PPP literature is the identification of formal (contract structure) and informal (leadership, trust, and relational governance) mechanisms that reduce distributional impacts. These feedback on each other to facilitate partnership formation, minimize moral hazard, and retain project momentum. Informal mechanisms allowed partners to bridge "cultural divides" (see Noble & Rogers, 206), to build rapport and trust, and to identify mutual project goals and benefits (Benítez-Ávila et al., 2018; Kumaraswamy et al., 2015). Contracts provide a blueprint for behavior of participating actors by articulating expectations, goals, and mechanisms for conflict resolution (Benítez-Ávila et al., 2018; Noble & Jones, 2006). Within the seven infrastructure PPP contracts, partners identified mutual goals and benefits, quantified performance-based standards, and provided procedures project re-assessment and termination (GMPB IA, 2014; IRWD DRES, 2014; OCWD & Poseidon, 2018; SMWD/Cadiz MOU, 2011; SMWD/LMVA 2015; WPASA, 2012). Partners also minimized contract lock-in by pursuing “incremental partnerships” (see Leighland, 2018). This proactive approach reduced cost-overruns throughout the project lifetime and ensured long-term commitment to the project (Cruz & Marques, 2013; Demirel et al., 2016; Fridegotto, 2017; House, 2016).

Evolving environmental regulations and the complexity of the permitting process were the primary contributors to project delays and cost overruns in the California cases. For four cases, shifting – or sometimes conflicting - environmental regulations required partners to dedicate additional time and resources to either contest the new policy interpretations or to amend project designs. Moreover, the lack of a centralized permitting agency required project developers to submit permits to multiple local- , state-, and federal- level agencies, each with their own sets of procedures, forms, and timelines (Howard, 2015; Ocasio, 2015; Ulibarri et al, 2017). PPPs may be particularly at risk of experiencing permitting delays due to 1) the political controversy surrounding projects, 2) the presence of a private actor, and 3) and the complexity of technology or the multi-use project (see Ulibarri et al., 2017; Ulibarri & Tao, 2019). Mitigation measures proposed by regulatory agencies may render the projects no longer financially viable. The two PPP desalination cases illustrate the challenges of navigating California’s environmental regulatory regime. While a 150,000 MGD facility has reached commercial operation in Israel for $500 million (see Fikes, 2015), the final cost of the 50 MGD Carlsbad facility is roughly $1 billion. The regional facility resulted in rate increases of roughly $5 dollars per month, or roughly 6% of average rates of Tier 2 water users. Streamlining the permitting process[49]

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[49] The Center for Biological Diversity, for example, was able to dispute the Cadiz project on the grounds of who served as the lead agency for the CEQA process. The Center argued San Bernardino County, not Santa Margarita,

(Howard, 2015; Hewes & Randolph, 2018) and increased collaboration and communication between regulatory agencies and project developers (Ulibarri et al., 2017) can assist in reducing costs and lags for PPP project development.

Rayner et al., (2005) argue that reliability and water quality are "binding constraints" in the water sector – historically, water utilities have strived to minimize cost while ensuring adequate and safe water deliveries. Interviews revealed that responds experienced similar constraints, and tied their decisions heavily to the public's expectation of continuous water service. Evaluations of PPPs focused on unit cost of water, but also the project's ability to diversify water supplies, create emergency supplies, increase O&M efficiency, and transfer skills or technology to the public sector. Public sector project participants were ultimately willing to accept increased project costs to meet the broader sustainability and resilience goals of their utility.

The long-term nature of PPPs creates the risk of "lock-in" to contract structures that pass costs along to the public (Hodge & Greve, 2007; Hughes, 2017; Koppenjan, 2015). The $177 million Rialto PPP, for example, included $30 million in upfront payment to invest in redevelopment of Rialto airport, $27 million to refinance the city debt, and $30 million for catch up lease payment (Table Rock Infrastructure, 2015). These upfront payments increased the financial solvency of the Rialto water district and created more than 5,000 permanent jobs in the city (Jensen, 2012; Table Rock Infrastructure, 2015). However, Lobina (2014) and other critics of the contract structure argue that these costs are borne by ratepayers in the long-term (Hughes, 2017; Lambert, 2013). Per the contract agreement, the public partner must increase by 115% to

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should have led the environmental impact review because this is where groundwater basin under review resides (Rothman, 2016). CEQA policies may have to be updated to account for PPP cases that include multiple public partners.

guarantee a return on investment for the project. The Rialto case ultimately demonstrates the challenges of securing financing when technical and financial capacity of the public partner is low.

The differences in outputs and outcomes across the Rialto case and the other projects illuminates that the tradeoff between equity and economic efficiency can also occur at a broader scale. In PPP arrangements, the private sector selects and participates in projects that have the highest likelihood of being profitable (Abdel Aziz & Nabavi, 2014). Across the case sites, to ensure returns to investment, the private sector approached public partners with high technical and financial capacity. SMWD, SDCWA, IRWD, OCWD, and MNWD are all urban, middle-income to upper-middle income utilities with AA or AAA ratings. Yet, rural and low income communities are the ones that currently lack the technical and financial capacity to implement resilient solutions on their own (Ekstrom et al., 2018) and would benefit the most from leveraging private sector expertise and funding. This pattern of uneven economic development (see Siemiatycki, 2011) mirrors global PPP activity. Around the world, PPPs are “supply-driven” (Schaferhoff et al., 2009, p. 456): despite the demand for infrastructure in low-income regions, the majority of PPP projects are implemented in upper-middle countries (Andonova & Levy, 2003; Hoering, 2003; Nizkorodov; 2017). This gap between supply and demand is more pronounced in the water sector than other sectors (Nizkorodov, 2017) and stems from the unique characteristics of the sector. While the sector has a low profit margin (Albalate et al., 2013; Ameyaw & Chan, 2013, 2015), there are often high costs to extending service to poor and/or rural areas (Albalate et al., 2013; Dellas, 2012). Rural locations are often difficult to access, have ambiguous property rights, and cannot afford the full cost of services without additional subsidies (Loxley, 2013).

In their current form, PPPs may deepen inequality at a regional and a state level by providing water infrastructure upgrades and new sources of supply in middle- and upper-middle income regions while leaving "riskier" or less profitable upgrades to public agencies. Advancing equitable adaptation will require providing additional levels of assistance to drinking water managers and systems in rural and low-income settings (Ekstrom et al., 2018). Increasing adaptive capacity of low-income and rural utilities while minimizing distributional impacts will require establishing novel, flexible cross-sector partnership arrangements (such as the EPA's community-based PPP arrangement) and increasing low-interest state- and federal- funding sources (e.g. WIFIA).

Sustainability vs. Resilience

A review of sustainability and resilience literature revealed that scholars link the two concepts in diverging ways (Lew et al., 2015; Marchese et al., 2018; Roostaie et al., 2019). Scholars have described resilience as a component of sustainability, sustainability as a component of resilience, and sustainability and resilience as two independent concepts. There is rising concern that this definitional imprecision has rendered the concepts as buzzwords (Lew et al., 2015; Smith, 2012) that hinder scientific progress (Brand & Jax, 2007) and limit practical application to development (Davidson et al., 2019). The challenges of operationalizing resilience have created uncertainty in how the water sector must adapt or transform to withstand different hydrological futures (Rodina, 2019).

Definitions of sustainability and resilience are political choices rather than technical ones (Dewulf et al., 2019). Failure to define resilience "of what," "at what scale," and "for whom" can obscure impacts of resilient-oriented policies to marginalized groups and ecological systems (Dewulf et al., 2019; Meerow et al., 2019; Porter & Davoudi, 2012; Vale, 2014). These impacts can have tradeoffs across temporal and geographical scales that increase social and ecological system vulnerabilities (Krueger et al., 2020). Only a handful of articles have directly examined the tradeoffs between sustainability and resilience strategies (see Chelleri, Waters, et al., 2015; Kythreotis & Bristow, 2016). No studies have examined these tradeoffs within the context of water management and infrastructure (Rodina, 2019). This research addressed a critical literature gap by examining the interdependencies and tradeoffs between sustainability and resilience.

Evaluation of PPP impacts suggest that gains in short-term resilience can occur at the expense of distributional impacts to low-income water users (e.g. Rialto) or to ecosystems (e.g. Cadiz). Conversely, increasing social-ecological system resilience will contribute to long-term system sustainability. Environmental groups have identified potential adverse environmental impacts of three infrastructure projects: Cadiz, the HB Desalination Plant, and the Carlsbad desalination plant. All three PPPs are supply-oriented, regional strategies that provide substantial "drought-proof" gains to local water portfolios (SMWD, n.d.-e, para 3; Weston, 2016b): The projects can provide roughly 20% of SMWD's (SMWD, n.d.-d), 8 to 10% of SDCWA's, and 18% of OCWD's water needs (Wisckol, 2019). The ecological impacts of these PPPs must be carefully monitored, as these reliability and water supply gains may result in irreversible damages to aquatic and desert ecosystems.

These supply-oriented, short-term gains in water reliability can provide a buffer for systems to adapt to large-scale anthropogenic stressors such as climate change (Foudi, 2014). Hard infrastructure approaches can also provide public and policy-makers with the security (and perceived reliability) to pursue alternative water solutions (Feldman, 2018). However, achieving socio-technical systems that can withstand multiple hydrological futures will require moving from engineering resilience to social-ecological resilience approaches (Eriksson et al., 2014;

Lawson et al., 2020; Mao et al., 2017; Vale, 2014). The cases reveal that considerations of ecological well-being requires significant intervention on behalf of the regulatory regime (Koppenjan 2015; Patil et al. 2016; Taylor & Harman, 2016). Hueskes et al. (2015) suggest that historically, public partners have provided a low emphasis on environmental or social justice considerations in project and partner selection. At case sites, environmental sensitivity and consideration of ecological impacts was dependent on the organizational leadership of utilities. NGOs may play a critical role in future PPPs by increasing environmental sensitivity of projects, monitoring adverse environmental impacts, and serving as "bridges" between regulatory agencies and water utilities.

Inclusion of diverse stakeholders throughout the project lifetime can ensure projects minimize distributional and ecological impacts and align with community needs (Kumaraswamy et al., 2015; Marana et al., 2018). This participatory element may be particularly important in low-income regions. Failure to gauge willingness to pay of water users, ensure infrastructure aligns with technical capacity of local operators, or assuage concerns surrounding private sector privatization can result in projects that are financially not viable (Bond, 2010; Hall et al., 2005; Loxley, 2013), exclude low-income water users (Dellas, 2012) or are maladaptive in the long-term (Mert & Dellas, 2012). In the California cases, only two infrastructure projects provided opportunities for civic society to provide feedback on the project structure and PPP terms of agreement. Community engagement focused on securing buy-in from the public and NGOs, thus potentially reinforcing technocratic values towards resilience and sustainability (see Rodina, 2019). Civic society utilized "voice" primarily through project opposition, ultimately contributing to project delays and increased costs. Yet, the responsibility of gaining community buy-in of infrastructure PPPs was predominantly shifted to the private partner. Future PPP participants must carefully how to include diverse stakeholders throughout the project life-time and how to allocate risks of community buy-in.

"Opening the Door" for future PPP Projects

Projects have also altered the informal institutions of participating public agencies. The innovative outputs and perceived success of the PPP projects increased staff buy-in to future collaboration. The success of the projects also encouraged project participants to share the PPP lessons learned and outcomes with other water stakeholders by providing open-source code, leading public tours of facilities, presenting at conferences, and publishing journal articles and media articles. Disseminating findings across networks can increase opportunities for social learning (Deslatte et al., 2017; Gunderson et al., 2006; Pahl-Wostl, 2008) and can legitimize norms and practices, thus reducing reputational and technical risks of adopting innovative strategies (Kiparsky et al., 2013). Observation events (3/15/2019) and media articles (see Onyeneho, n.d.; Walton, 2019) suggest that the infrastructural and data-oriented strategies developed in the PPP projects are slowly being implemented in other locations in California.

Uptake of PPPs will depend on the technical and financial capacity of public agencies (Kiparsky et al., 2013), the degree to which water utilities are embedded in water networks (Lawson et al., 2002), and organizational leaders' ability to recognize projects that are well-suited for a PPP structure. This research – and the work of other practitioners and scholars – has showcased the challenges of evaluating value for money across long-time horizons (Leighton, 2018): the future unit cost of water at case sites is dependent on future regulatory curtailments, climate change effects, and uncertainty surrounding MWD and electricity costs. A recent survey of American Water Works Association members suggests that stakeholders are skeptical of a PPP approach to water management (AWWA & EY, 2019). AWWA members could only envision a PPP approach for large-scale, technically complex projects in which parties will benefit by shifting risks to the private partner. Moreover, survey respondents were more likely to favor reclamation projects that complemented, rather than, replaced service provision. Project participants at case sites identified PPPs as effective solutions for economies of scale, as costs can be distributed amongst ratepayers and reduce distributional impact (#5; #11). Respondents also identified stormwater capture, land-use mitigation efforts, reclamation and recycling, biosolid extraction, and data-analysis as areas where the private sector could contribute meaningfully to addressing pressing water challenges (#1; #5; #11; #12; #14). While water quality treatment was not identified by respondents as a potential pathway for PPPs, the private sector may be instrumental in overcoming the technical and financial constraints of PFAS treatment and detection.

10.1 Study Limitations and Generalizability

A challenge in studying public-private partnerships is access (Valente, 2010). Interview, observation, shadowing, and access to internal documents was highly dependent on the rapport established with key informants and points of contact at each case site. An additional challenge that may have impacted the quality and depth of data at each case site was the external and internal pressure for the project to succeed. As future revenue and grant funding opportunities depend on the perceived success of projects and the reputations of project partners, some respondents were reluctant to disclose project challenges, particularly those focused on collaboration between partners or the role of state-level legislature in influencing local water policy decisions. Private partners, in particular, were reticent to participate in interviews. As a result of these constraints, there is a greater proportion of public rather than private respondents participating in the interview process. The small number of interview respondents (21 respondents across 26 interviews) can limit the generalizability of the study. This research has overcome these limitations through the triangulation of data through three additional qualitative methods

Generalizability is also limited by the unique socio-economic, political, and infrastructural context of the cases and of California's water system. California's water management system is multi-layered, with local, regional, state, and federal agencies and policies managing various portions of the water cycle (Pinter et al., 2019). The state's water system, economy, and robust environmental regulation has evolved over a 170 year time-span and has undergone multiple stages of water system transformation (see Hanak et al., 2011; Hundley, 2001). A path dependency approach suggests that institutions enabling and governing PPPs will differ in each country due to each region's socio-technical constraints and past decisions made by key stakeholders. Ultimately, PPP outcomes and processes will not be the same in each country (Matos-Castaño et al., 2014; Mu et al., 2011; Skelcher, 2010).

The first wave of PPPs was primarily implemented in regions with high technical and financial capacity. Only one case, the Rialto infrastructure upgrades, represents an application of a PPP to a low-income region with a high proportion of traditionally marginalized populations. Regions that would be able to replicate these gains to sustainability and resilience would need to have broad PPP enabling frameworks, robust environmental regulations, a developed water system, and the capacity to implement formal and informal mechanisms for partnership development, management, and monitoring.

Despite these limitations in generalizability, this study uncovers broader lessons that can aid practitioners across the globe:

(1) PPP projects do not materialize overnight, but instead require a number of socio-technical conditions (political will, robust regulatory regimes, project and partner fit) to create windows of opportunity.
(2) PPPs are not simply “free money” or a “mega-credit cards” (see Hodge & Greve, 2004, 2007), but require significant dedication of resources and time to formal and informal mechanisms that enable partnership formation and maintenance (van der Hurk, 2018). To avoid overestimating value for money of projects, public agencies must include transaction costs in their PPP budgets (Leighton, 2018).
(3) PPPs can provide significant gains in efficiency, capacity, and service provision of public utilities. However, given the tradeoffs between equity and economic efficiency, PPPs may not always be an appropriate mechanism for development (Dellas, 2012; Hewes & Randolph, 2018; Hughes, 2017). Projects must be tailored to meet the needs, capacities, and willingness-to-pay of local communities (Mert & Dellas, 2012).
(4) Regardless of the vehicle of infrastructure delivery, project evaluations must account for social and ecological tradeoffs across temporal and geographic scales. Gains in resilience at the expense of ecological well-being or marginalized populations is not sustainable and will be maladaptive in the long-term (Vale, 2014).

10.2 Future Research

The PPPs in this study have only recently been adopted by water managers. A longitudinal perspective on project evaluation will ultimately refine best practices and narrow the conditions under which a PPP is the most efficient and effective arrangement in improving financial viability and social welfare. Additionally, it is important to examine the long-term effects of PPP projects on institutional capacity. What kind of institutional and water system transformation are P3s enabling? Surveys of water managers in the U.S. water sector has revealed that utilities are concerned that shifting water management responsibility to the private sector could weaken the capacity of public sector in the long term:

> P3s can lead to the municipality or other owner becoming ‘ignorant’ to the actual process of producing water/cleaning wastewater, and becoming nothing more than an administration identifying who they are paying for the production of the items being sold — potentially and eventually leading to the privatization of all utilities, which may lead to big problems when truly considered. (AWWA & EY, 2019, p.11)

While this study examined PPP outputs and outcomes, a long-term analysis of the role of PPPs in altering institutional roles and capacity is needed.

Future research must also pay closer attention to institutional mechanisms and norms underlying PPP adoption and development. This study uncovered that the role of leadership can promote innovation and experimentation in a sector that is highly risk-averse (Lach et al., 2005; Rayner et al., 2011; Farrelly & Brown, 2011; Kiparsky et al., 2013). Leaders such as General Managers, project managers, and boards of directors can influence the culture of water utilities, create safe spaces and serve as “buffer” for risk, and incentivize collaboration within and across sectors. While the role of leadership has been extensively studied in management literature, few studies have conducted analyses of how leaders can directly influence PPP project impacts (see Noble & Jones, 2006 and Som et al., 2020 for exceptions) Future research should closely examine the role of individual actors within water policy networks and how they shape local and state-level drivers for collaborative governance.

An interesting finding raised during interviews was that the distribution of risks for innovative technologies might shift in the future (#14). PPP projects are “relatively rare” in California (Douglass & Sykes, 2013, p. 3), especially in the water sector. Private partners such as Poseidon and AMS are entering into new markets in California, and thus, may bear an inefficient allocation of risks to entice public water agencies to enter into unsolicited partnerships (Finley, 2015). Future studies should also examine changes in bargaining power and risk allocation between partners as technologies become more established within a particular market.

10.3 Concluding Remarks

Since the early 1990s, an aggressive top-down push from organizations such as the World Bank, United Nations, and the International Monetary Fund have propagated PPPs as a vehicle of growth to both developed and developing countries alike. Enticed by the promises of increased efficiency, lower project costs, and a reduction of budgetary pressure (Hodge & Greve 2007), federal and local governments have embraced this phenomenon with little consideration of its long-term political, environmental, and distributional effects. Yet, findings and evaluations of PPPs over the last thirty years have been inconclusive at best (Leighton, 2018). Academic discourse around public-private partnerships has been largely divided (Hodge & Greve 2010; Leighton, 2018), with critics rejecting the management approach outright and proponents touting PPPs as a developmental panacea that overcomes the inefficiencies of public management. In the field, “balanced discussion is rare” (Hodge & Greve 2010, p. 9).

This research suggests that when carefully evaluated and managed, PPPs may provide the key to future growth and development by injecting innovation, funding, and technological capacity into infrastructure systems. The collaborative nature of this method can allow public partners to tackle “wicked” problems through the joint production of knowledge, pooling of resources, and the effective allocation of risks. However, public managers seeking to adopt PPPs as a development approach must understand that PPPs are not merely a tool to raise finance for infrastructure provision, but are long-term collaborations that require significant investment of time and resources (Dormois et al., 2005; Matos-Castano et al., 2014). Partnerships should be built with care, and must be tailored to geographic scale and the region’s specific environmental, economic, social, institutional limitations. Risks must be carefully assigned on a project-by-project basis, as resources, capacity of partners, and regulatory structures may differ in each partnership (Ng & Loosemore, 2007). Finally, water agencies must carefully weigh project fit, distributional impacts, and environmental benefits and harms of proposed PPP projects prior to “locking in” to contract agreements. Failure to carefully consider these factors may ultimately reduce long-term system resilience and sustainability by burdening cities and water districts with maladaptive water management strategies.

APPENDIX

Type of PPI	Definition
Management and Lease	***Private operator manages state-owned enterprise (SOE) for a fixed period of time. Ownership and investment decisions remain with public partner.***
Management Contract	The public partner pays private operator to manage a facility
Lease Contract	The public partner leases the assets to the private operator
Concessions	***Private partner manages state-owned enterprise for a fixed period of time and absorbs majority of investment risk.***
Rehabilitate, Operate, Transfer (ROT)	Private sponsor rehabilitates existing facility, then operates until end of contract period
Rehabilitate, Lease, Transfer (RLT)	Private sponsor rehabilitates public facility, leases it from public partner, and operates it until the end of the contract period,
Build, Rehabilitate, Operate, Transfer (BROT)	A private developer builds an add-on to an existing facility or rehabilitates existing assets and operates it until the end of the contract period
Greenfields Projects	***Private entity or a public-private venture builds and operates a new facility. Depending on the contract structure, the facility may be transferred back to the public sector at the end of the contract duration***
Build, Lease, Transfer (BLT)	Private sponsor builds a new facility, transfers ownership to public partner, and then leases the facility from the government
Build, Operate, Transfer (BOT)	Private sponsor builds a new facility, then owns and operates the facility throughout contract period. The facility is transferred to the public partner at the end of the contract period.
Build, Own, Operate (BOO)	Private sponsor builds new facility, then owns and operates the facility.
Merchant	Private sponsor builds a new facility. Unlike BLT, BOT, BOO, government provides no revenue guarantees.
Rental	Governments rent mobile power plants from private partners for a short period of time (1-15 years). Private sponsor places the facility at its own risk. Government compensates for risk by providing revenue guarantees.
Divestitures	***Private partner buys stock in state-owned enterprise through asset sail, public offering, or mass privatization program***
Partial	Public partner transfers part of equity to private partner. Private stake in facility management is determined on a case-by-case basis

Table A1 Definitions of types and sub-types of Private Participation in Ifnrastructure (PPI). Adapted from World Bank PPI Database Glossary (2016)

Case Site	**Year**	**Award Title**	**Agency**
Gobernadora Multipurpose Basin	2015	Best of the Best Special Recognition for Sustainability Contributions	Urban Land Institute (ULI)
	2015	Award for Sustainable and Green Development	Orange County Business Council
	2015	Water Project of the Year Award	American Society of Civil Engineers
	2015	Certificate of Recognition	California Legislature
Lake Mission Viejo	2018	Innovative PPP award	Green Technology
	2019	Clair A. Hill Water Agency Award for Excellence	Association of California Water Agencies (ACWA)
Energy Storage Project	2018	Best Public Private Partnership Award	OC Business Council
	2018	Golden Hub of Innovation	Association of California Cities - Orange County (ACC - OC)
Cadiz		Top 10 Private Investment in Infrastructure Project	BluePrint 2025
Carlsbad Desalination	2019	Award for Engineering Excellence	American Council of Engineering Companies (ACEC)
	2017	Membrane Facility of the Year	American Membrane Technology Association AMTA)
	2017	Grand Award for Engineering Excellence	American Council of Engineering Companies (ACEC)
	2017	Claire Hill Award for Excellence	Association of California Water Agencies (ACWA)
	2016	International Desalination Plant of the Year	Global Water Intelligence (GWI)
	2016	Design-Build Project of the Year	Design-Build Institute of America
	2016	Energy Champion	Sempra Energy
	2013	Deal of the Year of the Far West Region	The Bond Buyer
	2012	Global Desalination Deal of the Year	Global Water Intelligence (GWI)
	2012	North American Infrastructure Deal of the Year	Infrastructure Investor Magazine
	2012	Largest U.S. Project Financing Deal	Bloomberg News
	2012	North American Water Deal of the Year	Project Finance
DataKind	2017	Golden Hub of Innovation	Association of California Cities - Orange County (ACC - OC)
	2018	Impact Award	WaterNow Alliance
2 Sigma	2018	Governor’s Environmental and Economic Leadership Award	CalEPA

Table A2: Awards and Accolades presented to project participants for PPP projects

	Tiong (1996)	Gupta & Narasimhan (1998)	Qioa *et al.* (2001)	Jefferies *et al.* (2002)	Askar & Gab-allah (2002)	Jamali (2004)	Li *et al.* (2005)	Zhang (2005)	Jefferies (2006)	Chen & Doloi (2008)	Tsitsifli & Kanakoudis (2008)	Chen (2009)	Chan *et al.* (2010)	Dulaimi *et al.* (2010)	Meng, Zhao, & Shen (2011)	Babatunde *et al.* (2012)	Cheung *et al.* (2012)	Hwang, Zhao, Gay (2012)	Zhao *et al.* (2013)	Ismail (2013)	Ameyaw & Chan (2014)	Osei-Kyei & Chan (2015)	Osei-Kyei & Chan (2016)	Pinz *et al.* (2017)	**Total**
Economic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sound financial package	X	X	X	X	X			X								X	4				2		X	X	**11**
Stable Economic Conditions			X				X						X	X		X				X				X	**7**
Acceptable Toll/Tariff Levels	X		X							X	X			X											**5**
Appropriate Risk Allocation							X	X		X	X	X	X		X	X	5	2		X	13	1		X	**14**
Competitive Procurement Process					X		X		X	X	X		X		X	X		4			11	5			**11**
Available Financial Market				X			X	X											X	X					**5**
Project Profitability	X							X							X				X		12		X	X	**7**
Low Barriers to Entry										X															**1**
Low Start-up Cost										X															**1**
Technical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Short Construction Period		X																							**1**
Technical expertise of consortium	X	X	X	X	X	X	X	X			X			X			3	3	X		4	2	X		**16**
Appropriate Project Identification	X		X	X			X		X						X	X			X						**8**
Technology Transfer			X									X													**2**
Training Public Personnel		X																			9			X	**3**
Local Knowledge and Expertise											X										10				**2**
Use of Professional Advisors															X										**1**
Political	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stable Political Support/Commitment			X	X		X	X			X	X		X	X		X			X	X	1	3	X	X	**15**
Efficient Approval Process				X					X			X													**3**
Strong Legislation & Regulatory Systems				X			X			X	X		X			X	1	6	X	X	5			X	**12**
Strong and Capable Public Partner									X									1			6				**3**
National PPP Policy & Supporting Unit																					7				**1**
High Degree of Internal Coordination																					14				**1**
Social	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clear project goals									X															X	**2**
Entrepreneurship and Leadership	X																								**1**
Partner Commitment	X		X			X						X					2				8			X	**7**
Public Support		X		X			X				X		X						X		3	4	X	X	**10**
Openness and Communication						X																	X	X	**3**
Trust				X		X																		X	**3**
Shared authority							X					X					5	7						X	**5**
Compatibility					X			X																	**2**
Environmental Impact	X																		X						**2**
Total	**9**	**5**	**8**	**9**	**4**	**6**	**10**	**6**	**5**	**7**	**8**	**5**	**6**	**4**	**5**	**7**	**5**	**7**	**8**	**5**	**14**	**5**	**5**	**12**	-

Table A3: Critical success factors of infrastructural public-private partnerships identified in 24 peer-reviewed studies. In total, authors identified 165 CSFs across economic, political, social, and environmental impact categories. Studies that directly focus on water PPPs are in blue, whereas studies that incorporate sustainability-oriented PPPs are in green. (adapted from Nizkorodov, 2017)

	#1	#2	#3	#4	#5	#6	#7/ #8	#9	#10	#11	#12	#13	#14	#15	#16	#17	#18	#19	#20	#21	Obs. 8/30/18	Obs. 3/15/19	Obs. 8/29/19	Obs. 11/26/19	Shadow 2/27/29	Shadow 3/15/19	Shadow 4/26/19	Shadow 12/18/19	**Total**
Be open to opportunities diverse perspectives			X	X		X			X			X			X														**6**
Ensure partner fit	X				X		X			X		X	X						X										**8**
Complementary skills and resources										X		X																	**2**
Long-term commitment					X					X																	X		**3**
Ensure project fit	X			X	X			X		X	X		X									X			X	X	X	X	**12**
Financial Viability/Project Profitability					X					X			X			X									X		X		**6**
Conduct independent analysis of BAT and anticipated outcomes										X					X						X								**3**
Trust and rapport between partners										X		X				X			X								X		**5**
Identify mutual benefits and project goals	X				X				X	X	X	X	X		X				X	X					X		X	X	**13**
Understand your and your partner's needs															X				X										**2**
Include End-Users and Affected Stakeholders							X	X		X						X					X	X	X			X	X		**10**
Provide training to staff and personnel										X												X					X		**3**
Include "bridges" and "translators" to facilitate communication across sectors								X																		X			**2**
Consitent and transparent communication between partners		X					X	X			X													X					**6**
Establish points of contact for each parnter							X	X		X																			**4**
Learn about outcomes/lessons learned from others who have participated in PPPs				X	X					X				X	X	X				X			X						**8**
Hire technical and legal expertise																X			X	X			X						**4**
Robust constract structure										X		X	X				X			X				X			X		**7**
Include clauses that protect public partner										X		X								X							X		**4**
Establish clear roles for each actor													X							X				X					**3**
Efficient risk allocation																	X												**1**
Include flexibility throughout process										X	X																		**2**
Secure grant and loan funding										X						X			X	X		X							**5**
Presence of Strong Leaders	X	X		X	X	X		X		X	X			X					X				X						**11**
Robust procurement process																X													**1**
Staff Buy-in									X	X														X					**3**

Table A4: Best practices of PPP projects, as identified by respondents in semi-structured interviews (#1-#21), observations, and shadowing/tours of case sites. Best practices in green are those that were identified across 20% interviews and field notes.

Sample Interview Guide

Thank you for participating in this study. This research aims to examine is two-fold: to examine the process of PPP formation and the impact of PPPs.

With your permission, I would like to record the interview for my records. Interview responses will be anonymous and will not be shared with anyone. If it any point you wish to stop the recording or to stop the interview process, please let me know and we will do so.

Background Knowledge on Respondent

1. Tell me a little bit about your role in the project.
    a. How did you become involved in this project?
    b. When did you become involved?
2. How would you define a PPP?
    a. What is your previous experience with PPPs?

Partnership Formation / Procurement Process

3. Why was there a need for this project?
4. How did you decide on who to partner with?
    a. [if competitive bidding takes place] What award criteria did you use to select the project partner?
    b. [if unsolicited proposal] Who approached whom in the partnership?
5. Did you have any reservations about partnering with FIRM/PARTNER?
6. What were your goals for the project?
7. What were your partner's goals?

Negotiation and Partner Inputs

8. What are the terms of the contract?
    a. What do you gain out of the project?
    b. What does your partner gain out of the project?
9. How did you agree on partner roles and responsibilities?
    a. What is your AGENCY’s role in the project?
    b. What is your PARTNER’s role?
    c. Have these responsibilities changed over time?
10. Who else participated in the project?
    a. What was the role of these additional actors/non-partners?

Project Design

11. Walk me through how you and your partners designed all of the elements of project.
    a. What factors were important to consider during the project design?
12. Who was consulted during the design phase of the project?
    a. How was this feedback integrated?
13. What were the anticipated project costs?
    a. What were the final project costs?
    b. How were these costs shared between partners?
    c. What opportunities were there for additional funding sources?

Project Implementation

14. Walk me through the process of implementation.
    a. What went well?
    b. What challenges did you experience?
    c. How were these challenges addressed?
15. Did any parts of the project need to re-negotiated?
    a. Walk me through the process of re-negotiation.

Operation and Management

16. How is the facility operating?
    a. What is going well?
    b. What challenges have the O&M staff experienced, if any?
17. What are the total operating costs?

Public Engagement [social dimension]

18. How did you share information about the project with the public?
    a. What information was shared?
    b. What opportunities did individuals have to provide feedback regarding the project?
    c. What ideas, if any, were incorporated into the project design or implementation?
    d. Was there any opposition to the project?
    e. How was that opposition resolved?
19. How did you share information about the project with policy-makers/water managers?

PPP Impacts and Success

20. How did this project impact the community?
    a. *[Social dimension]* – How has this project impacted water or tax-payer rates?
    b. *[Environmental dimension]* What are the environmental benefits of the project?
    c. *[Environmental dimension]* Are there any potential environmental harms?
21. How did this project impact your water district?
22. What elements of this collaboration were successful? [if not covered earlier]
23. What elements of this collaboration could be improved? [if not covered earlier]

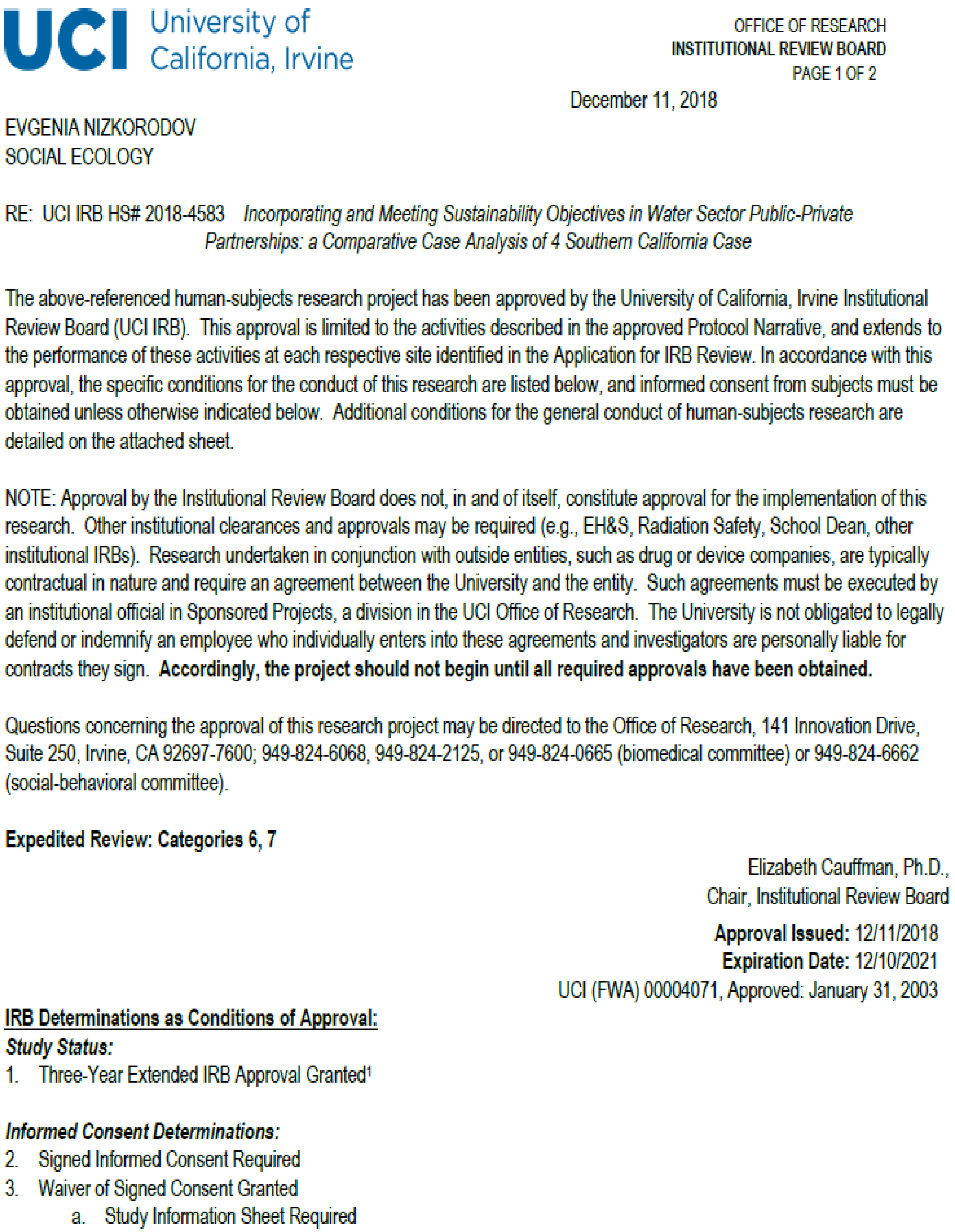
Lessons Learned and Best Practices

24. What was your perception of PPPs prior to this project?
    a. Has this viewpoint changed after completing the project?
    b. Would you enter into another partnership, if the opportunity came up?
25. What have you learned from this project?
26. What advice would you give to someone who is interested in entering into a PPP?

Broader Context

27. What challenges is your water district facing currently and in the future?
    a. How does your water district plan to address these challenges?
28. What role do you see PPPs playing in addressing these challenges?

Institutional Review Board – Study Approval Letter



UCI University of California, Irvine

OFFICE OF RESEARCH
INSTITUTIONAL REVIEW BOARD
PAGE 1 OF 2

December 11, 2018

EVGENIA NIZKORODOV
SOCIAL ECOLOGY

RE: UCI IRB HS# 2018-4583 *Incorporating and Meeting Sustainability Objectives in Water Sector Public-Private Partnerships: a Comparative Case Analysis of 4 Southern California Case*

The above-referenced human-subjects research project has been approved by the University of California, Irvine Institutional Review Board (UCI IRB). This approval is limited to the activities described in the approved Protocol Narrative, and extends to the performance of these activities at each respective site identified in the Application for IRB Review. In accordance with this approval, the specific conditions for the conduct of this research are listed below, and informed consent from subjects must be obtained unless otherwise indicated below. Additional conditions for the general conduct of human-subjects research are detailed on the attached sheet.

NOTE: Approval by the Institutional Review Board does not, in and of itself, constitute approval for the implementation of this research. Other institutional clearances and approvals may be required (e.g., EH&S, Radiation Safety, School Dean, other institutional IRBs). Research undertaken in conjunction with outside entities, such as drug or device companies, are typically contractual in nature and require an agreement between the University and the entity. Such agreements must be executed by an institutional official in Sponsored Projects, a division in the UCI Office of Research. The University is not obligated to legally defend or indemnify an employee who individually enters into these agreements and investigators are personally liable for contracts they sign. **Accordingly, the project should not begin until all required approvals have been obtained.**

Questions concerning the approval of this research project may be directed to the Office of Research, 141 Innovation Drive, Suite 250, Irvine, CA 92697-7600; 949-824-6068, 949-824-2125, or 949-824-0665 (biomedical committee) or 949-824-6662 (social-behavioral committee).

Expedited Review: Categories 6, 7

Elizabeth Cauffman, Ph.D.,
Chair, Institutional Review Board

Approval Issued: 12/11/2018
Expiration Date: 12/10/2021
UCI (FWA) 00004071, Approved: January 31, 2003

IRB Determinations as Conditions of Approval:

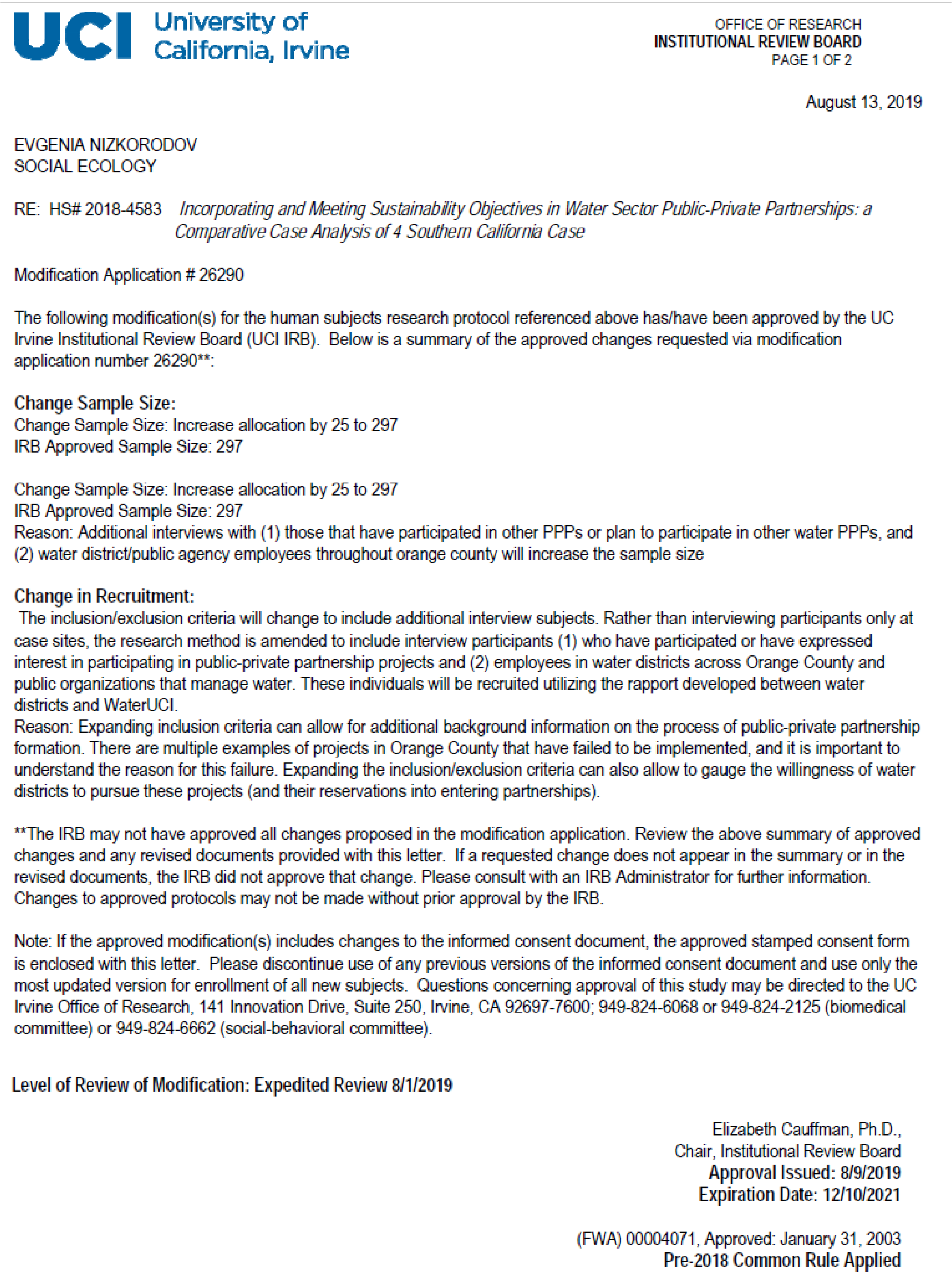
Study Status:

1. Three-Year Extended IRB Approval Granted[1]

Informed Consent Determinations:

2. Signed Informed Consent Required
3. Waiver of Signed Consent Granted
    a. Study Information Sheet Required

Institutional Review Board - Approval of Study Modifications



UCI University of California, Irvine

OFFICE OF RESEARCH
INSTITUTIONAL REVIEW BOARD
PAGE 1 OF 2

August 13, 2019

EVGENIA NIZKORODOV
SOCIAL ECOLOGY

RE: HS# 2018-4583 *Incorporating and Meeting Sustainability Objectives in Water Sector Public-Private Partnerships: a Comparative Case Analysis of 4 Southern California Case*

Modification Application # 26290

The following modification(s) for the human subjects research protocol referenced above has/have been approved by the UC Irvine Institutional Review Board (UCI IRB). Below is a summary of the approved changes requested via modification application number 26290**:

Change Sample Size:
Change Sample Size: Increase allocation by 25 to 297
IRB Approved Sample Size: 297

Change Sample Size: Increase allocation by 25 to 297
IRB Approved Sample Size: 297
Reason: Additional interviews with (1) those that have participated in other PPPs or plan to participate in other water PPPs, and (2) water district/public agency employees throughout orange county will increase the sample size

Change in Recruitment:
The inclusion/exclusion criteria will change to include additional interview subjects. Rather than interviewing participants only at case sites, the research method is amended to include interview participants (1) who have participated or have expressed interest in participating in public-private partnership projects and (2) employees in water districts across Orange County and public organizations that manage water. These individuals will be recruited utilizing the rapport developed between water districts and WaterUCI.
Reason: Expanding inclusion criteria can allow for additional background information on the process of public-private partnership formation. There are multiple examples of projects in Orange County that have failed to be implemented, and it is important to understand the reason for this failure. Expanding the inclusion/exclusion criteria can also allow to gauge the willingness of water districts to pursue these projects (and their reservations into entering partnerships).

**The IRB may not have approved all changes proposed in the modification application. Review the above summary of approved changes and any revised documents provided with this letter. If a requested change does not appear in the summary or in the revised documents, the IRB did not approve that change. Please consult with an IRB Administrator for further information. Changes to approved protocols may not be made without prior approval by the IRB.

Note: If the approved modification(s) includes changes to the informed consent document, the approved stamped consent form is enclosed with this letter. Please discontinue use of any previous versions of the informed consent document and use only the most updated version for enrollment of all new subjects. Questions concerning approval of this study may be directed to the UC Irvine Office of Research, 141 Innovation Drive, Suite 250, Irvine, CA 92697-7600; 949-824-6068 or 949-824-2125 (biomedical committee) or 949-824-6662 (social-behavioral committee).

Level of Review of Modification: Expedited Review 8/1/2019

Elizabeth Cauffman, Ph.D.,
Chair, Institutional Review Board
Approval Issued: 8/9/2019
Expiration Date: 12/10/2021

(FWA) 00004071, Approved: January 31, 2003
Pre-2018 Common Rule Applied

WORKS CITED

Abbaszadeh, N. (2018, February 6). Letter to the Honorable Mayor and Council Members regarding the Memorandum of Understanding with Moulton Niguel Water District for Collaborative Effort to Improve Surface Water Quality.

Adamala, S. (2017). An overview of big data applications in water resources engineering. *Machine Learning Research*, *2*(1), 10-18.

Adams, A. & Cox, A.L. (2008). Questionnaires, in-depth interviews, and focus groups. In Cairns, Paul and Cox, Anna L. (eds.), *Research Methods for Human Computer Interaction*. Cambridge, UK: Cambridge University Press, pp. 17–34.

Adjarian, F. (2017). Water Infrastructure: California's Aging Lifeline. *Water UCI Colloquium Series*. May 17, 2017. Irvine, CA: University of California Irvine.

Ajami, N.K. (2018). A 21st Century Financing Framework to Support Water Sector Paradigm Shift. *Water UCI/UCI Sustainability Colloquium Series*. January 24, 2018. Irvine, CA: University of California Irvine.

Ajami, N.K. (2012). *Comments on the Cadiz Conservation, Recovery, and Storage Project draft Environmental Impact Report*. Oakland, CA: Pacific Institute.

Ajami, N.K., Thompson Jr., B.H., Victor, D.G. (2014). *The path to water innovation*. The Brookings Institution: Washington, DC

Albalate, D., Bel, G., & Geddes, R. R. (2013). Recovery Risk and Labor Costs in Public–Private Partnerships: Contractual Choice in the US Water Industry. *Local Government Studies*, *39*(3), 332–351. https://doi.org/10.1080/03003930.2013.778831

Albers, M., & Deppisch, S. (2013). Resilience in the light of climate change: Useful approach or empty phrase for spatial planning?. *European Planning Studies*, *21*(10), 1598-1610.

Alderton, B. (2017, November 16). If there's a Doheny desalination plant, South Coast Water District wants to build and run it. Retrieved 29 December 2019 from https://www.latimes.com/socal/coastline-pilot/news/tn-dpt-me-lb-doheny-desalination-20171116-story.html

Alderton, B. (2016, September 19). Poseidon interested in exploring public-private partnership for desalination plant. *The Los Angeles Times*. Retrieved 13 March 2020 from https://www.latimes.com/socal/daily-pilot/tn-dpt-me-poseidon-desalination-letter-20160920-story.html

Algemene Rekenkamer [Court of Audit]. (2013). *Contract management in DBFMO*. Tweede Kamer vergaderjaar 2012-2013, 33 639, nrs. 1-2. https://english.rekenkamer.nl/publications/reports/2013/06/06/contract-management-of-dbfmo-projects

Allaire, M., Wu, H., & Lall, U. (2018). National trends in drinking water quality violations. *Proceedings of the National Academy of Sciences*, *115*(9), 2078-2083.

Allen, C. R., & Gunderson, L. H. (2011). Pathology and failure in the design and implementation of adaptive management. *Journal of Environmental Management*, *92*(5), 1379-1384. https://doi.org/10.1016/j.jenvman.2010.10.063

American Society of Civil Engineers (ASCE). (2019). 2019 Report Card for California's Infrastructure. Retrieved 3 August 2020 from https://www.infrastructurereportcard.org/state-item/california/

American Society of Civil Engineers (ASCE). (2017). Infrastructure report card 2017. Retrieved from https://www.infrastructurereportcard.org/cat-item/drinking_water/

American Society of Civil Engineers (ASCE). (2016). *Failure to act: Closing the infrastructure investment gap for America's economic future.* Washington D.C.: ASCE.

American Water Works Association (AWWA) & Ernst & Young Infrastructure Advisors, LLC (EY). (2019). To P3 or not to P3. *A water industry view on the relevance of public-private partnership delivery models*. Retrieved from https://www.ey.com/en_us/transactions/three-questions-on-public-private-partnerships-for-us-city-water-projects

Ameyaw, E.E. & Chan, A.P.C. (2016). A Fuzzy Approach for the Allocation of Risks in Public-Private Partnership Water-Infrastructure Projects in Developing Countries. *Journal of Infrastructure Systems, 22*(3). DOI: 10.1061/(ASCE)IS.1943-555X.0000297

Ameyaw, E. E., & Chan, A. P. C. (2015). Risk allocation in public-private partnership water supply projects in Ghana. *Construction Management and Economics*, *33*(3), 187–208. https://doi.org/10.1080/01446193.2015.1031148

Ameyaw, EE. & Chan, A.P.C. (2014). Identifying Public-Private Partnership (PPP) Risk in Managing Water Supply in Projects in Ghana. *Journal of Facilities Management, 11*(2), 152-182. Doi: 10.1108/14725961311314651

Ameyaw, E.E. & Chan, A.P.C. (2013). First PPP Application in the Urban Water Supply Sector: Performance and Lessons from Ghana. In *Proceedings of the 19th CIB World Building Congress, Brisbane 2013: Construction and Society.* Eds. By Kajewski, S., Manley, K, & Hampson K. Brisbane, Australia: Queensland University of Technology.

Andonova, L.B. & Levy, M.A. (2003). Franchising Global Governance: Making Sense of the Johannesburg Type Two Partnerships. *Yearbook of International Cooperation on Envrionemtna and Development 2003/2003.* Eds. Stokke, O.S. & Thommessen, O.B. London, UK: Earthscan.

Andrews, R. & Entwistle, T. (2010). Does Cross-Sectoral Partnership Deliver? An Empirical Exploration of Public Service Effectiveness, Efficiency, and Equity. *Journal of Public Administration Research and Theory, 20*(3), 679-701.

Associated General Contractors of America (AGC). (2020). Public-private partnership basics. Retrieved 12 March 2020 from https://www.agc.org/public-private-partnership-p3-basics#_ftn2

Baehler, K. J., & Biddle, J. C. (2018). Governance for adaptive capacity and resilience in the US water sector. *Ecology and Society*, *23*(4). https://doi.org/10.5751/ES-10537-230424

Barnett, J., Evans, L. S., Gross, C., Kiem, A. S., Kingsford, R. T., Palutikof, J. P., ... & Smithers, S. G. (2015). From barriers to limits to climate change adaptation: path dependency and the speed of change. *Ecology and Society*, *20*(3). http://dx.doi.org/10.5751/ES-07698-200305

Bartlett, L.A. (n.d.). Charley Wilson: A Legacy of Accomplishment. Retrieved 14 May 2020 from https://bos5.ocgov.com/article/charley-wilson-legacy-accomplishment

Brand, F. S., & Jax, K. (2007). Focusing the meaning (s) of resilience: resilience as a descriptive concept and a boundary object. *Ecology and Society*, *12*(1).

Beevers, M. (2016). Can Public-Private Partnerships Help Rebuild War-Torn Societies?. In Matthew, R., Goodrich, K., Harron, K., Maharramli B., & Nizkorodov, E (Eds.), *Continuity and Change in Global Environmental Politics: The Social Ecology of the Anthropocene.* The WSPC Reference Set on Natural Resources and Environmental Policy in the Era of Global Change. pp. 3-32. World Scientific Publishing Co. Ltd. pp. 199-218.

Bell, S. (2002). Institutionalism: Old and New. In G.M. Hodgson, W.J. Samuels, and M.R. Tool (Eds.), *The Elgar Companion to Institutional and Evolutionary Economics.*

Benítez-Ávila, C., Hartmann, A., Dewulf, G., & Henseler, J. (2018). Interplay of relational and contractual governance in public-private partnerships: The mediating role of relational norms, trust and partners' contribution. *International Journal of Project Management, 36*(3), 429-443.

Berg, N., & Hall, A. (2017). Anthropogenic warming impacts on California snowpack during drought. *Geophysical Research Letters, 44*(5), 2511-2518.

Berrone, P., Ricart, J. E., Duch, A. I., Bernardo, V., Salvador, J., Piedra Peña, J., & Rodríguez Planas, M. (2019). EASIER: An Evaluation Model for Public–Private Partnerships Contributing to the Sustainable Development Goals. *Sustainability*, *11*(8), 2339. DOI: 10.3390/su11082339

Bhan, M. (2013). The role of public-private partnerships in U.S. environmental policy. Case of the EPA and the U.S. semiconductor industry. *The Public Purpose*, *XI*, 49-68.

Bliss, L. (2015, December 16). A Look inside the largest desalination plant in the western hemisphere. *Bloomberg City Lab*. Retrieved 14 July 2020 from https://www.bloomberg.com/news/articles/2015-12-16/san-diego-s-carlsbad-desalination-plant-is-the-largest-in-the-western-hemisphere#:~:text=San%20Diego's%20Carlsbad%20Desalination%20Plant,in%20the%20Western%20Hemisphere%20%2D%20Bloomberg

Bloomfield, P. (2006). The Challenging Business of Long-Term Public-Private Partnerships: Reflections on Local Experience. *Public Administration Review*, *66*(3), 400-411. https://doi.org/10.1111/j.1540-6210.2006.00597.x

Blumenstock, J. (2018) Don't forget people in the use of Big Data for development. *Nature*, *561* 170–2 https://www.nature.com/articles/d41586-018-06215-5

Boltz, F., Poff, N. L., Folke, C., Kete, N., Brown, C. M., Freeman, S. S. G., ... & Rockström, J. (2019). Water is a master variable: solving for resilience in the modern era. *Water Security*, *8*, 100048.

Bourke, M. F., Bunts, D., & Butler, P. A. (2019). California's First Swimming Lake Using Recycled Water. Journal-American Water Works Association, 111(9), 56-63. https://doi.org/10.1002/awwa.1361

Bovaird, T. (2010). A Brief Intellectual History of the Public-Private Partnership Movement. In G. Hodge, C. Greve, and A. Boardman (Eds.), *International Handbook on Public-Private Partnerships* (pp. 43–67). Cheltenham, UK: Edward Elgar

Boxall, B. (2016, December 16). A $1-billion desalination plant might be coming to Huntington Beach, but it will test California's environmental rules. Retrieved 29 February 2020 from https://www.latimes.com/local/lanow/la-me-poseidon-desalination-20161005-snap-story.html

Boyd-Barrett, C. (2015, February 3). Santa Paula will buy wastewater treatment plant. *Ventura Star County*. Retrieved 22 March 2020 from http://archive.vcstar.com/news/local/santa-paula/santa-paula-will-buy-wastewater-treatment-plant-ep-913480310-348917371.html

Boyer, E.J. & Van Slyke, D.M. (2019). Citizen attitudes toward public-private partnerships. *American Review of Public Administration*, *49*(3), 259-274.

Boyer, E., Cooper, R. & Kavinoky, J. (n.d.). *Public-Private Partnerships and Infrastructure Resilience: How PPPs Can Influence More Durable Approaches to U.S. Infrastructure*. National Chamber Foundation.

Brown, R., Ashley, R., & Farrelly, M. (2011). Political and professional agency entrapment: an agenda for urban water research. *Water Resources Management*, *25*(15), 4037-4050. https://link.springer.com/article/10.1007/s11269-011-9886-y

Bruce, A., Brown, C., Avello, P., Beane, G., Bristow, J., Ellis, L., ... & Matthews, N. (2020). Human dimensions of urban water resilience: Perspectives from Cape Town, Kingston upon Hull, Mexico City and Miami. *Water Security*, *9*, 100060.

Bryan, B. (2016, October 27). Trump campaign unveils plan to spend $1 trillion on roads, bridges, and other infrastructure with no tax hikes. *Business Insider*. Retrieved 23 April 2020 from https://www.businessinsider.com/trump-campaign-1-trillion-infrastructure-plan-with-no-tax-hike-2016-10

Bughin, J., Seong, J., Manyika, J., Chui, M., Joshi, R. (2018). *Notes from the AI frontier: Modeling the impact of AI on the world economy.* Mckinsey Global Institute

Build American Bureau. (2019). Public-private partnerships overview. Retrieved from https://www.transportation.gov/buildamerica/programs-services/p3

Bunts, D. (2017, December 1). Letter to the Finance and Administration Committee: Consideration and Action on Financing for the Lake Mission Viejo Advanced Water Treatment Facility

Bureau of Land Management (BLM). (2017, October 13). BLM to Cadiz. Retrieved 20 December 2019 from http://www.cadizinc.com/downloads/BLM%20to%20Cadiz%2010-13-17.pdf

Burke, R., & Demirag, I. (2017). Risk transfer and stakeholder relationships in Public Private Partnerships. *Accounting Forum*, *41*(1), 28–43. https://doi.org/10.1016/j.accfor.2016.06.004

Butler, D., Ward, S., Sweetapple, C., Astaraie-Imani, M., Diao, K., Farmani, R., & Fu, G. (2017). Reliable, resilient and sustainable water management: the Safe & SuRe approach. *Global Challenges*, *1*(1), 63-77. https://onlinelibrary.wiley.com/doi/full/10.1002/gch2.1010

Cadiz Inc. (2019a). Frequently Asked Questions. Cadiz Water Project, a Public-Private Partnership. Retrieved 26 November 2019 from https://www.cadizwaterproject.com/

Cadiz Inc. (2019b). Project Timeline. Cadiz Water Project, a Public-Private Partnership. Retrieved 30 November 2019 from https://www.cadizwaterproject.com/project-timeline/

California City News. (2012, June 20). Rialto tallies protest votes against water rate increases; Union submits petitions for measure. *California City News*. Retrieved 23 June 2020 from https://www.californiacitynews.org/2014/06/rialto-tallies-protest-votes-against-water-rate-increases-union-submits-petitions-measure

California Data Collaborative (CaDC). (n.d.-a). Overview of CaDC Analytics. Retrieved 4 February 2020 from http://californiadatacollaborative.org/analytics

California Data Collaborative (CaDC). (n.d.-b). What is the CaDC?. Retrieved 4 February 2020 from http://californiadatacollaborative.org/about

California Department of Water Resources (CA DWR). (n.d.). California precipitation. Southwest Climate Science Center. Retrieved 17 March 2020 from https://water.ca.gov/LegacyFiles/floodmgmt/hafoo/csc/docs/CA_Precipitation_2pager.pdf

California Department of Water Resources (CA DWR), CA Fish & Wildlife, California Water Boards, California Water Quality Monitoring Council, California Governor's Office of Planning and Research, California Government Operations Agency, Delta Stewardship

Council, & California Natural Resources Agency. (2018). *Strategic Plan for Assembly Bill 1755, the Open and Transparent Water Data Act.* Retrieved from https://water.ca.gov/ab1755

California Legislative Information. (n.d.). Chapter 15. Infrastructure Financing [5956 - 5956.10]. Retrieved from https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=GOV&division=6.&title=1.&part=&chapter=14.&article=

California Natural Resources Agency (CNRA), California Environmental Protection Agency (Cal EPA), & the California Department of Food & Agriculture (CDFA). (2020). *2020 water resilience portfolio. In response to the Executive Order N-10-19.* Retrieved from http://waterresilience.ca.gov/

California Natural Recourses Agency (CNRA), California Environmental Protection Agency (Cal EPA), & California Department of Food & Agriculture (CDFA). (2016). *California Water Action Plan.* Retrieved from https://resources.ca.gov/CNRALegacyFiles/docs/Final_Water_Action_Plan.pdf

California Water News Daily. (2019, February 13). Water Chemistry Expert Tells Cadiz Water Project Review Board Opponent-Funded Springs Work Flawed. California Water News Daily. Retrieved 3 November 2019 from californiawaternewsdaily.com/infrastructure/water-chemistry-expert-tells-cadiz-water-project-review-board-opponent-funded-springs-work-flawed/

California Water News Daily. (2017, June 20). Moulton Niguel Water District wins "Golden Hub of Innovation Award." Retrieved 25 August 2020 from http://californiawaternewsdaily.com/drought/moulton-niguel-water-district-wins-golden-hub-of-innovation-award/

Callahan, N.V. (2012). Rialto, Calif., Closes $177 Million Utilities P3. *Public Works Financing, December 2012*.

Capistrano Dispatch. (2011, November 23). Calm Waters? *The Capistrano Dispatch.* Retrieved 25 August 2020 from https://www.thecapistranodispatch.com/calm-waters/

Carpintero, S., & Helby Petersen, O. (2016). Public–private partnerships (PPPs) in local services: Risk-sharing and private delivery of water services in Spain. *Local Government Studies*, *42*(6), 958–979. https://doi.org/10.1080/03003930.2016.1204297

Carter, L., Kaga, R., Maier, T., Heathcote, C., Aguerre, J.A. …. & Akhtar, S. (2017). *Public-private partnerships reference guide*. Washington DC: World Bank

Charmaz, K. (2003). Grounded theory: Objectivist and constructivist methods. In N. K. Denzin, & Y. S. Lincoln (Eds.), *Strategies for qualitative inquiry* (2nd ed., pp. 249-291). Thousand Oaks, CA: Sage.

CDM Smith, Inc. (2018). *2018 Orange County Water Reliability Study*. Retrieved from https://www.mwdoc.com/your-water/water-supply/local-water-supply/orange-county-water-supply-reliability-study/

Chapelle, C. & Hanak, E. (2015). California's water quality challenges. Public Policy Institute of California. Retrieved from https://www.ppic.org/publication/californias-water-quality-challenges/

Chelleri, L., Schuetze, T., & Salvati, L. (2015). Integrating resilience with urban sustainability in neglected neighborhoods: Challenges and opportunities of transitioning to decentralized water management in Mexico City. *Habitat International*, *48*, 122-130.

Chelleri, L., Waters, J. J., Olazabal, M., & Minucci, G. (2015). Resilience trade-offs: addressing multiple scales and temporal aspects of urban resilience. *Environment and Urbanization*, *27*(1), 181-198.

Chen, J., Chen, T. H. Y., Vertinsky, I., Yumagulova, L., & Park, C. (2013). Public-Private Partnerships for the Development of Disaster Resilient Communities. *Journal of Contingencies and Crisis Management*, *21*(3), 130–143. https://doi.org/10.1111/1468-5973.12021

Chen, C. & Doloi, H. (2008). BOT Application in China: Driving and Impeding Factors. *International Journal of Project Management*, *26*(4), 388-398. Doi: 10.1016/j.ijproman.2007.07.002

Chen, C., Hubbard, M., & Liao, C.-S. (2013). When Public–Private Partnerships Fail. *Public Management Review*, *15*(6), 839-857. doi: 10.1080/14719037.2012.698856

Cheong, S. M., Choi, G. W., & Lee, H. S. (2016). Barriers and solutions to smart water grid development. *Environmental Management*, *57*(3), 509-515.

Cheung, Esther, Chan, Albert, & Kajewski, Stephen L. (2012) Factors Contributing to Successful Public Private Partnership Projects: Comparing Hong Kong with Australia and the United Kingdom. *Journal of Facilities Management*, *10*(1), pp. 45-58. DOI: 10.1108/14725961211200397

Choi, J. H., Chung, J., & Lee, D. J. (2010). Risk perception analysis: Participation in China's water PPP market. *International Journal of Project Management*, *28*(6), 580-592. DOI: 10.1016/j.ijproman.2009.10.010

Chou, J. S., & Pramudawardhani, D. (2015). Cross-country comparisons of key drivers, critical success factors and risk allocation for public-private partnership projects. *International Journal of Project Management*, *33*(5), 1136-1150. DOI: 10.1016/j.ijproman.2014.12.003

Christian-Smith, J., Levy, M. C., & Gleick, P. H. (2015). Maladaptation to drought: a case report from California, USA. *Sustainability Science*, *10*(3), 491-501. DOI: 10.1007/s11625-014-0269-1

Chung, D., Hensher, D. A., & Rose, J. M. (2010). Toward the betterment of risk allocation: Investigating risk perceptions of Australian stakeholder groups to public–private-partnership tollroad projects. *Research in Transportation Economics*, *30*(1), 43–58. https://doi.org/10.1016/j.retrec.2010.10.007

City of Long Beach. (2015, August 11). Governor Brown Signs Long Beach Civic Center Legislation. Press Release #CM 081115. Retrieved 8 May 2020 from http://www.longbeach.gov/press-releases/governor-brown-signs-long-beach-civic-center-legislation/

City of Mission Viejo. (2017). City of Mission Viejo 2017-2019 Adopted Budget. Retrieved 18 February 2020 from https://cityofmissionviejo.org/sites/default/files/FY2017-19-Adopted-Budget-Reduced.pdf

City of Rialto. (2011). Urban Water Management Plan. Retrieved 15 March 2020 from https://water.ca.gov/LegacyFiles/urbanwatermanagement/2010uwmps/Rialto,%20City%20of/Rialto%202010%20UWMP%2008-17-11.pdf

Clarke, C. (2017, May 22). The unique Mojave Desert oasis at the center of the Cadiz controversy. *KCET*. Retrieved 24 December 2019 from https://www.kcet.org/shows/earth-focus/the-unique-mojave-desert-oasis-at-the-center-of-the-cadiz-controversy

Clarke, C. (2012. June 28). What the Cadiz Water Plan is and why it needs to be stopped. *KCET*. Retrieved 15 December 2019 from https://www.kcet.org/socal-focus/what-the-cadiz-water-plan-is-and-why-it-needs-to-be-stopped

Clean Energy Capital. (2014). Financial analysis of proposed Huntington Beach Ocean Water Desalination Project.

Cohen, R. (2019, 26 November). Water bandits: How one company almost got away with draining the Mojave Desert. *Earth Justice*. Retrieved 12 March 2020 from https://earthjustice.org/features/mojave-national-monument-water-legal-fight-cadiz

Cook, P.A. (2016). Irvine Ranch Water District Batery Energy Storage Program. Presented at the Association of California Water Agencies 30 November 2016. Retrieved 20 July 2017 from https://www.acwa.com/wp-content/uploads/2017/04/Paul-Cook-Energy-Storage.Irvine-Ranch.pdf

Cools, M., Slagmulder, R., & Van den Abbeele, A. G. (2011). Management control in inter-organizational relationships: Lessons learnt from public-private partnerships. *Katholieke Universiteit Leuven Department of Accountancy, Finance, and Insurance Working Paper*, No. 1154.

Corominas, L., Garrido-Baserba, M., Villez, K., Olsson, G., Cortés, U., & Poch, M. (2018). Transforming data into knowledge for improved wastewater treatment operation: A critical review of techniques. *Environmental Modelling & Software*, *106*, 89-103.

Corrigan, M.B., Hambene, J., Hudnut III, W., Levitt, R.L., Stainback, J., Ward, R., & Witestein, N. (2005). Ten principles for successful public/private partnerships. Washington D.C.: Urban Land Institute

Cournoyer C. (2013). Why isn't the U.S. better at public-private partnerships? Retrieved 18 March 2020 from https://www.governing.com/topics/finance/gov-public-private-partnerships-in-america.html

Cox, M. 2016. Comparing water access regimes under conditions of scarcity: The tale of two communities in the United States. In Pistor, K. and De Schutter, O. (Eds), Governing access to essential resources, pp. 214-233. New York: Columbia University Press

Cruz, C. O., & Marques, R. C. (2013). Flexible contracts to cope with uncertainty in public–private partnerships. *International Journal of Project Management*, *31*(3), 473–483. https://doi.org/10.1016/j.ijproman.2012.09.006

Cuniff, MM. (2014, November 19). San Juan Capistrano still owes $40 million for groundwater plant. *The Orange County Register*. Retrieved 25 August 2020 from https://www.ocregister.com/2014/11/19/san-juan-capistrano-still-owes-40-million-for-groundwater-plant/

Data Clinic. (n.d.). Data Clinic - what we do. Retrieved 12 February from https://dataclinic.twosigma.com/

DataKind. (2016). Forecasting water demand in California when every drop counts. Retrieved 7 February 2020 from https://www.datakind.org/projects/forecasting-water-demand-in-california-when-every-drop-counts

DataKind. (n.d.) About us. Retrieved 7 February 2020 from https://www.datakind.org/about

Data USA. (2019). Data USA: Explore, map, compare, and download U.S. Data. Retrieved 26 December 2019 from https://datausa.io/

Davis, C. A., & O'Rourke, T. D. (2011). ShakeOut Scenario: Water system impacts from a M7.8 San Andreas earthquake. *Earthquake Spectra*, *27*(2), 459–476.

Davis, C., & Shamma, J. (2019). Improving the Resilience of Southern California Water Supply Aqueduct Systems to Regional Earthquake Threats. *National Acady of Engineering*, *49*(2), 60–67.

Davidson, K., Nguyen, T. M. P., Beilin, R., & Briggs, J. (2019). The emerging addition of resilience as a component of sustainability in urban policy. *Cities*, *92*, 1-9.

Davoudi, S. (2012). Resilience: a bridging concept or a dead end? “Reframing” resilience: challenges for planning theory and practice interacting traps. *Planning Theory & Practice*, *13*(2), 299-333.

Dawsey, J. (2018, January 7). Mixed signals on infrastructure plan emerge from Trump retreat. The Washington Post. Retrieved 1 February 2020 from https://www.washingtonpost.com/politics/mixed-signals-on-infrastructure-plan-emerge-from-trump-retreat/2018/01/07/56aa5a8c-f3db-11e7-91af-31ac729add94_story.html

Dayton, K. (2016, August 19). Desalination Plant's Critics Are Partly to Blame for Expensive Water. *Voice of San Diego.* Retrieved 16 April 2020 from https://www.voiceofsandiego.org/topics/opinion/critics-of-the-more-expensive-carlsbad-desalination-project-water-are-a-major-reason-why-the-water-is-more-expensive/

De Schepper, S., Haezendonck, E., & Dooms, M. (2015). Understanding pre-contractual transaction costs for Public–Private Partnership infrastructure projects. *International Journal of Project Management*, *33*(4), 932-946. https://doi.org/10.1016/j.ijproman.2014.10.015

Debevoise & Plimpton LLP. (2019). Public-private partnerships in the USA. *Lexology*. Retrieved 12 March 2020 from https://www.lexology.com/library/detail.aspx?g=d1d1835b-849e-4ded-87a6-fd79b0fc6d54

Delmon, J. (2009). *Private sector investment in infrastructure: Project finance, PPP projects and risks*. Kluwer Law International.

Dellas, E. (2011). CSD Water Partnerships: Privatization, Participation, and Legitimacy. *Ecological Economics*, *70*, 1916-1923. Doi: 10.1016/j.ecolecon.2011.04.007

Demirel, H. Ç., Leendertse, W., Volker, L., & Hertogh, M. (2016). Flexibility in PPP contracts–Dealing with potential change in the pre-contract phase of a construction project. *Construction Management and Economics*, *35*(4), 196-206. https://doi.org/10.1080/01446193.2016.1241414

Department of Toxic Substances Control (DTSC). (2018). Public participation during CEQA. *Public participation manual.* Retrieved from https://dtsc.ca.gov/wp-content/uploads/sites/31/2018/07/OEA_Pol_PublicParticipationManual_Chapter5.pdf

Department of Water and Power (DWP) & LA County Public Works. (2017*). Building water resilience in Los Angeles County: A report*. H2O4LA. Retrieved from https://dpw.lacounty.gov/wrp/docs/WRP_DRAFT_170918.pdf

Deslatte, A., Feiock, R. C., & Wassel, K. (2017). Urban pressures and innovations: Sustainability commitment in the face of fragmentation and inequality. *Review of Policy Research*, *34*(5), 700-724.

Dewulf, A., Karpouzoglou, T., Warner, J., Wesselink, A., Mao, F., Vos, J., ... & Hoang, L. (2019). The power to define resilience in social–hydrological systems: Toward a power-sensitive resilience framework. *Wiley Interdisciplinary Reviews: Water*, *6*(6), e1377.

Deye, A. (2015, June 16). US infrastructure public-private partnerships: ready for takeoff? Kennedy School Review. Retrieved 8 August 2019 from https://ksr.hkspublications.org/2015/06/16/us-infrastructure-public-private-partnerships-ready-for-takeoff/

Diffenbaugh, N. S., Swain, D. L., & Touma, D. (2015). Anthropogenic warming has increased drought risk in California. *Proceedings of the National Academy of Sciences, 112*(13), 3931-3936.

Dilling, L., Daly, M. E., Kenney, D. A., Klein, R., Miller, K., Ray, A. J., ... & Wilhelmi, O. (2019). Drought in urban water systems: Learning lessons for climate adaptive capacity. *Climate Risk Management*, *23*, 32-42.

DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, *48*(2), 147-160.

Dolnicar, S., & Hurlimann, A. (2011). Water alternatives—who and what influences public acceptance?. *Journal of Public Affairs*, *11*(1), 49-59. https://onlinelibrary.wiley.com/doi/full/10.1002/pa.378

Dormois, R., Pinson, G., & Reignier, H. (2005). Path-dependency in public–private partnership in French urban renewal. *Journal of Housing and the Built Environment, 20*(3), 243-256. https://link.springer.com/article/10.1007/s10901-005-9008-3

Douglas, B.S. & Sykes, J.A. (2013). Public-Private Partnerships in California. *California Public Law Journal*.

Eggimann, S., Mutzner, L., Wani, O., Schneider, M. Y., Spuhler, D., Moy de Vitry, M., ... & Maurer, M. (2017). The potential of knowing more: A review of data-driven urban water management. *Environmental Science & Technology*, 51(5), 2538-2553.

Ekstrom, J. A., Klasic, M. R., Fencl, A., Lubell, M., Baker, E., & Einterz, F. (2018). *Drought management and climate adaptation of small, self-sufficient drinking water systems in California*. California Natural Resources Agency. https://www.energy.ca.gov/sites/default/files/2019-12/Water_CCCA4-CNRA-2018-004_ada.pdf

Emerson, K. & Nabatchi, T. (2015). *Collaborative Governance Regimes.* Washington D.C.: Georgetown University Press.

Engle, N. L. (2011). Adaptive capacity and its assessment. *Global Environmental Change*, *21*(2), 647-656.

Engle, N. L., Johns, O. R., Lemos, M. C., & Nelson, D. R. (2011). Integrated and adaptive management of water resources: tensions, legacies, and the next best thing. *Ecology and Society*, *16*(1).

Enserink, M. & Chin, G. (2015). The end of privacy. *Science*, 347(6221), 490−491.DOI: 10.1126/science.347.6221.490

Environmental Financial Advisor Board. (2008). *Public private partnerships in the provision of water and wastewater services: Barriers and incentives.* Retrieved from https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100AM1T.TXT

United States Environmental Protection Agency (EPA). (2018). EPA's 6th inking water infrastructure needs survey and assessment. Retrieved 20 November 2019 from https://www.epa.gov/dwsrf/epas-6th-drinking-water-infrastructure-needs-survey-and-assessment

Environmental Protection Agency (EPA). (2018, August 16). EPA Receives Record Number of Letters of Interest for WIFIA Water Infrastructure Loans. Retrieved 1 February 2020 from https://www.epa.gov/newsreleases/epa-receives-record-number-letters-interest-wifia-water-infrastructure-loans-0

Environmental Protection Agency (EPA). (2018, January 10). EPA Launches New Program with $1 Billion in Loans Available for Water Infrastructure Projects. Retrieved 18 March 2020 from https://archive.epa.gov/epa/newsreleases/epa-launches-new-program-1-billion-loans-available-water-infrastructure-projects.html

Environmental Protection Agency (EPA). (2017). Technical fact sheet. Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA). US Environmental Protection Agency.

Environmental Protection Agency (EPA). (2015a). *Community Based Public-Private Partnerships (CBP3s) and Alternative Market-Based Tools for Integrated Green Stormwater Infrastructure, A Guide for Local Governments.*

Environmental Protection Agency. (EPA). (2015b). *Systems Measures of Water Distribution System Resilience.*

Environmental Protection Agency (EPA). (2011). EPA’s Clean Water and Drinking Water Infrastructure Sustainability Policy. Retrieved 21 June 2017 from https://www.epa.gov/sites/production/files/2016-01/documents/clean-water-and-drinking-water-infrastructure-sustability-policy.pdf

Environmental Protection Agency (EPA). (2008). EFAB Report: Public Private Partnerships in the Provision of Water and Wastewater Services: Barriers and Incentives.

Environmental Protection Agency (EPA). (n.d.-a). Basics of water resilience. Retrieved 5 April 2020 from https://www.epa.gov/waterresilience/basics-water-resilience

Environmental Protection Agency (EPA). (n.d.-b). Basic information about Nonpoint source pollution (NPS). Retrieved 14 February 2020 from https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution

Eriksson, M. G., Gordon, L. J., & Kuylenstierna, J. (2014). Cross-sectoral approaches help build water resilience–reflections. *Aquatic Procedia*, *2*, 42-47.

Eskaf, S. (2015, September 9). Four trends in government spending on water and wastewater utilities since 1956. *The UNC School of Government Environmental Finance Blog.* Retrieved 4 February 2020 from http://efc.web.unc.edu/2015/09/09/four-trends-government-spending-water/#comments

Executive Order 136563. (2013, November 6). Executive Order 13653—Preparing the United States for the Impacts of Climate Change. *Federal Register, 78*(215), 66819-66824.

Executive Order N-10-19. (2019, April 29). Executive Order N-10-19. Executive Department State of California. Retrieved from https://www.gov.ca.gov/wp-content/uploads/2019/04/4.29.19-EO-N-10-19-Attested.pdf?utm_source=Water+in+West+-+ALL&utm_campaign=07d64dcf01-EMAIL_CAMPAIGN_2019_05_01_02_53_COPY_01&utm_medium=email&utm_term=0_aae11e48ba-07d64dcf01-

Expert System Team. (2017, 7 March). What is machine learning? A definition. *Machine Learning Blog*. Retrieved from https://expertsystem.com/machine-learning-definition/

Falkenmark, M., Wang-Erlandsson, L., & Rockström, J. (2019). Understanding of water resilience in the Anthropocene. *Journal of Hydrology X*, *2*, 100009.

Farrelly, M., & Brown, R. (2011). Rethinking urban water management: Experimentation as a way forward?. *Global Environmental Change*, *21*(2), 721-732. https://doi.org/10.1016/j.gloenvcha.2011.01.007

Fears, D. (2015, July 8). Calif. city's desalination push sparks debate over cost, environmental harm. *The Washington Post.* Retrieved 14 July 2020 from https://www.washingtonpost.com/national/health-science/california-citys-desalination-push-sparks-debate-over-costs-coastal-impact/2015/07/08/8f0b2ede-1a84-11e5-bd7f-4611a60dd8e5_story.html

Federal Highway Administration (FWHA). (2018). State P3 Legislation. US Department of Transportation. Retrieved from https://www.fhwa.dot.gov/ipd/p3/legislation/

Federal Highway Administration (FWHA). (n.d.). Transportation Infrastructure Finance and Innovation Act (TIFIA). US Department of Transportation. Retrieved from https://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_credit_assistance/tifia/

Federal Emergency Management Agency (FEMA). (2018). Learn about Presidential Policy Directive-8: National Preparedness. Department of Homeland Security. Retrieved 8 March 2020 from https://www.fema.gov/learn-about-presidential-policy-directive-8

Feinstein, D. & Friedman, L. (2017, August 21). Op-Ed: The scheme to pump desert water to L.A. could destroy the Mojave. California's Legislature needs to block it. *Los Angeles Times.* Retrieved 20 November 2019 from https://www.latimes.com/opinion/op-ed/la-oe-feinstein-friedman-cadiz-mojave-desert-20170821-story.html

Feinstein, L., Phurisamban, R., Ford, A., Tyler, C., & Crawford, A. (2017). *Drought and equity in California*. Oakland, CA: Pacific Institute.

Feldman, D.L. (2018). *The Water-Sustainable City*. *Science, Policy, and Practice*. City Series. Edward Elgar Publishing

Feldman, D.L. (2017). *Water Politics: Governing Our Most Precious Resource.* Cambridge, UK: Polity.

Feldman, D. L. (2016). The West's Water – multiple uses, conflicting values, interconnected fates. In K. Miller, A. Harnlet, D. Kenney, and K. Redmond (Eds.), *Western water policy in a variable and changing Climate – insights from the Western United States*. Taylor & Francis.

Feldman, D. L., & Ingram, H. M. (2009). Making science useful to decision makers: climate forecasts, water management, and knowledge networks. *Weather, Climate, and Society, 1*(1), 9-21.

Fenner Valley Water Authoirty (FVWA). (n.d.). Cadiz Valley Water Conservation, Recovery and Storage Project. Retrieved 16 July 2020 from https://www.fvwa.org/cadiz-water-project/

Field, E.H. & 2014 Working Group on California Earthquake Probabilities (2015). UCERF3: A new earthquake forecast for California's complex fault system. *U.S. Geological Survey, Fact Sheet No. 2015–3009,* 1-6. DOI: 10.3133/fs20153009.

Fielding, K.S., Dolnicar, S., & Schultz, T. (2018). Public acceptance of recycled water. *International Journal of Water Resources Development*, 1-37. https://www.tandfonline.com/doi/full/10.1080/07900627.2017.1419125

Fikes, B. (2015, December 13). State's biggest desal plant to open: What it means. Retrieved 1 November 2019 from https://www.sandiegouniontribune.com/news/environment/sdut-poseidon-water-desalination-carlsbad-opening-2015dec13-htmlstory.html

Fiksel, J., Goodman, I., & Hecht, A. (2014). Resilience: navigating toward a sustainable future. *Journal of Solutions, 5*(5), 38-47.

Finley, A. (2015, May 15). Slaking California's thirst – if politics allows. *Wall Street Journal*. Retrieved 24 December 2019 from https://www.wsj.com/articles/slaking-californias-thirstif-politics-allows-1431729692

Florizone, R., & Carter, L. (2013). A Winning Framework for Public-Private Partnerships: Lessons from 60-Plus IFC Projects. International Finance Corporation, World Bank Group. *Smart Lessons*, No. 80896

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global environmental change*, *16*(3), 253-267.

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and society*, *15*(4).

Forrer, J., Kee, J. E., Newcomer, K. E., & Boyer, E. (2010). Public-Private Partnerships and the Public Accountability Question. *Public Administration Review, May/June*, 475-484.

Fridegotto, G. (2017, 9 November). Public private partnerships: Wastewater treatment. Comprehensive financial solutions for city resilience conference. *IFC*. Retrieved 15 November 2019 from https://www.gfdrr.org/sites/default/files/events/crp-bkk1-ppp-wastewater.pdf

Fuenfschilling, L., & Truffer, B. (2016). The interplay of institutions, actors and technologies in socio-technical systems—An analysis of transformations in the Australian urban water sector. *Technological Forecasting and Social Change*, 103, 298-312.

Garrido-Baserba, M., Corominas, L., Cortés, U., Rosso, D., & Poch, M. (2020). The fourth-revolution in the water sector encounters the digital revolution. *Environmental Science & Technology*, *54*(8), 4698-4705.

Gerrits, L., & Verweij, S. (2018). *The evaluation of complex infrastructure projects: A guide to qualitative comparative analysis*. Edward Elgar Publishing.

Gilroy, L. (2014, May 27). Congress passes water bill promoting public-private partnerships. *Reason Foundation*. Retrieved 1 February 2020 from https://reason.org/commentary/congress-water-bill-ppp/

Giurco, D. P., White, S. B., & Stewart, R. A. (2010). Smart metering and water end-use data: Conservation benefits and privacy risks. *Water*, *2*(3), 461-467.

Global Infrastructure Hub. (n.d.). PPP Contract Management. A G20 Initiative. Retrieved 14 March 2020 from https://managingppp.gihub.org/?utm_source=English%20media%20release&utm_medium=Media%20release&utm_campaign=PPP%20Contract%20Management%20launch

Glaser, B. G., & Straus, A. L. (2017). *Discovery of grounded theory: Strategies for qualitative research*. London, UK: Routledge.

Global Infrastructure Hub. (2019). *G20 IWG Report on the Results of the Survey on Public-Private Partnership Developments in the G20 Economies*. National Center for Public Private Partnership, Ministry of Finance of the Russian Federation, State Development Corporation. https://content.gihub.org/live/media/1495/gih_managingppp_summary.pdf

GlobeNewswire. (2019, April 22). Research Findings Reveal 85% of Orange County Voters Support a Desalination Plant in Huntington Beach. *Globe Newswire.* Retrieved 29 February 2020 from https://www.globenewswire.com/news-release/2019/04/22/1807387/0/en/Research-Findings-Reveal-85-of-Orange-County-Voters-Support-a-Desalination-Plant-in-Huntington-Beach.html

Gober, P. (2013). Getting Outside the Water Box: The Need for New Approaches to Water Planning and Policy. *Water Resources Management*, *27*, 955-957.

Gobernadora Multi-purpose basin Implementation Agreement (GMB IA). (2012, November 14)

Gonzales, P., & Ajami, N. K. (2017). An integrative regional resilience framework for the changing urban water paradigm. *Sustainable Cities and Society*, 30, 128-138.

GovLab. (n.d.). Designing a data collaborative. The Gov Lab. Retrieved 22 August 2020 from https://datacollaboratives.org/canvas.html

Graham, S., & Marvin, S. (2001). *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition*. London, UK: Routledge

Greenberg, J. (2014, March 24). Desalination in Israel Means Robust Water Resilience. *Government Technology*. Retrieved 1 June 2020 from https://www.govtech.com/fs/news/Desalination-in-Israel-Means-Robust-Water-Resilience-.html

Grimsey, D. & Lewis, M.K. (2004). *Public Private Partnerships. The Worldwide Revolution in Infrastructure Provision and Project Finance.* Cheltenham, UK: Edward Elgar

Grimsey, D., & Lewis, M. K. (2002). Evaluating the risks of public private partnerships for infrastructure projects. *International Journal of Project Management*, *20*(2), 107–118. https://doi.org/10.1016/S0263-7863(00)00040-5

Grizen, E.M. (n.d.). Report on P3 projects and legislation in California. Peckar & Abramson, P.C. Retrieved 7 May 2020 from https://www.pecklaw.com/wp-content/uploads/2013/10/Gruzen_P3-California_Alert.pdf

Hadjimichael, A., Comas, J., & Corominas, L. (2016). Do machine learning methods used in data mining enhance the potential of decision support systems? A review for the urban water sector. *AI Communications*, *29*(6), 747-756.

Hamlin, S. (2018, July 22). Santa Paula Waste Water Facility | Did the City Buy a Lemon? *Citizens Journal*. Retrieved 22 March 2020 from https://www.citizensjournal.us/santa-paula-waste-water-facility-did-the-city-buy-a-lemon/

Hanak, E., Gray, B., Lund, J. R., Mitchell, D., Chappelle, C., Fahlund, A., ... & Suddeth, R. (2014). *Paying for water in California*. San Francisco, CA: Public Policy Institute of California.

Hanak, E., Lund, J., Dinar, A., Gray, B., Howitt, R., Mount, J., …. & Thompson, B. (2011). *Managing California's water: From conflict to reconciliation.* San Francisco, CA: Public Policy Institute of California. http://www.ppic.org/main/publication.asp?i=944

Harris-Lovett, S. R., Binz, C., Sedlak, D. L., Kiparsky, M., & Truffer, B. (2015). Beyond user acceptance: A legitimacy framework for potable water reuse in California. *Environmental Science & Technology*, *49*, 7552–7561. https://pubs.acs.org/doi/10.1021/acs.est.5b00504

Hayes, S., Desha, C., Burke, M., Gibbs, M., & Chester, M. (2019). Leveraging socio-ecological resilience theory to build climate resilience in transport infrastructure. *Transport Reviews*, *39*(5), 677-699.

Harris-Lovett, S. R., Binz, C., Sedlak, D. L., Kiparsky, M., & Truffer, B. (2015). Beyond user acceptance: A legitimacy framework for potable water reuse in California. *Environmental science & technology*, *49*(13), 7552-7561. DOI: 10.1021/acs.est.5b00504

Head, B.W. & Alford, J. (2015). Wicked problems: Implications for public policy and management. *Administration and Society*, *47*(6), 711-739.

Heinmiller, T. (2009). Path dependency and collective action in common pool governance. *International Journal of the Commons*, *3*(1), 131-147.

Hewes, W. & Randolph, S. (2018). *Public-private partnerships in California. How governments can innovate, attract investment, and improve infrastructure performance.* Bay Area Council Economic Institute.

Hira, A., & Hira, R. (2000). The new institutionalism: Contradictory notions of change. *American Journal of Economics and Sociology, 59*(2), 267-282.

Hill, M., & Engle, N. L. (2013). Adaptive capacity: tensions across scales. Environmental Policy and Governance, 23(3), 177-192.

Hirchsman, A.O. (1970). *Exit, voice, and loyalty. Responses to decline in firms, organizations, and states.* (Vol. 25). Harvard university press.

Ho, S. P., & Tsui, C. (2009). The Transaction Costs of Public-Private Partnerships: Implication on PPP Governance Design.

Hodge, G. A. (2004). The risky business of public–private partnerships. *Australian journal of public administration*, *63*(4), 37-49.

Hodge, G. & Greve, C. (2007). Public-Private Partnerships: An International Performance Review. *Public Administration Review* (May/June), 545-558.

Hodge, G. A., & Greve, C. (2017). On public–private partnership performance: A contemporary review. *Public Works Management & Policy*, *22*(1), 55-78.

Hodge, G., Greve, C., & Biygautane, M. (2018). Do PPP's work? What and how have we been learning so far?. *Public Management Review*, *20*(8), 1105-1121. https://doi.org/10.1080/14719037.2018.1428410

Hoering, U. (2003). *Panacea PPP. Public Private Partnership in German Development Corporation.* Berlin, Germany: WEED.

Holling, C.S. (1996). Engineering resilience vs. ecological resilience. In Peter Schulze (ed)., *Engineering within ecological constraints* (pp. 31-44). National Academy of Engineering.

Holling, C.S. (1986). Resilience of ecosystems; local surprise and global change. In W.C. Clark & R.E. Munn (eds)., *Sustainable development of the biosphere* (pp. 292-317). Cambridge, UK: Cambridge University Press.

Hopy, P. (2015). Risk Allocation in Public-Private Partnerships: Maximizing value for money. International Institute for Sustainable Development.

Hossain, F., Beighley, E., Burian, S., Chen, J., Mitra, A., Niyogi, D., ... & Wegner, D. (2017). Review of approaches and recommendations for improving resilience of water management infrastructure: The case for large dams. *Journal of Infrastructure Systems*, *23*(4), 02517001.

House, S. (2016). Responsive regulation for water PPP: Balancing commitment and adaptability in the face of uncertainty. *Policy and society*, *35*(2), 179-191.

Howard, P.K. (2015). *Two years, not ten years. Redesigning infrastructure approvals*. Brooklyn, NY: Common Good.

Hueskes, M., Verhoest, K., & Block, T. (2017). Governing public–private partnerships for sustainability. *International Journal of Project Management, 35*(6), 1184–1195. https://doi.org/10.1016/j.ijproman.2017.02.020

Hughes, J. (2017). *The financial impacts of alternative water project delivery models: A closer look at nine communities*. UNC Environmental Finance Center.

Hughes, S. & Mullin, M. (2015). Local water politics. In K. Conca & E. Weinthal (Eds.), *The Oxford Handbook of Water Politics and Policy* (pp. 284-310). Oxford University Press

Hughes, S., & Pincetl, S. (2014). Evaluating collaborative institutions in context: the case of regional water management in southern California. Environment and Planning C: Government and Policy, 32(1), 20-38.

Hui, I., Ulibarri, N., & Cain, B. (2018). Patterns of participation and representation in a regional water collaboration. *Policy Studies Journal, 0*(0), 1-28

Hundley, N. (2001). *The great thirst: Californians and water—A history*. Univ of California Press.

Huttner, N., King, K., Whitney, J. (2018). Sustainable governance and funding for open water data in California. Redstone.

Iossa, E. Martimort., D. (2015). The Simple Microeconomics of Public-Private Partnerships. *Journal of Public Economic Theory*, *17*(1), 4-48. DOI: 10.1111/jpet.12114

Irvine Ranch Water District (IRWD) – DRES Portfolio B. (2018, May 3). Amended and restated energy management services agreement.

Irvine Ranch Water District (IRWD). (2017, March 22). Energy Storage Project. Retrieved 1 November 2019 from https://www.irwd.com/home/construction/energy-storage-project

Irvine Ranch Water District (IRWD). (n.d.). Water supply and reliability. Retrieved 15 March 2020 from https://www.irwd.com/services/water-supply-reliability

Ivory, D., Protess, B., Palmer, G. (2016). In American towns, private profits from public works. *The New York Times.* Retrieved 27 December 2019 from https://www.nytimes.com/2016/12/24/business/dealbook/private-equity-water.html

Janis, A. (2008, May 1). Schwarzenegger pleads for public-private infrastructure investments. *Infrastructure Investor*. Retrieved May 7 2020 from https://www.infrastructureinvestor.com/schwarzenegger-pleads-for-public-private-infrastructure-investments/

Jeffares, H., Sullivan, H., & Bovaird, T. (2009). Beyond the Contract – The Challenge of Evaluating Performance(s) of Public-Private Partnerships. Paper for the annual conference of International Research Society for Public Management,(IRSPM), Copenhagen, Denmark.

Jefferies, M., Rowlinson, S., & Gameson, R. (2002). Critical Success Factors of the BOOT Procurement System: Reflections from the Stadium Australia Case Study. *Engineering Construction & Architectural Management*, *9*(4), 352-361. Doi: 10.1108/eb021230

Johannessen, Å., Rosemarin, A., Thomalla, F., Gerger Swartling, Å., Axel Stenström, T., & Vulturius, G. (2014). Strategies for building resilience to hazards in water, sanitation and hygiene (WASH) systems: The role of public private partnerships. *International Journal of Disaster Risk Reduction*, *10*, 102–115. https://doi.org/10.1016/j.ijdrr.2014.07.002

Johannessen, Å., & Wamsler, C. (2017). What does resilience mean for urban water services?. *Ecology and Society*, *22*(1).

Jooste, S. F., Levitt, R., & Scott, D. (2011). Beyond ‘one size fits all’: how local conditions shape PPP-enabling field development. *The Engineering Project Organization Journal*, *1*(1), 11-25.

Jones, L. M., Bernknopf, R., Cox, D., Goltz, J., Hudnut, K., Mileti, D., ... & Seligson, H. (2008). *The ShakeOut Scenario.* USGS Open File Report 2008-1150 and California Geological Survey Preliminary Report 25. Reston, VA: U.S. Geologic Survey

Kane, J.W. & Tomer, A. (2019, May 10). Shifting into an era of repair” Us infrastructure spending trends. Brookings Institute. Retrieved 18 March 2020 from https://www.brookings.edu/research/shifting-into-an-era-of-repair-us-infrastructure-spending-trends/

Kashian, R. & Winden, M. (2015). *An Assessment of Lakefront Property Values Based on a Decline in Water Levels: It's Impact on Value and Taxes*. Fiscal and Economic Research Center, University of Wisconsin. Retrieved 17 August 2020 from https://rkld.org/wp-content/uploads/2015/05/Kashian-UW-W-Economic-Report-3-29-15.pdf

Ke, Y., Wang, S., & Chan, A. P. (2010). Risk allocation in public-private partnership infrastructure projects: comparative study. *Journal of Infrastructure Systems*, *16*(4), 343-351. DOI: 10.1061/(ASCE)IS.1943-555X.0000030

Kim, Y., Kang, N., Jung, J., & Kim, H. S. (2016). A review on the management of water resources information based on big data and cloud computing. *Journal of Wetlands Research*, *18*(1), 100-112.

Kiparsky, M., Sedlak, D. L., Thompson Jr, B. H., & Truffer, B. (2013). The innovation deficit in urban water: the need for an integrated perspective on institutions, organizations, and technology. *Environmental engineering science*, *30*(8), 395-408. https://doi.org/10.1089/ees.2012.0427

Klein, P.G. (1998). New institutional economics. *Encyclopedia of Law and Economics*. Bouckeart, B. & De Geest, G. (eds). Cheltenham, UK: Edward Elgar Publishing Limited.

Kline, S. (2017). The public-private partnership challenge in the US. *Bipartisan Policy Center*. Retrieved 18 March 2020 from https://bipartisanpolicy.org/blog/the-public-private-partnership-challenge-in-the-us/

Koo, D., Piratla, K., & Matthews, C. J. (2015). Towards sustainable water supply: schematic development of big data collection using internet of things (IoT). *Procedia engineering*, *118*, 489-497.

Koppenjan, J.F.M.V. (2015). PPPs for Green Infrastructures: Tensions and Challenges. *Current Opinion in Environmental Sustainability*, *12*(30), 30-34. DOI: 10.1016/j.cosust.2014.08.010

Koppenjan, J. F. M., & Enserink, B. (2009). Public-Private Partnerships in Urban Infrastructures: Reconciling Private Sector Participation and Sustainability. *Public Administration Review*, *69*(2), 284–296. https://doi.org/10.1111/j.1540-6210.2008.01974.x

Korayem, I. M., & Ogunlana, S. O. (2019). The "Water-Specific PPP Risk Model": A Case Study in Egypt. In Clark, R.M. & Hakim, S. (eds), Public Private Partnerships: Construction, protection and rehabilitation of critical infrastructures. Cham, Switzerland: Springer International Publishing

Krueger, E. H., Borchardt, D., Jawitz, J. W., & Rao, P. S. C. (2020). Balancing security, resilience, and sustainability of urban water supply systems in a desirable operating space. *Environmental Research Letters*. https://iopscience.iop.org/article/10.1088/1748-9326/ab6c2d

Kumaraswamy, M., Zou, W., & Zhang, J. (2015). Reinforcing relationships for resilience–by embedding end-user 'people'in public–private partnerships. *Civil Engineering and Environmental Systems*, *32*(1-2), 119-129.

Kythreotis, A. P., & Bristow, G. I. (2017). The 'resilience trap': exploring the practical utility of resilience for climate change adaptation in UK city-regions. *Regional Studies*, *51*(10), 1530-1541.

Lach, D., & Rayner, S. (2017). Are forecasts still for wimps?. *Journal of the Southwest*, *59*(1), 245-263. https://muse.jhu.edu/article/664806/pdf

Lach, D.; Ingram, H.; Rayner, S. (2005). Maintaining the status quo: How institutional norms and practices create conservative water organizations. *Texas Law Review, 83(7)*, 2027-2054

Lake Mission Viejo [LMV]. (2015) Lake refill option selected: Advanced Purified Water Plan Moves Forward. Lake Mission Viejo Association Newsletter, June 2015.

Lake Mission Viejo [LMV]. (n.d.-a). History of LMVA. Retrieved 18 February 2020 from https://lakemissionviejo.org/133/History-of-LMVA

Lambert, S. (2013, March 1). Big deal: Public-private concession brings relief to struggling water wastewater system. Water World. Retrieved 6 January 2020 from https://www.waterworld.com/drinking-water/distribution/article/16190868/big-deal-publicprivate-concession-brings-relief-to-struggling-water-wastewater-system

Lawson, E., Farmani, R., Woodley, E., & Butler, D. (2020). A Resilient and Sustainable Water Sector: Barriers to the Operationalisation of Resilience. *Sustainability*, *12*(5), 1797.

Le Maître, D. & O'Farrell, P.J. (2008). Social-ecological resilience in a dry environment. People and water resources in the Little Karoo. In Michael Burns & Alex Weaver (eds.), *Exploring sustainability science: A Southern African perspective* (pp. 339-383). African Sun Media.

Lebeck, S.(2018, May 1). Toward a playbook for public-private partnerships. *GreenBiz*. Retrieved 8 August 2019 from https://www.greenbiz.com/article/toward-playbook-public-private-partnerships

Lee, A. (2019, February 7). The cost of doing nothing: Why investing in our Nation's infrastructure cannot wait. Written Testimony of Ms. Angele Lee, Director of Charlotte Water, North Carolina before the Committee on Transportation & Infrastructure, United States House of Representatives. The Water Environment Federation | The National Association of Clean Water Agencies. Retrieved from https://docs.house.gov/meetings/PW/PW00/20190207/108831/HHRG-116-PW00-Wstate-LeeA-20190207.pdf

Leigland, J. (2018). Public-Private Partnerships in Developing Countries: The Emerging Evidence-based Critique. The World Bank Research Observer, 33(1), 103–134. https://doi.org/10.1093/wbro/lkx008

Lew, A. A., Ng, P. T., Ni, C. C., & Wu, T. C. (2016). Community sustainability and resilience: Similarities, differences and indicators. *Tourism Geographies*, *18*(1), 18-27.

Lewis, R. C., Johns, L. E., & Meeker, J. D. (2015). Serum biomarkers of exposure to perfluoroalkyl substances in relation to serum testosterone and measures of thyroid function among adults and adolescents from NHANES 2011–2012. *International journal of environmental research and public health*, *12*(6), 6098-6114. https://doi.org/10.3390/ijerph120606098

Li, B. Akintoye, A., Edwards, P.J., & Hardcastle, C. (2005). The Allocation of Risk in PPP/PFI Construction Projects in the UK. *International Journal of Project Management*, *23*(1), 25-35. DOI: 10.1016/j.ijproman.2004.04.006

Liu, T., & Wilkinson, S. (2011). Adopting innovative procurement techniques: obstacles and drivers for adopting public private partnerships in New Zealand. *Construction Innovation*, *11*(4), 452-469.

Liu, J., Love, P.E.D., Smith, J., Davis, P. (2014). Life-Cycle Critical Success Factors for Public-Private Partnership Infrastructure Projects. *Journal of Management in Engineering*, *31*, 401-407. Doi: 10.1061/(ASCE)ME.1943-5479.0000307, Lloyd Owen, D. A. (2016). Public–private partnerships in the water reuse sector: a global assessment. *International Journal of Water Resources Development*, *32*(4), 526-535. https://doi.org/10.1080/07900627.2015.1137211

Lopez, J. (n.d.) Developing innovative, data-driven watershed solutions. Moulton Niguel Water District. Retrieved from https://www.waterboards.ca.gov/water_issues/programs/stormwater/storms/docs/seminars/1_mnwd_joone_lopez.pdf

Lopez, A., & Haines, S. (2017). Exploring the usability of probabilistic weather forecasts for water resources decision-making in the United Kingdom. *Weather, Climate, and Society*, *9*(4), 701-715.

Lowrey, J. L., Ray, A. J., & Webb, R. S. (2009). Factors influencing the use of climate information by Colorado municipal water managers. *Climate Research*, *40*(1), 103-119.

Loxley, J. (2013). Are public–private partnerships (PPPs) the answer to Africa's infrastructure needs? *Review of African Political Economy, 40*(137), 485-495. doi: 10.1080/03056244.2013.817091

Lund, J. (2018, March 26). California's water data problems are symptoms of inchoate science and technical activities. *California Water Blog.* Retrieved 5 April 2020 from https://californiawaterblog.com/2018/03/26/californias-water-data-problems-are-symptoms-of-inchoate-science-and-technical-activities/

Lund, J. Medellin-Azuara, J., Durand, J. Stone, K.. (2018). Lessons from California's 2012–2016 Drought. *Journal of Water Resources Planning and Management*, *144*(10). https://ascelibrary.org/doi/full/10.1061/%28ASCE%29WR.1943-5452.0000984

Mahoney, J. (2000). Path dependence in historical sociology. *Theory and Society*, *29*(4), 507-548.

Makovšek, D., & Moszoro, M. (2018). Risk pricing inefficiency in public–private partnerships. *Transport Reviews*, *38*(3), 298–321. https://doi.org/10.1080/01441647.2017.1324925

Mann, T. & Hughes, s. (2017, September 26). Lawmakers" Trump calls public-private infrastructure partnerships 'more trouble than they're worth.' *The Wall Street Journal*. Retrieved 3 February 2020 from https://www.wsj.com/articles/lawmakers-trump-calls-public-private-infrastructure-partnerships-more-trouble-than-theyre-worth-1506471610

Mao, F., Clark, J., Karpouzoglou, T., Dewulf, A., Buytaert, W., & Hannah, D. (2017). HESS Opinions: A conceptual framework for assessing socio-hydrological resilience under change. *Hydrology & Earth System Sciences*, *21*(7).

Marana, P., Labaka, L., & Sarriegi, J. M. (2018). A framework for public-private-people partnerships in the city resilience-building process. *Safety science*, *110*, 39-50.

Marchese, D., Reynolds, E., Bates, M. E., Morgan, H., Clark, S. S., & Linkov, I. (2018). Resilience and sustainability: Similarities and differences in environmental management applications. *Science of the Total Environment*, *613*, 1275-1283.

Markus, M.R. (2014, April 29). Response to Comments on Orange County Water District January 2014 Poseidon Resources Huntington Beach Ocean Desalination Project Information Report. Retrieved 23 March 2020 from https://www.ocwd.com/media/4594/residents-for-responsible-desalination-04292014.pdf\

Markus, M.R. & Torres, E. (n.d.). How to overcome public perception issues on potable reuse projects. Orange County Water District. Retrieved 22 August 2020 from https://www.ocwd.com/media/7984/gwrs-outreach.pdf

Marlow, D. R., Moglia, M., Cook, S., & Beale, D. J. (2013). Towards sustainable urban water management: A critical reassessment. *Water Research*, *47*(20), 7150-7161.

Matos-Castaño, J., Mahalingham, A., Dewulf, G. (2014). Unpacking the path-dependent process of institutional change for PPPs. *Australia Journal of Public Administration, 73*(1), 47-66. https://doi.org/10.1111/1467-8500.12062

McLennan, E. & Maclean, F. (2019). *Public Private-partnerships (PPPs): An industry perspective on their role as drivers of infrastructure resilience.* Briefing Paper. UK: Arup and Resilience Shift.

McQuaid, R. W., & Scherrer, W. (2010). Changing reasons for public–private partnerships (PPPs). *Public Money & Management*, *30*(1), 27-34. doi: 10.1080/09540960903492331

Medema, W., McIntosh, B. S., & Jeffrey, P. J. (2008). From premise to practice: a critical assessment of integrated water resources management and adaptive management approaches in the water sector. Ecology and Society, 13(2).

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38-49. https://doi.org/10.1016/j.landurbplan.2015.11.011

Meijerink, S., and D. Huitema. 2010. Policy entrepreneurs and change strategies: lessons from sixteen case studies of water transitions around the globe. *Ecology and Society*, *15*(2): 21.

Mert, A., & Dellas, E. D. (2012). Assessing the legitimacy of technology transfer through partnerships for sustainable development in the water sector. In P. H. Pattberg, F. Biermann, S. Chan, & A. Mert (Eds.), *Public-private Partnerships for Sustainable Development. Emergence, Influence and Legitimacy* (pp. 209-238). Cheltenham, UK: Edward Elgar.

Metropolitan Water District of Southern California. (2019). Water rates and charges. Retrieved 24 December 2019 from http://www.mwdh2o.com/WhoWeAre/Management/Financial-Information/Pages/default.aspx

Metropolitan Water District (MWD). (2018). Metropolitan facts. Retrieved from http://www.mwdh2o.com/PDF_NewsRoom/6.4.2_District_at_glance.pdf

Metropolitan Water District (MWD). (2015a). Overview. Retrieved from http://www.mwdh2o.com/WhoWeAre/Mission/Pages/default.aspx

Metropolitan Water District (MWD). (2015b). Sources of supply. Retrieved from http://www.mwdh2o.com/AboutYourWater/Sources%20Of%20Supply/Pages/default.aspx

Mitchell, D., Hanak, E., Baerenklau, K., Escriva-Bou, A., McCann, H., Pérez-Urdiales, M., & Schwabe, K. (2017). *Building drought resilience in California's cities and suburbs*. Public Policy Institute of California.

Moulton Niguel Water District. (2018). Memorandum of Understanding Memorandum of Understanding for Collaboration and Joint Analysis in Support of Surface Water Quality Enhancement in South Orange, California.

Moulton Niguel Water District. (2015). *2015 Urban water management Plan.*

Moulton Niguel Water District. (n.d.-a). About MNWD. Retrieved 3 February 2020 from https://www.mnwd.com/aboutmnwd/

Moulton Niguel Water District (MNWD). (n.d.-b). Water, Recycled Water, & Wastewater Operations. Retrieved 10 February 2020 from https://www.mnwd.com/operations/

Mount, J. & Hanak, E. (2019). Water use in California. Public Policy Institute of California (PPIC). Retrieved 22 August 2020 from https://www.ppic.org/publication/water-use-in-california/

Mount, J. Hanak, E., Baerenklau, K., Butsic, V., Chappelle, C. Excriva-Bou, A. …. & Xu, Z. (2018). *Managing drought in a changing climate: Four essential reforms*. San Francisco, CA: Public Policy Institute of California.

Moy de Vitry, M., Schneider, M. Y., Wani, O. F., Manny, L., Leitão, J. P., & Eggimann, S. (2019). Smart urban water systems: what could possibly go wrong?. *Environment, al Research Letters*, *14*(8), 081001.

Mu, R., De Jong, M., & Koppenjan, J. (2011). The rise and fall of Public–Private Partnerships in China: a path-dependent approach. *Journal of Transport Geography*, *19*(4), 794-806. https://www.sciencedirect.com/science/article/pii/S0966692310001602

Mukherjee, M. (n.d.) Collaborative spatial temporal solutions to stormwater challenges. Retrieved from https://s3.amazonaws.com/dntstatic//374725d7-6c17-4583-667b-c20e1f004ebb

Muller, M. (2018). Cape Town's drought: Don't blame climate change. *Nature*, *559*, 174-176.

Municipal Water District of Orange County (MWDOC). (2017). Orange County Water Supply. Retrieved 19 April 2020 from https://www.mwdoc.com/wp-content/uploads/2017/05/Water-Supply-1.pdf

Municipal Water District of Orange County (MWDOC). (n.d.). Orange County Water Supply Sources in Ficasl Year 2018/2019. Retrieved 11 May 2020 from https://www.mwdoc.com/orange-county-water-supply-sources/

National Institute of Health. (2020, April 17). NIH to launch public-private partnership to speed COVID-19 vaccine and treatment options. Retrieved 14 August 2020 from https://www.nih.gov/news-events/news-releases/nih-launch-public-private-partnership-speed-covid-19-vaccine-treatment-options

National League of Cities. (2020, April 29). How COVID-19 Will Reshape Public-Private Partnerships. Retrieved 14 August 2020 from https://citiesspeak.org/2020/04/29/how-covid-19-will-reshape-public-private-partnerships/

National Parks Conservation Association (NCPA). (2019, April 16). Science confirms Cadiz Water Project would harm the largest spring in the Mojave Trails National Monument. Retrieved 19 December 2019 from https://www.npca.org/articles/1810-science-confirms-cadiz-water-project-would-harm-the-largest-spring-in

National Research Council (NRC) (2004). *Adaptive Management for Water Resources Project Planning*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10972.

National Security Strategy (2010, May). Retrieved 8 April 2020 from https://obamawhitehouse.archives.gov/sites/default/files/rss_viewer/national_security_strategy.pdf

Navigant Consulting, Inc & HDR Engineering Inc.. (2015). Embedded energy plan final report. Retrieved 1 November 2019 from https://www.irwd.com/images/pdf/doing-business/energy-programs/1.%20Embedded%20Energy%20Plan%20-%20Final%20Report.pdf

Newhart, K. B., Holloway, R. W., Hering, A. S., & Cath, T. Y. (2019). Data-driven performance analyses of wastewater treatment plants: A review. *Water research*, *157*, 498-513

Newmeyer, T. & Paletta, D. (2017, September 26). Trump backs off vow that private sector should help pay for infrastructure package. *The Washington Post.* Retrieved 1 February 2020 from https://www.washingtonpost.com/powerpost/trump-backs-off-vow-that-private-sector-should-help-pay-for-infrastructure-package/2017/09/26/02dd02f6-a327-11e7-ade1-76d061d56efa_story.html

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American journal of community psychology*, *41*(1-2), 127-150.

Ng, A., & Loosemore, M. (2007). Risk allocation in the private provision of public infrastructure. *International Journal of Project Management*, *25*(1), 66–76. https://doi.org/10.1016/j.ijproman.2006.06.005

Nisar, T.M. (2007). Risk Management in Public-Private Partnerships Contracts. *Public Organization Review*, *7*, 1-19. DOI: 10.1007/s11115-006-0020-1

Nizkorodov, E. (2017). *Closing the Infrastructure Gap? The Role of Public-Private Partnerships in Water Sector Development and the Economic, Political, and Social Factors that Determine Project Success*. Master's Thesis, University of California Irvine.

Noble, G., & Jones, R. (2006). The role of boundary-spanning managers in the establishment of public-private partnerships. *Public administration*, *84*(4), 891-917.

Ocasio, K. M. N. (2015). Feeling Salty: Regulating Desalination Plants in the United States and Spain. *Cornell Int'l LJ*, *48*, 451.

Office of Governor Gavin Newsom. (2020, April 15). Governor Newsom Announces Cross-Sector Partnerships to Support Distance Learning and Bridge the Digital Divide. Retrived 7 May 2020 from https://www.gov.ca.gov/2020/04/20/governor-newsom-announces-cross-sector-partnerships-to-support-distance-learning-and-bridge-the-digital-divide/

Office of Governor Gavin Newsom. (2020, April 20). Governor Newsom Announces New Initiatives to Support California Workers Impacted by COVID-19. Retrieved7 May 2020 from https://www.gov.ca.gov/2020/04/15/governor-newsom-announces-new-initiatives-to-support-california-workers-impacted-by-covid-19/

Onyeneho, I.A. (n.d.) *Machine learning for water main pipe condition assessment*. Fracta

Ormerod, K. J., Redman, S., & Kelley, S. (2019). Public perceptions of potable water reuse, regional growth, and water resources management in the Reno-Sparks area of northern Nevada, USA. *City and Environment Interactions*, *2*, 100015.

Orange County Board of Supervisors. (2004). The Ranch Plan Planned Community program text. Retrieved 23 March 2020 from http://www.ocpublicworks.com/civicax/filebank/blobdload.aspx?BlobID=9252

Orange County Register. (2008, November 19). San Juan Capistrano takes over water-plant operations from business. *The Orange County Register*. Retrieved 25 August 2020 from https://www.ocregister.com/2008/11/19/san-juan-capistrano-takes-over-water-plant-operations-from-business/

Orange County Water District (OCWD). (2020, February 6). Water agencies in Orange County initiates steps to protect pubic health. OCWD.

Orange County Water District (OCWD). (2019). Addressing PFOA/PFOS in Orange County. OCWD.

Orange County Water District (OCWD). (n.d.). How water works in Orange County. Retrieved from https://www.ocwd.com/learning-center/how-water-works-in-oc/

Orange County Water District (OCWD) & Poseidon Resources (Surfside) LLC. (2018, June 6). Term Sheet Water Reliability Agreement. Huntington Beach Seawater Desalination Project.

Osei-Kyei, R. & Chan, A.P.C. (2015). Review of Studies on the Critical Success Factors for Public-Private Partnership (PPP) projects from 1990 to 2013. *International Journal of Project Management*, *33*, 1334-1346. DOI: 10.1016/j.ijproman.2015.02.008

Pahl-Wostl, C. (2008). Requirements for adaptive water management. In C. Pahl-Wostl, P. Kabat, & J. Moltgen Eds.), Adaptive and integrated water management (pp. 1-22). Springer, Berlin, Heidelberg.

Pahl-Wostl, C. Sendzimir, J., Jeffrey, P, Jeroen, A., Berkamp, G., & Cross, K. (2007). Managing change toward adaptive water management through social learning. *Ecology and Society*, *12*(2), 30.

Pannu, C. (2012). Drinking water and exclusion: A case study from California's Central Valley. *California Law Review*, *100*(1), 223-268.

Parks, R., Mclaren, M., Toumi, R., Rivett, U. (2019). Experiences and lessons in managing water from Cape Town. *Grantham Institute Briefing Paper, No. 29*

Patil, N.A., Tharun, D., & Laishram, B. (2015). Infrastructure development through PPPs in India: Criteria for sustainability assessment. *Journal of Environmental Planning and Management*, *59*(4), 708-729. DOI: 10.1080/09640568.2015.1038337

Patterson, L., Doyle, M., & Gershuny, G. (2019). Building an Internet of Water - A report from the 2017 to 2019 Internet of Water roundtables. The Aspen Institute.

Pattberg, P. Biermann, F., Chan, S. & Mert, A. (Eds.), *Public-private Partnerships for Sustainable Development. Emergence, Influence and Legitimacy* (pp. 209-238). Cheltenham, UK: Edward Elgar.

PERC Water Corporation. (2015, February 12). Santa Paula Water Recycling Facility Awarded Plant of the Year. *CISION PR Newswire*. Retrieved 8 April 2020 from https://www.prnewswire.com/news-releases/santa-paula-water-recycling-facility-awarded-plant-of-the-year-300034584.html

PERC Water Corporation. (n.d.). Case Study: Santa Paula Water Recycling Facility. *Water Online*. Retrieved from https://www.wateronline.com/doc/case-study-santa-paula-water-recycling-0001

Pessoa, A. (2010). Reviewing PPP Performance in Developing Economies. In G. Hodge, Greve, C., & Boardman, A (Ed.), *International Handbook on Public Private-Partnerships (PPPs).* Cheltenham, UK: Edward Elgar Publishing Limited.

Peters, B.G. (2019). *Institutional theory in political science. The New Institutionalism*. 4th Edition. Cheltenham, UK | Northampton, USA: Edward Elgar Publishing

Phillips, E. E. (2013, June 20). Water plant’s long journey. *The Wall Street Journal*. Retrieved 1 November 2019 from https://www.wsj.com/articles/SB10001424127887324049504578545661598973132

Phillips, A.M. & Pesce, A. (2019, October 14). California finds widespread water contamination of ‘forever chemicals.’ *Los Angeles Times*. Retrieved 1 April 2020 from https://www.latimes.com/politics/story/2019-10-10/california-finds-widespread-contamination-of-chemicals

Pho, B. (2020, August 7). Water Officials Push Back Decision on Huntington Beach Desal Project Yet Again. *Voice of OC*. Retrieved 25 August 2020 from https://voiceofoc.org/2020/08/water-officials-push-back-decision-on-huntington-beach-desal-project-yet-again/

Phua, F.T.T. (2004). Modeling the Determinants of Multi-Firm Project Success: a Grounded Exploration of Different Participant Perspectives. *Construction Management Economics, 41*(4), 507-531

Pierce, G., Chow, N., Gmoser-Daskalakis, K., Roquermore, P., & Heil, N. (2019). *Analyzing Southern California supply investments from a human right to water perspective: The proposed Poseidon Ocean Water Desalination Plant in Orange County*. Los Angeles, CA: UCLA Luskin Center for Innovation.

Pincetl, S., Porse, E., Mika, K. B., Litvak, E., Manago, K. F., Hogue, T. S., ... & Gold, M. (2019). Adapting Urban Water Systems to Manage Scarcity in the 21st Century: The Case of Los Angeles. *Environmental management*, *63*(3), 293-308.

Pincetl. S., & Glickfeld, M. (2015). *Water management in Los Angeles County; A research report.* UCLA Institute of the Environment and Sustainability

Pincetl, S., & Hogue, T. S. (2015). California's new normal? Recurring drought: addressing winners and losers. Local Environment, 20(7), 850-854.

Pinter, N., Lund, J., & Moyle, P. (2019). The California water model: Resilience through failure. *Hydrological Processes, 33*, 1775-1779. DOI: 0.1002/hyp.13447

Pinz, A., Roudyani, N., & Thaler, J. Public-private partnerships as instruments to achieve sustainability-related objectives: the state of the art and a research agenda. *Public Management Review, 20*(1), 1-22. DOI: 10.1080/14719037.2017.1293143

Ponce Romero, J. M., Hallett, S. H., & Jude, S. (2017). Leveraging big data tools and technologies: addressing the challenges of the water quality sector. *Sustainability*, 9(12), 2160.

Porse, E., Mika, K. B., Litvak, E., Manago, K. F., Hogue, T. S., Gold, M., ... & Pincetl, S. (2018). The economic value of local water supplies in Los Angeles. *Nature Sustainability*, *1*(6), 289-297. https://**doi**.org/10.1038/s41893-018-0068-2

Posedion Water. (n.d.). Environmental Stewardship. Retrieved 4 June 2020 from https://www.poseidonwater.com/environmental-stewardship.html

Poston, B. & Stevens, M. (2015, Feb 16). L.A.'s aging water pipes; a $1-billion dilemma. *The Los Angeles Times*. Retrieved 4 February 2020 from https://graphics.latimes.com/la-aging-water-infrastructure/

Powell, W. W., & DiMaggio, P. J. (Eds.). (1991). *The new institutionalism in organizational analysis*. University of Chicago press.

PPP Knowledge Lab. (2019). Benefits and pitfalls of unsolicited proposals. World Bank Group. Retrieved 20 December 2019 from https://pppknowledgelab.org/guide/sections/79-benefits-and-pitfalls-of-unsolicited-proposals

Presidential Policy Directive / PPD-21. (2013, February 21) Policy Directive -- Critical Infrastructure Security and Resilience. Retrieved 8 April 2020 from https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil

Presidential Policy Directive / PPD-8. (2011, March 30). Policy Directive – National Preparedness. Department of Homeland Security. Retrieved 8 April 2020 from https://www.dhs.gov/presidential-policy-directive-8-national-preparedness

Private Participation in Infrastructure (PPI). (2020). Data Visualization. World Bank Group. Retrieved 10 June 2020 from https://ppi.worldbank.org/en/visualization

Probe Research Inc. (2014). *2014 Water issues public opinion poll.* San Diego, CA: SDCWA.

Public-Private Infrastructure Advisory Facility (PPIAF). 2009. *Overview of PPP experience. Historical Context.* https://ppiaf.org/sites/ppiaf.org/files/documents/toolkits/highwaystoolkit/6/pdf-version/1-21.pdf

Pusok, K. (2016). Public-private partnerships and corruption in the water and sanitation sectors in developing countries. *Political Research Quarterly, 69*(4), 678-691. DOI: 10.1177/1065912916658552

PWC. (2016). Public-private partnerships in the US: The state of the market and the road ahead.

PwC Advisory LLC (2017). *Resilient infrastructure public-private partnerships (PPPs): Contracts and procurement. The case of Japan*. Tokyo, Japan: World Bank's Global Infrastructure Facility (GIF) Tokyo Disaster Risk Management (DRM) Hub and the Public-Private Infrastructure Advisory Facility (PPIAF)

Quiggin, J. (2005). Public-private partnerships: options for improved risk allocation. *Australian Economic Review*, *38*(4), 445.

Rabe, B. G. (1995). Integrated environmental permitting: Experience and innovation at the state level. *State & Local Government Review*, 209-220.

Rasche, A., Morsing, M., & Wetter, E. (2019). Assessing the legitimacy of "open" and "closed" data partnerships for sustainable development. *Business & Society*, 0007650319825876.

Rasekh, A., Hassanzadeh, A., Mulchandani, S., Modi, S., & Banks, M. K. (2016). Smart water networks and cyber security. *Journal of Water Resources Planning and Management, 142*(7)

Rea & Parker Research. (2012). San Diego County Water Authority 2012 Public Opinion Poll Report. Retrieved 4 May 2020 from https://www.sdcwa.org/public-opinion-research

Rea & Parker Research. (2004). San Diego County Water Authority 2004 Telephonic Public Opinion and Awareness Survey. Retrieved 4 May 2020 from https://www.sdcwa.org/public-opinion-research

Reinhardt, W.G. (ed.). (2012). Carlsbad Desal Financial Closing. *Public Works Financing, December 2012*

Rendon, A. (2018, March 20). Speaker Rendon announces opposition to Cadiz Water Project. Retrieved 27 December 2019 from https://speaker.asmdc.org/press-releases/speaker-rendon-announces-opposition-cadiz-water-project

Residents for Responsible Desalination (R4RD). (n.d.) Responsible vs. irresponsible desalination chart. Retrieved 23 March 2020 from http://r4rd.org/about-residents-for-responsible-desalination/mission/

Ritchie, E.I. (2018, November 2). Lease for $330 million Dana Point Harbor renovation is inked. *The Orange County Register*. Retrieved 1 February 2020 from https://www.ocregister.com/2018/11/02/lease-for-330-million-dana-point-harbor-renovation-is-inked/

Rittel, H.W.J. & Webber, M.M. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 1973, 4*, 155-169. DOI: 10.1007/BF01405730

Rivard, R. (2017a, May 25). San Diegans pay some of the highest water rates in the state and the country. Voice of San Diego. Retrieved 1 November 2019 from https://www.voiceofsandiego.org/topics/government/san-diegans-pay-some-of-the-highest-water-rates-in-the-state-and-country/

Rivard, R. (2017b, August 29). Desal Plant Is Producing Less Water Than Promised. Retrieved 1 November 2019 from https://www.voiceofsandiego.org/topics/science-environment/desal-plant-producing-less-water-promised/

Rivard, R. (2016, August 30). The desalination plant is finished but the debate over it isn't. Retrieved 23 March 2020 from https://www.voiceofsandiego.org/topics/science-environment/desalination-plant-finished-debate-isnt/

Robinson, A. (2019, December 13). Top WOrkplaces 2019: Respect is key at Moulton Niguel Water District. *The Orange County Register*. Retrieved 3 February 2020 from https://www.ocregister.com/2019/12/13/top-workplaces-2019-respect-is-key-at-moulton-niguel-water-district/?fbclid=IwAR39Cx5asPY-LuCuBdb9UEhZgkI_JBe5w2CQ_ixtIoutG9jU_uXPhEvgznw

Rocha, L., & Porensky, A. (2020). Urban drool tool: integration water usage data with watershed data to engage the community in using water wisely. 2020 Water Data Science Symposium. Retrieved 2 August 2020 from https://www.youtube.com/watch?v=gr16yEPQgNk&feature=youtu.be&t=1483

Rock, M.K. & Saunier, C. (2019, January 16). Memorandum to the Honorable Mayor and Members of the City Council to Authorize the City Manager to Receive and File the Recycled Water Master Plan Update as Required by the Waste Discharge Requirement Permit for the Santa Paula Water Recycling Facility. City Council Meeting Agenda Item. Retrieved 22 March 2020 from http://santapaulaca.iqm2.com/Citizens/FileOpen.aspx?Type=1&ID=1376&Inline=True

Rodina, L. (2019). Defining "water resilience": Debates, concepts, approaches, and gaps. *Wiley Interdisciplinary Reviews: Water*, *6*(2), e1334

Rogers, P. (2014, May 29). Nation's largest ocean desalination plant goes up near San Diego; Future of California coast? *Mercury News*. Retrieved 1 November 2019 from https://www.mercurynews.com/2014/05/29/nations-largest-ocean-desalination-plant-goes-up-near-san-diego-future-of-the-california-coast/

Romero, M. (2015). G20's plan for infrastructure financing poses serious challenges to developing countries. Society for International Development. Retrieved 14 March 2020 from https://www.sidint.net/content/g20%E2%80%99s-plan-infrastructure-financing-poses-serious-challenges-developing-countries

Romm, J., Conrad, E., & Måren, I. E. (2018). Resilient Governance of Water Regimes in Variable Climates: Lessons from California's Hydro-Ecological Zones. *Water*, *10*(2), 196.

Roostaie, S., Nawari, N., & Kibert, C. J. (2019). Sustainability and resilience: A review of definitions, relationships, and their integration into a combined building assessment framework. *Building and Environment*, *154*, 132-144.

Ross, T. W., & Yan, J. (2015). Comparing Public–Private Partnerships and Traditional Public Procurement: Efficiency vs. Flexibility. *Journal of Comparative Policy Analysis: Research and Practice*, *17*(5), 448-466. doi: 10.1080/13876988.2015.1029333

Saari, L. (2018, April 2). Battle for Bolsa Chica: Dredging is needed to save the preserve, but who will pay for it? *Orange Coast*. Retrieved 29 February 2020 from https://www.orangecoast.com/essays/battle-bolsa-chica-dredging-needed-save-preserve-will-pay/

Sacramento Bee. (2016). Jeffrey Kightlinger, Gen. Mngr & CEO for Metro Water District, S. Ca, answers questions from Dan Morain and audience at Sacramento Bee. Retrieved from https://vimeo.com/174895102

San Diego County Water Authority (SDCWA). (2019a). Seawater desalination: The Claude "Bud" Lewis Desalination Plant and related facilities. Retrieved 13 November 2019 from https://www.sdcwa.org/sites/default/files/desal-carlsbad-fs-single.pdf

San Diego County Water Authority (SDCWA). (2019b, October 24). Positive operating performance boosts desal plant bond rating. SDCWA. Retrieved 29 May 2020 from https://www.sdcwa.org/positive-operating-performance-boosts-desal-plant-bond-rating

San Diego County Water Authority (SDCWA). (2014). Drought highlights value of diversification. Annual Report, 2014. Retrieved 11 May 2020 from https://www.sdcwa.org/annualreport/2014/water-supply-reliability

San Diego County Water Authority (SDCWA). (2004, July 22). Public opinion survey shows strong support for water supply diversification. Retrieved 29 February 2020 from https://carlsbaddesal.sdcwa.org/county-residents-strongly-support-seawater-desalination/

San Diego County Water Authority (SDCWA). (2002, November 14). Water Authority Board Approves Desalination Term Sheet. Retrieved 20 February 2020 from https://www.sdcwa.org/water-authority-board-approves-desalination-term-sheet

San Diego County Water Authority (SDCWA). (n.d.). Water supplies. Retrieved 15 March 2020 from https://www.sdcwa.org/water-supplies

SMWD. (2016, April 21). Lake Mission Viejo Advanced Purified Water Treatment Facility. Retrieved 18 February 2020 from https://watereuse.org/wp-content/uploads/2015/01/SMWD-Lake-Mission-Viejo-Advanced-Purified-Water-Treatment-Facility-2016-04-21.pdf

Santa Margarita water District (SMWD). (2015). *2015 Urban water management plan.* https://www.smwd.com/DocumentCenter/View/1823/2015-Urban-Water-Management-Plan

Santa Margarita Water District (SMWD). (2014). Santa Margarita Water District Comprehensive Annual Financial Report for the Fiscal Year Ended June 30, 2014. Retrieved 22 June, 2019 from https://www.ac.ocgov.com/wp-content/uploads/2017/08/Santa-Margarita-Water-District-6-30-14.pdfSanta Margarita Water District (SMWD). (2012a, December). Rising imported water costs result in rates increase. SMWD continues to seek efficiencies to contain price. *On Tap*. Retrieved 18 April 2020 from https://www.smwd.com/ArchiveCenter/ViewFile/Item/54

Santa Margarita Water District (SMWD). (2012b). Cadiz Water Conservation, Recovery, and Storage Project: Groundwater Monitoring Program. Retrieved 29 November 2019 from https://www.smwd.com/231/Cadiz-Project

Santa Margarita Water District (SMWD). (2012c). Cadiz Water Conservation, Recovery, and Storage Project: Stabilizing Rates. Retrieved 29 November 2019 from https://www.smwd.com/231/Cadiz-Project

Santa Margarita Water District (SMWD). (n.d.-a). About us. Retrieved 15 March 2020 from http://smwd.com/316/About-Us

Santa Margarita Water District. (n.d.-b) Trampas Canyon Reservoir & Dam. Retrieved 7 February 2020 from https://smwd.com/313/Trampas-Reservoir

Santa Margarita Water District. (n.d.-c). California's first recycled water recreational lake. Retrieved 16 February 2020 from http://www.smwd.com/333/Lake-Mission-Viejo-ATWF

Santa Margarita Water District (SMWD). (n.d.-d). Cadiz project. Retrieved 25 November 2019 from https://www.smwd.com/231/Cadiz-Project

Santa Margarita Water District (SMWD). (n.d.-e). Cadiz project - CEQA Documents. Retrieved 25 November 2019 from https://www.smwd.com/258/Cadiz-Project---CEQA-Documents

SMWD/Cadiz MOU (2011). Memorandum of Understanding by and among Santa Margarita Water District, Cadiz, Inc., and the County of San Bernardino related to the Cadiz Valley Water Conservation, Recovery, and Storage Project.

Santa Margarita Water District [SMWD] and Lake Mission Viejo Association [LMVA]. (2016, April 27). Agreement for facilities construction and purchase of advanced purified water.

Scheibe, J. (2013, September 16). Santa Paula, sewage plant operator square off over chloride levels in discharge. *Ventura County Star*. Retrieved 22 March 2020 from http://archive.vcstar.com/news/santa-paula-sewage-plant-operator-square-off-over-chloride-levels-in-discharge-ep-292320883-351603741.html/

Schmidt, V. A. (2010). Taking ideas and discourse seriously: explaining change through discursive institutionalism as the fourth 'new institutionalism'. *European Political Science Review*, *2*(1), 1-25. DOI: :10.1017/S175577390999021X

Schmidt, V. A. (2009). Comparative institutional analysis. In T. Landman, & N. Robinson (Eds.), *Handbook of Comparative Politics* (pp. 125-142). Thousand Oaks, CA: Sage.

Schmidt, V. A. (2008). Discursive institutionalism: The explanatory power of ideas and discourse. *Annual Review of Political Science, 11*, 303-326. DOI: 10.1146/annurev.polisci.11.060606.135342

Schoemaker, R. (2014). Institutional quality and private sector participation: theory and empirical findings. *European Journal of Government and Economics*, *3*(2), 105-118.

Schoeman, J., Allan, C., & Finlayson, C. M. (2014). A new paradigm for water? A comparative review of integrated, adaptive and ecosystem-based water management in the Anthropocene. *International Journal of Water Resources Development*, *30*(3), 377-390.

Schwarzenegger, A. (2010, May 10). Governor Schwarzenegger Applauds CTC Vote on Public-Private Partnership. Press Release. Retrieved 7 May 2020 from https://votesmart.org/public-statement/509244/governor-schwarzenegger-applauds-ctc-vote-on-public-private-partnership#.XrSKhmhKhPY

Scott, W. R. (2014). *Institutions and organizations: Ideas, interests, and identities*. 4th Edition. Los Angeles, CA | London, UK | New Delhi, India | Washington D.C.: SAGE Publications.

Sedlak, D. (2014). Water 4.0: The past, present and future of the world's most vital resource. Yale University Press.

Shaheen, S., Totte, H., & Stocker, A. (2018). Future of mobility. White paper. UC Berkley UConnect. Retrieved 19 April 2020 from https://escholarship.org/uc/item/68g2h1qv

Shambaugh, G. & Matthew, R. (2016). Sustaining public-private partnerships. In Matthew, R., Harron, C., Goodrich, K., Maharramli, B., & Nizkorodov, E. (Eds.), *The Social Ecology of the Anthropocene: Continuity and Change in Global Environmental Politics*. WSPC Reference on Natural Resource and Environmental Policy in the Era of Global Change. Volume 2. World Scientific Publishing Company.

Shueh, J. (2016, August 22). California Lt. Gov. Gavin Newsom Talks Transparency, Civic Tech, State IT Reforms. *Government Technology*. Retrieved 12 March 2020 from https://www.govtech.com/people/California-Lt-Gov-Gavin-Newsom-Talks-Transparency-Civic-Tech-State-IT-Reforms.html

Shapiro, H.-Y., & Rosenquist, E. M. (2004). Public/private partnerships in agroforestry: The example of working together to improve cocoa sustainability. *Agroforestry Systems, 61–62*(1–3), 453–462. https://doi.org/10.1023/B:AGFO.0000029025.08901.9c

Shen, L. Y., Platten, A., & Deng, X. P. (2006). Role of public private partnerships to manage risks in public sector projects in Hong Kong. *International journal of Project management*, *24*(7), 587-594. DOI: 10.1016/j.ijproman.2006.07.006

Sherman, L., Cantor, A., Milman, A., & Kiparsky, M. (2020). Examining the complex relationship between innovation and regulation through a survey of wastewater utility managers. *Journal of Environmental Management*, *260*, 110025.

Shimura, T. (2015, May 20). The pressure's on: No more drinking water to fill up Lake Mission Viejo. *The Orange County Register*. Retrieved 17 August 2020 from https://www.ocregister.com/2015/05/20/the-pressures-on-no-more-drinking-water-to-fill-up-lake-mission-viejo/

Shrestha, A., Chan, T.-K., Aibinu, A. A., & Chen, C. (2017). Efficient risk transfer in PPP wastewater treatment projects. *Utilities Policy*, *48*, 132–140. https://doi.org/10.1016/j.jup.2017.03.003

Shrodes, N. (2019, November 11). Rally Alert: Last Chance to Oppose Ocean Desal in LA. *Heal the Bay*. Retrieved 14 July 2020 from https://healthebay.org/oppose-ocean-desalination-in-la/

Shukla, S., Safeeq, M., AghaKouchak, A., Guan, K., & Funk, C. (2015). Temperature impacts on the water year 2014 drought in California. *Geophysical Research Letters, 42*(11), 4384-4393. DOI: 10.1002/2015GL063666

Siemiatycki, M. (2011). Urban Transportation Public-Private Partnerships: Drivers of Uneven Development? *Environment and Planning A, 43*(7), 1707-1722. DOI: 10.1068/a43572

Skelcher, C. & Sullivan, H. (2008). Theory Driven Approaches to Analyzing Collaborative Performance. *Performance Management Review, 10*(6) ,751-777. DOI: 10.1080/14719030802423103

Smith, H. M. (2014). 33. Understanding resilience: Implications for the water sector. *Global Water: Issues and Insights, 193*.

Som, R. M., Omar, Z., Ismail, I. A., & Alias, S. N. (2020). Understanding leadership roles and competencies for public-private partnership. *Journal of Asia Business Studies*.

Sorensen, A. (2015). Taking path dependence seriously: an historical institutionalist research agenda in planning history. *Planning Perspectives*, *30*(1), 17-38.

Southern California Edison (SCE). (2020). Leading the deployment of battery storage. Retrieved 5 May 2020 from https://www.edison.com/home/innovation/energy-storage.html

Spang, E.S., Holguin, A.J. & Lodge, F.J. (2018). The estimated impact of California's urban water conservation mandate on electricity consumption and greenhouse gas emissions *Environmental Research Letters, 13*(1)

Storbjörk, S., Hjerpe, M., & Glaas, E. (2019). Using Public–Private Interplay to Climate-Proof Urban Planning? Critical Lessons from Developing a new Housing District in Karlstad, Sweden. *Journal of Environmental Planning and Management*, *62*(4), 568-585. DOI: 10.1080/09640568.2018.1434490

Spraul, K., & Thaler, J. (2019). Partnering for good? An analysis of how to achieve sustainability-related outcomes in public–private partnerships. *Business Research*, 1-27.

State Water Resources Control Board (2020a, February 6). Response Levels Lowered for Water Systems Statewide as PFAS Investigation Continues. Retrieved from https://www.waterboards.ca.gov/press_room/press_releases/2020/pr02062020_pfoa_pfos_response_levels.pdf

State Water Resources Control Board (2020b). Per- and Polyfluoroalkyl Substances (PFAS). Retrieved 3 April 2020 from https://www.waterboards.ca.gov/water_issues/programs/pfas/

State Water Resources Control Board (SWRCB). (2019). Options for implementation of a statewide low-income water rates assistance program.

State Water Resources Control Board (SWRCB). (1977, March 2). In the matter of alleged waste, unreasonable use, method of use, or method of diversion of water by Mission Viejo Company. Decision directing prevention of water and unreasonable use of water. Decision 1463.

Steinberg, J. (2011c, June 18). Privatizing water. *San Gabriel Valley Tribune*. Retrieved 6 January 2020 from https://www.sgvtribune.com/2011/06/18/privatizing-water/

Stevens, M. (2014, October 30). Lake Mission Viejo isn't feeling California drought, yet. Retrieved 17 February 2020 from https://www.latimes.com/local/orangecounty/la-me-lake-mission-viejo-20141030-story.html

Stevens, A. & Chong, W. (n.d.). California is no stranger to dry conditions, but the drought from 2011-2017 was exceptional. Drought.gov. Retrieved 18 February 2020 from https://www.drought.gov/drought/california-no-stranger-dry-conditions-drought-2011-2017-was-exceptional

Strickland, W. (2012, May 7). Introduction to the California Infrastructure Finance Act. Private Water Law. Retrieved 12 March 2020 from https://privatewaterlaw.com/2012/05/07/introduction-to-the-california-infrastructure-finance-act/

Strickland, W. (2011, February 11). California mutual water company basics. Private Water Law. Retrieved 12 March 2020 from https://privatewaterlaw.com/2011/02/18/california-mutual-water-company-basics/

Stringfellow, K. & Sizek ,J. (2018, February 5). The trouble with Cadiz. KCET. Retrieved 15 December 2019 from https://www.kcet.org/shows/artbound/the-trouble-with-cadiz

Sugg, Z. (2018, July 31). Assembly Bill 1755 and the politics of California water data. Water in the West. Retrieved 5 April 2020 from https://waterinthewest.stanford.edu/news-events/news-insights/assembly-bill-1755-and-politics-california-water-data

Sundararajan, S., & Suriyagoda, N. (2016). *Climate Risks and Resilience in Infrastructure PPPs*: *Issues to be Considered*. Public-Private Infrastructure Advisory Facility, World Bank Group.

Surfrider Foundation (2015, December 10). Carlsbad desalination plant opening: The wrong solution at the wrong time. Retrieved 20 November 2019 from https://www.surfrider.org/press-center/entry/carlsbad-desalination-plant-opening-the-wrong-solution-at-the-wrong-time?gclid=EAIaIQobChMI36jUiJqN5%E2%80%A6

Susha, I. (2020). Establishing and implementing data collaborations for public good: A critical factor analysis to scale up the practice. *Information Polity*, (Preprint), 1-22. https://content.iospress.com/articles/information-polity/ip180117

Susha, I., Grönlund, Å., & Van Tulder, R. (2019). Data driven social partnerships: Exploring an emergent trend in search of research challenges and questions. *Government Information Quarterly*, *36*(1), 112-128. https://doi.org/10.1016/j.giq.2018.11.002

Susha, I., Janssen, M., & Verhulst, S. (2017a). Data Collaboratives as a New Frontier of Cross-Sector Partnerships in the Age of Open Data: Taxonomy Development. Proceedings of the 50th Hawaii International Conference on System Sciences, 2691-2700.

Susha, I., Janssen, M., & Verhulst, S. (2017b). Data collaboratives as “bazaars”?. A review of coordination problems and mechanisms to match demand for data with supply. *Transforming Government: People, Process and Policy*, 11(1), 157 – 172

Susha, R. & Gil-Garcia, J.R. (2019). A collaborative governance approach to partnerships addressing public problems with private data. In *Proceedings of the 52nd Hawaii International Conference on System Sciences*.

Sustain SoCal. (2020, July 16). Water resiliency through connectivity. *Community Teleconference Series*. Retrieved from https://sustainsocal.org/community-teleconference-series/

Table Rock (2019). Assessing Rialto at 5 Years. Retrieved 20 October 2019 from https://tablerockpartners.com/rialto-at-5-years/

Tahir, F., Baloch, A. A., & Ali, H. (2020). Resilience of Desalination Plants for Sustainable Water Supply in Middle East. In *Sustainability Perspectives: Science, Policy and Practice* (pp. 303-329). Springer, Cham. https://link.springer.com/chapter/10.1007/978-3-030-19550-2_15

Talbot, A. (2019). Urban water conservation in the Sacramento, California region during the 2014-2016 drought (Masters Thesis, University of California, Davis). Retrieved from https://watershed.ucdavis.edu/shed/lund/students/AmyTalbot2019.pdf

Taylor, A. Miller, Z., Colvin. J., & Mascaro, L. (2020, March 13). Trump declares national emergency, announces public-private partnership to expand coronavirus testing. *Fortune*. Retrieved 18 March 2020 from https://fortune.com/2020/03/13/trump-declares-national-emergency-over-coronavirus/

Taylor, B. M., & Harman, B. P. (2016). Governing urban development for climate risk: What role for public–private partnerships? *Environment and Planning C: Government and Policy*, *34*(5), 927–944. https://doi.org/10.1177/0263774X15614692

Timmerman, J. G., Beinat, E., Termeer, K., & Cofino, W. (2010). Analyzing the data-rich-but-information-poor syndrome in Dutch water management in historical perspective. *Environmental Management*, *45*(5), 1231-1242.

Tortajada, C., Kastner, M. J., Buurman, J., & Biswas, A. K. (2017). The California drought: Coping responses and resilience building. *Environmental Science & Policy*, *78*, 97-113.

Trangkanont, S., & Charoenngam, C. (2014). Critical failure factors of public-private partnership low-cost housing program in Thailand. *Engineering, Construction and Architectural Management*, *21*(4)

True North Research. (2019). *2019 Water issues public opinion poll.* San Diego, CA: SDCWA.

Uddameri, V. (2018). Big data, computing, and water resources hazards. *JAWRA Journal of the American Water Resources Association*, 54(4), 765-766.

Ulibarri, N. (2017). Does collaboration affect the duration of environmental permitting processes?. *Journal of Environmental Planning and Management, 61*(4), 617-634.

Ulibarri. N. (2015a). Tracing Process to Performance of Collaborative Governance: A Comparative Case Study of Federal Hydropower Licensing. *Policy Studies Journal, 43*(2): 283-308.

Ulibarri, N. (2015b). Collaboration in Federal Hydropower Licensing: Impacts on Process, Outputs, and Outcomes. *Public Performance and Management Review, 38*(4): 578-606

Ulibarri, N., & Tao, J. (2019). Evaluating environmental permitting process duration: the case of clean water act Section 404 permits. *Journal of Environmental Planning and Management*, *62*(12), 2124-2144.

Ulibarri, N., Cain, B. E., & Ajami, N. K. (2017). A framework for building efficient environmental permitting processes. *Sustainability*, *9*(2), 180.

United Nations. (2016). Sustainable Development Knowledge Platform. Retrieved 8 July 2016 from https://sustainabledevelopment.un.org/?menu=1300

United Nations Development Programme. (2006). *Decentralized governance of natural resources*. Kenya, UNDP.

United Stated Geological Survey (USGS). (2017 May 5). Letter to Senator Feinstein. Retrieved 24 December 2019 from https://www.feinstein.senate.gov/public/_cache/files/8/0/801e8535-fcf3-451c-846d-bba83576dd9e/3FB73610D2AEC2890FF68B0B680E5F44.2017.05.08-usgs-cadiz-recharge-rates.pdf

Vaitla, B. (2014). *The landscape of big data for development. Key actors and major themes research.* Data2x. https://data2x.org/wp-content/uploads/2019/09/LandscapeOfBigDataForDevelopment_10_28-1.pdf

Vale, L. J. (2014). The politics of resilient cities: whose resilience and whose city?. *Building Research & Information*, *42*(2), 191-201.

van den Hurk, M. (2018). Public–Private Partnerships: Where Do We Go From Here? A Belgian Perspective. *Public Works Management & Policy*, *23*(3), 274-294.

Varady, R. G., Zuniga-Teran, A. A., Garfin, G. M., Martín, F., & Vicuña, S. (2016). Adaptive management and water security in a global context: definitions, concepts, and examples. *Current opinion in environmental sustainability*, *21*, 70-77.

Ventura County Grand Jury. (2013). Final report on the Santa Paula Waste Water Treatment Plant. Retrieved 22 March 2020 from https://vcportal.ventura.org/GDJ/docs/reports/2012-13/Santa_Paula_Waste_Water_Treatment_Plant.pdf

Verhulst, S. Young, A., & Srinivasan, P. (n.d.). *An introduction to data collaboratives. Creating public value by exchanging data.* The Gov Lab. Retrieved 22 August 2020 from https://datacollaboratives.org/static/files/data-collaboratives-intro.pdf

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society*, *9*(2).

Walton, B. (2019, January 24). Water utilities call on Big Data to guide pipe replacements. *Circle of Blue*. Retrieved 27 March 2020 from https://www.circleofblue.org/2019/world/water-utilities-call-on-big-data-to-guide-pipe-replacements/

Ward, R.C., Loftis, J.C., & McBride, G.B. (1986). The “data-rich but information-poor” syndrome in water quality monitoring. *Environmental Management*, *10*(3), 291-297.

Wardekker, A. (2018). Resilience principles as a tool for exploring options for urban resilience. *Solutions*, *9*(1)

Water Data Advisory Council. (2019). Water data advisory council recommendations. Retrieved 7 July 2020 from https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/AB-1755/Water_Data_Advisory_Council_Recommendations.pdf

Water Industry News. (n.d.). Santa Paula PPP buyback leaves a sweet taste. Retrieved 21 March 2020 from http://waterindustry.com/New%20Projects/santa%20paula-1.htm

Water Online. (2005, March 4). New Reverse Osmosis Water Plant Is 'Declaration Of Independence' For San Juan Capistrano. *Water Online*. Retrieved 25 August 2020 from https://www.wateronline.com/doc/new-reverse-osmosis-water-plant-is-declaratio-0001

Water Purchase and Sale Agreement (WPASA). (2012, July 31). Retrieved 13 August 2019 from https://www.sdcwa.org/sites/default/files/files/waterpurchaseagreement.pdf

Wesoff, E. (2020, May 2). Southern California Edison wants its new, huge 770 MW battery storage procurement online fast. *PV Magazine.* Retrieved 5 May 2020 from https://pv-magazine-usa.com/2020/05/02/southern-california-edison-wants-huge-770-mw-battery-storage-procurement-online-fast/

Wharton, UPenn. (2015). A Tale of Two Public-Private Partnership Cities. Knowledge @ Wharton. Retrieved 21 November 2019 from https://knowledge.wharton.upenn.edu/article/a-tale-of-two-public-private-partnership-cities/

WhiteHouse.gov (2018, February 12). Remarks by President Trump in meeting with state and local officials on Infrastructure Initiative. Retrieved 1 February 2020 from https://www.whitehouse.gov/briefings-statements/remarks-president-trump-meeting-state-local-officials-infrastructure-initiative/

WRA Environmental Consultants (2019). Revised Poseidon Huntington Beach Desalination Facility Marine Life Mitigation Plan: Bolsa Chica. Retrieved 27 February 2020 from https://www.waterboards.ca.gov/santaana/water_issues/programs/Wastewater/Poseidon/2019/Appendix_TT3_Updated_Bolsa_Chica_MLMP.pdf

Weinberg, K. & McCraner, T. (2012). Staff Recommendation to the Board of Directors to adopt the resolution of the Water Purchase Agreement with Poseidon Resources (Channelside LP). San Diego County Water Authority. Retrieved from https://www.sdcwa.org/sites/default/files/files/water-management/desal/Special%20Board%20Meeting%20Desal%20Board%20Memo%2011-21.pdf

Weston, M. (2016a, July 11). There's More to Drought-Proofing Than Water Mandates. *Voice of San Diego.* Retrieved 23 March 2020 from https://www.voiceofsandiego.org/topics/opinion/theres-drought-proofing-water-mandates/

Weston, M. (2016b, August 15). Desalination plant's value to ratepayers is clear. *Voice of San Diego.* Retrieved 23 March 2020 from https://www.voiceofsandiego.org/topics/opinion/carlsbad-desalination-projects-value-to-ratepayers-is-clear/

Wettenhall, r. (2010). Mixes and partnerships through time. In G.A. Hodge, C. Greve, & A. E. Boardman (eds)., *International handbook on public-private partnerships*. Edward Elgar Publishing.

Wisckol, M. (2020, January 17). 'Forever chemicals' in Orange County drinking water to force widespread well closures. *Orange County Register*. Retrieved 3 April 2020 from https://www.ocregister.com/2020/01/17/forever-chemicals-in-orange-county-drinking-water-to-force-widespread-well-closures/

Wisckol, M. (2020, August 10). Poseidon's desalination plan for Huntington Beach delayed again. *The Orange County Register*. Retrieved 25 August 2020 from https://www.ocregister.com/2020/08/07/poseidons-desalination-plan-for-huntington-beach-delayed-again/

Wisckol, M. (2019, March 22). Poseidon optimism grows for desalination plant but several hurdles remain. The Orange County Register. Retrieved 17 November 2019 from https://www.ocregister.com/2019/03/22/poseidon-optimism-grows-for-desalination-plant-but-several-hurdles-remain/

Wisckol, M. (2018, May 1). Poseidon desalination plant: What to know about its pros and cons for Southern California water. *The Orange County Register*. Retrieved 17 November 2019 from https://www.ocregister.com/2018/05/01/what-to-know-about-the-poseidon-desalination-plant-and-its-pros-and-cons-for-southern-california-water/

Woetzel, J., Remes, J., Boland, B., Lv, K., Sinha, S., Strube, G., ... & Von der Tann, V. (2018). *Smart cities: Digital solutions for a more livable future*. New York, NY, USA: McKinsey Global Institute.

Wong, E. P. Y., de Lacy, T., & Jiang, M. (2012). Climate change adaptation in tourism in the South Pacific—Potential contribution of public–private partnerships. *Tourism Management Perspectives*, *4*, 136–144. https://doi.org/10.1016/j.tmp.2012.08.001

Wu, J. Public-Private Partnerships for Sustainable Construction Projects: Opportunities and Challenges. In *Proceeding of the 20th International Symposium on Advancement of Construction Management and Real Estate*. Ed. by Wu, Y., Zheng, S., Luo, J., Wang, W. Mo, Z., & Shan, L.

Wunderman, J. & Dunn, L. (2019, January 11). Public-private partnerships can help California get moving again. *The Orange County Register*. Retrieved 1 February 2020 from https://www.ocregister.com/2019/01/11/public-private-partnerships-can-help-california-get-moving-again/

Xu, L., Marinova, D., & Guo, X. (2015). Resilience thinking: a renewed system approach for sustainability science. *Sustainability Science*, *10*(1), 123-138.

Zetland, D. (2009). The End of Abundance: How Water Bureaucrats Created and Destroyed the Southern California Oasis. *Water Alternatives*, *2*(3), 349 - 365. http://www.water-alternatives.org/index.php/alldoc/articles/vol2/v2issue3/63-a2-3-4/file