Tapping the Oceans

The Political Ecology of Seawater Desalination and the Water-Energy Nexus in Southern California and Baja California

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Abstract

Notions of connectivity and relationality increasingly pervade theories, discourses and practices of environmental governance. Recently, the concept of the 'resource nexus' has emerged as an important new framework that emphasises the interconnections, tensions and synergies between sectors that have traditionally been managed separately. Part of a broader trend towards integrated environmental governance, nexus thinking rests on the premise that the challenges facing water, energy, food and other resources are inexorably connected and contingent. Although presenting itself as a radically new framework, the nexus discourse in current form is techno-managerial in character, profoundly de-politicising, and reinforces neoliberal approaches to environmental governance. At the same time, the 'material turn' in social science research has re-engaged ideas of social, political and material relationality to understand the complexity and heterogeneity of the socio-natural condition in the twenty-first century. Although theoretically and ontologically diverse, the fields of political ecology, assemblage thinking and infrastructure studies all critically interrogate the politics of relationality.

Mobilising an urban political ecology framework, and drawing on notions of emergence and distributed agency from assemblage thinking, this research examines the politics of the water-energy nexus through a critical analysis of the extraordinary emergence of seawater desalination as a significant new urban water supply for Southern California, USA, and Baja California, Mexico. Research was conducted in the San Diego–Tijuana metropolitan region, where a large desalting facility has recently been completed to supply San Diego with purified ocean water, and a larger 'binational' facility is planned in Mexico to supply both sides of the border. The research makes three broad contributions. First, to understand desalination as emerging from the historical coproduction and urbanisation of water and energy in the American West. Second, to examine the transitioning environmental politics concomitant with calls for greater understanding of interrelationality. And third, to interrogate the efficacy of technology in reconfiguring the co-constitution of water, energy and society.

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright statement

To my parents, Sue and Trevor.

Acknowledgements

Three year's work, compiled into a single document, does not of course, represent the efforts of a single person alone. Although it is my name on the title page, this thesis would not have been completed without the kind support of a great number of people. First and foremost, I would like to recognise Erik Swyngedouw and Stefan Bouzarovski, who have supervised and encouraged me in this endeavour. For supporting me, for challenging me intellectually, and for allowing me the freedom to pursue ideas –thank you! I would also like to thank all those who have given feedback on my work over the past three years, in particular, Jamie Doucette, Maria Kaika, Saska Petrova and Mark Usher. Furthermore, I would like to extend my gratitude to Tim Moss and James Evans for examining this thesis, and for their thoughtful and constructive comments. My studies and research were made possible by a doctoral scholarship from the School of Environment, Education and Development.

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Abbreviations

AF	. . . .	acre foot
ANT	. . . .	Actor Network Theory
APP	. . . .	Public-Private Contract of Association
BIR	. . . .	Baja Infrastructure Resources
BNWR	. . . .	Baja Norte Water Resources
CCC	. . . .	California Coastal Commission
CEC	. . . .	California Energy Commission
CESPT	. . . .	Comisión Estatal de Servicios Públicos de Tijuana
CFE	. . . .	Comisión Federal de Elecricidad
CPCFA	. . . .	California Pollution Control Financing Authority
CPUC	. . . .	California Public Utilities Commission
DPR	. . . .	Direct Potable Reuse
DWR	. . . .	Department of Water Resources
EIR	. . . .	Environmental Impact Report
GHG	. . . .	Greenhouse Gas
GWRS	. . . .	Groundwater Replenishment System
IBWC	. . . .	International Boundary and Water Commission
IDE	. . . .	Israel Desalination Enterprises
IID	. . . .	Imperial Irrigation District
IPR	. . . .	Indirect Potable Reuse
IWRM	. . . .	Integrated Water Resource Management
LADWP	. . . .	Los Angeles Department of Water and Power
MWD	. . . .	Metropolitan Water District of Southern California
ML	. . . .	mega litre
MFS	. . . .	Multi Stage Flash Distillation
NSC Agua	. . . .	Norte Sur Consolidated Agua
OCWD	. . . .	Norte Sur Consolidated Agua
PE	. . . .	Political Ecology
PPP	. . . .	Public-Private Partnership
RO	. . . .	Reverse Osmosis
ROGA	. . . .	Reverse Osmosis General Atomic
UNDP	. . . .	United Nations Development Programme
UPE	. . . .	Urban Political Ecology
SDCWA	. . . .	San Diego County Water Authority
SDG&E	. . . .	San Diego Gas and Electric Company
SEMARNAT	. . . .	Secretaria del Medio Ambiente y Recursos Naturales
STS	. . . .	Science and Technology Studies
SWP	. . . .	State Water Project
SWRCB	. . . .	State Water Resources Control Board
WPA	. . . .	Water Purchase Agreement

Water units

1 Gallon (US)	=	3.79 litres
1 cubic metre	=	1,000 litres
1 mega litre	=	1,000,000 litres
1 acre foot	=	325,851 Gallons
	=	1,233,489 litres
	=	1,233 m^3
	=	1.23 ML
1 million gallons/day	=	3,785,412 litres/day
	=	3,785 m^3/day
	=	3.79 ML/day
	=	1.38 cubic hectometres per year

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Desalting the Pacific

Water, energy, and the politics of relationality in California

The desalination assemblage

In the introduction to his seminal book, *California, The Great Exception*, originally published in 1949 to celebrate the hundred year anniversary of the California Constitution, Carey McWilliams reflects on the Golden State's illusionary status in the imagination of its people, and indeed of people around the world. "California," he writes, "has a meaning which is as clear today as when the word stood for a place not yet discovered" (McWilliams 1999, 3). This land isolated from the rest of North America by ocean, mountains, desert and forest has always stood for something not quite real; half promised land of abundance, half fantasy of what could be. It is a place where the raw, material primacy of economies is sharply clear, writ large in its history of resource booms and busts (Starr 1990), and where capital has forged extraordinary relations between people, technology and nature (Henderson 1998). A place where deserts bloom and rivers run dry, where national parks epitomise our delusions of pristine nature without human presence and where cities sprawl for hundreds of miles. Where water is piped laboriously over mountain ranges, and where rivers flow backwards out of the ocean. "California, which fools people into believing it is 'lush,'" Reisner (1986, 344) observes, "is a beautiful fraud." This mirage is created and sustained by a constant and extraordinary metabolic transformation of nature, mediated by mega infrastructures vast in scope and ambition, directed towards the re-ordering of nature and society towards the creation of a landscape where socio-material relationships are aligned under the logics of accumulation. In North America's desert southwest, the imperative of capital to, in the words of Harvey (1985, 150), "create a social and physical landscape in its own image," is palpable.

California, because of its extraordinary historical development, has long been the study of scholars wishing to understand the contradictory social and ecological logics of capitalism (Brechin 2006, Davis 2006, Henderson 1998, Mitchell 1996, Walker 2004, to highlight but a few). The monumental technological and political feats of controlling and diverting water in this arid state, and its implications for the development of the American West, have also been the subject of far more comprehensive works than this thesis (most notably Hundley 2001, Reisner 1986, Worster 1985). The research laid out in this volume is, by comparison, far narrower in scope. It takes as its analytical entry point the extraordinary emergence of large-scale seawater desalination as an alternative water 'solution' for the populous urban coastal belt of San Diego County, which lies on the Pacific coast south of Orange and Los Angeles counties, bordering Mexico. Broadly, it asks two things. First, what are the particular forms of socio-material relationality that precondition this most remarkable of technological adaptations? And second, in assembling the technological, material and political elements that render the Pacific Ocean a viable source of municipal water, what new forms of relationality are produced?

Desalination –or the removal of salt and other impurities to treat water to potable standard– sits at the apex of many contemporary debates in geography and environmental governance. The extraordinary characteristics of large-scale seawater desalination for municipal supply, and the socio-natural permutations it generates –particularly in the case of the binational desalting project between the United States and Mexico that is analysed in this research– elucidates relationships and processes that might otherwise remain unseen. The case of desalination, therefore, is used as an explanatory device to illuminate deeper theoretical questions. As such, this thesis is not really about desalination *per se*, but rather mobilises the political, discursive, ecological and economic themes that have emerged around the development of this infrastructural adaptation in a particular place –San Diego– to point to broader trends and issues. Its principal theoretical contributions are twofold.

Firstly, drawing particularly on Marxian urban political ecology (UPE) and assemblage thinking, it places different relational perspectives into dialogue. I argue that the great divide often imagined between the (simply understood) structuralist and post-structuralist social theories is not only typically over-stated, but also constructs a fictitious conceptual antithesis that ultimately narrows the explanatory potential of theory. This is not to deny the clear differences between UPE and assemblage thinking in their particular handling of socio-material relationality, but rather to productively mobilise these differences to ask novel questions that each alone is inadequate to address. Such perspectives are, I argue, important when theorising large urban infrastructures. As the key mediators between humans and our material environment in cities, infrastructures are both shaped by, and shape, urban socio-natural relationships (Bouzarovski et al 2015, Kaika and Swyngedouw 2000 Monstadt 2009, Moss 2014). A desalting plant is, in this sense, a relationship creator. But the relational permutations caused by the development of a piece of infrastructure as significant as a large-scale desalination plant necessarily go beyond local or regional water governance. A desalination plant is trans-scalar, intersecting political ecology from the local environmental politics of fish larvae to the geopolitics of multi-state river basin management and global climate change. Different concepts of relationality are therefore mobilised to address these different aspects of the desalination question, from detailed analysis of the technologies that create new connectivities, to interpreting broad relational context. The notion of the *desalination assemblage* is advanced to grasp the complexity and heterogeneity of the multi-scalar relationships, processes and materialities that are drawn together in the development of this infrastructural phenomenon.

Secondly, the thesis mobilises these theoretical perspectives and the analysis of desalination to critically interrogate the emerging notion of the *water-energy nexus*. Put simply, understood as part of a broader trend towards more integrated models of environmental and resource management, nexus thinking calls for greater recognition of the tensions and trade-offs between resource sectors that have traditionally been managed separately, and for the optimisation of synergies and shared goals between them (Andrews-Speed et al. 2015, Bazillian et al. 2011, Hussey and Pittock 2012, Olsson 2013, Olsson 2015, Verma, 2015). Through the development of seawater desalination, which represents the most energy-intense source of water available to cities (Elimelech and Phillip 2011), both the assumed separation between energy and water, and relative scarcities between them, become muddied. The desalting phenomenon, in this respect, illustrates starkly the inherent interconnections, interdependencies and tensions between different sectors of resource governance. Although rapidly gaining traction as a new buzzword of sustainable development (Cairns and Krywoszynska 2016), nexus thinking is still under-studied in geography. In particular, as chapter three argues, there has been a notable lack of critical engagement with the water-energy nexus so far. By teasing out the contradictions of desalination in the context of growing calls for greater integration between the water and energy sectors, this research represents an attempt to fill this knowledge gap.

Large-scale seawater desalination plants now supply cities on every continent, except Antarctica. The list of potential research sites for a project like this is, therefore, large and growing. San Diego presents, however, a particularly intriguing case and has, for a number of interesting reasons, recently become a focus of the desalination debate in North America and internationally. These reasons are highlighted later in the chapter and in chapter four. Now, however, I simply outline the specific analytical focus of the thesis. Research for this project was conducted in San Diego and Tijuana during 2014 and 2015. In addition to extensive documentary analysis and site visits to water and energy infrastructures, original data was collected, firstly, in 36 interviews with relevant experts, and secondly, through archival material viewed at San Diego State University, San Diego History Centre, City of San Diego Public Library and the National

Archives in Washington DC. The research focusses primarily on the development of two large desalting plants, the first in Carlsbad, northern San Diego County, the second in Rosarito Beach, just south of Tijuana (figure 1.1):

Carlsbad desalination plant. The Claude 'Bud' Lewis Carlsbad Desalination Plant, named after a former mayor of the City of Carlsbad, is located in north San Diego County. Currently the largest desalting facility in the Western Hemisphere, producing 189 mega litres (ML) a day (approximately 10% of the county's water demand), the Carlsbad plant was completed in November 2015. It is the outcome of a $1 billion public-private partnership (PPP) between Poseidon Resources, a private project developer, and the San Diego County Water Authority.

Rosarito Beach 'binational' desalination plant. Initially conceived as a public venture between various US and Mexican authorities as a spatial-ecological fix for the contested allocation of water in the Lower Colorado River Basin (SDCWA 2005, 2010), this project has since been restructured as a PPP between a company called NSC Agua and the State of Baja. The plant,

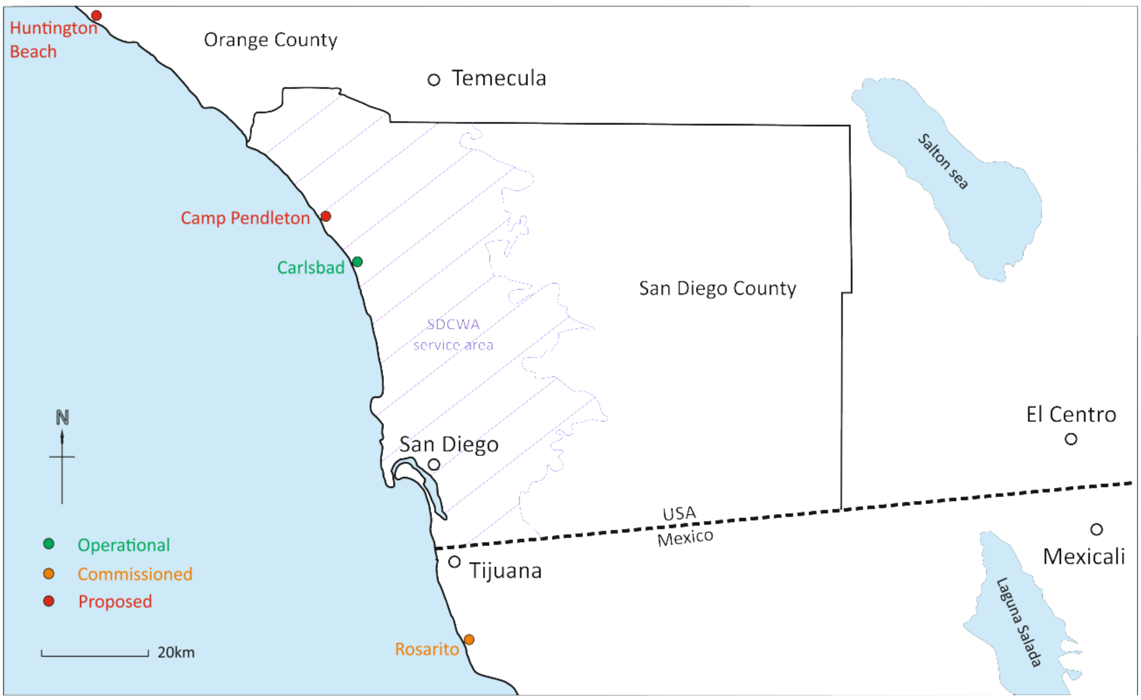

Figure 1.1: Map of San Diego County with existing and proposed desalination plants.

which was officially commissioned by the State of Baja in July 2016, represents the first attempt to trade purified seawater internationally. The first stage of the project should be complete in 2019, with full completion in 2022. Under current plans, half of the plant's 380 ML/day output will be sold to US off-takers, either as 'wet water,' delivered by pipeline across the border, or as a transfer of rights to Colorado River water, referred to as 'paper water.'

In addition to Rosarito and Carlsbad, several other facilities are planned for the region (also shown in figure 1.1). These include the Huntington Beach plant, just north of San Diego in Orange County, which is being proposed by Poseidon –the same developers as Carlsbad; and a project near the Marine base at Camp Pendleton, which is part of SDCWA's long term supply planning.

The empirical focus of the study is novel in two key respects. First, there is a lack of transboundary or cross-border geographical case study research (Peck 2003). Moreover, despite being the eighth most populous urban centre in the United States, San Diego has also received little critical attention. Second, although there is a growing literature within geography and political ecology engaging with the politics of desalination (March 2015), the development of the first ever binational seawater desalting project provides a particularly unique research study. In mobilising these themes, both in terms of the novelty of the theoretical approach and the explanatory potential of the empirical focus, this thesis engages with three core research questions:

1) How have historical urbanisation and the co-production of water-energy shaped the desalination 'solution' in Southern California?
2) How does seawater desalination intersect nexus thinking and associated contemporary trends towards more integrated models of environmental governance?
3) How are heterogeneous actors and factors re-aligned and enrolled, and what new forms of relationality are created in the emergence of the 'desalination assemblage'?

The research laid out in this volume is about the infrastructural co-constitution of water and energy in the production of urban space. Grounded in a relational Marxist urban political ecology framework, and drawing on notions of emergence and distributed agency from assemblage thinking, and of interconnectivity and contingency from a critical reading of nexus thinking, the research uses as its analytical entry point the extraordinary emergence of seawater desalination as a 'solution' to San Diego's water crisis. It argues that the desalination assemblage is produced by the historical interaction between water and energy, emerges through particular and contingent socio-material configurations, and embodies the contradictions of materially compartmentalised processes of urbanisation under capital. The rest of this introductory chapter proceeds in three parts. First, it sketches out the theoretical rationale and framework for this study. Second, it provides a more detailed discussion on the desalination phenomenon and the political contestations that have arisen around it. And third, the chapter gives an overview and context of desalination in San Diego.

Nature, society and nexus technologies

This thesis concerns the politics of relationality. Very broadly, it asks; how are people, the environment and technologies connected? And how are these connections being reconfigured, by whom and with what implications? By unearthing the complex discursive, material, political and economic actors and factors that are drawn together in the emergence of desalination in Southern California and Baja California, the thesis places several relational theories into dialogue. The critical materialist social sciences, from the philosophies of Marx to Latour, have, of course, always been based on an understanding of the physical and social world as deeply relational (Bakker and Bridge 2006). To Marxian thinkers the relationships between people, and between people and things, are shaped by the social relations of capital and given direction by the logics of accumulation (Harvey 1996, Moore 2015, Smith 1984). This is, above all, a notion of internal relationality, where nature (or particular materialisations of nature, like commodities) embody the social relations (like the wage-labour relation) through which they are produced, and where these relations unfold dialectically through contradictory forces (Merrifield 2002, Ollman 2003). By contrast, post-structuralist theories of society and nature develop a notion of more universal relationality. According to a Latourian conceptualisation, for example, everything is seen infinitely connected, with little form or difference between types of relation (Latour 2005). In chapter two I argue that at the heart of these differences lie divergent conceptualisations of the nature of relationality. Nevertheless, the relational materialist social sciences have largely argued for the formation of socially and ecologically more progressive or emancipatory forms of socio-material relationality, for instance in the movement towards a post-capitalist society (Harvey 2014) or the development of a post-human politics (Whatmore 2002).

In response to deepening ecological and social crises, and the extraordinary acceleration of the urbanisation of people and nature as a global phenomenon of contemporary capitalism, urban political ecology (UPE) has emerged as a burgeoning field of critical geographical analysis (Heynen 2014, Keil 2003). At the heart of the UPE project is a desire to elucidate how society's metabolism with material nature, as articulated through the logics of capital accumulation, drive the uneven processes of urbanisation (Heynen et al. 2006, Swyngedouw and Heynen 2003). This very much builds on David Harvey's (1996) notion of urban landscapes as being produced by capital for the optimisation of capital circulation. Thus, cities are seen as spaces where "society and nature, representation and being are inseparable, integral to each other, infinitely bound-up, yet simultaneously…full of contradictions, tensions and conflicts" (Swyngedouw 1996, 65). The processes of urbanisation, then, entrench and reconfigure socio-material relationships in particular ways, consistent with particular logics and trajectories.

UPE, by "blending representational, discursive, ideological, material, and biochemical constellations of uneven power relations through the notion of urban metabolism" (Heynen

2014, 599), has always adopted a somewhat hybrid theoretical approach. Indeed, the capacity of UPE scholars to draw on diverse theoretical concepts to grasp the complexities of contemporary urbanism, has added a great deal of explanatory capacity to the field. Yet, the focus of this thesis on a particular technological development, seawater desalination, also calls for more detailed analysis of the particular materialities of that technology, and the heterogeneous relationships that coalesce around it. Assemblage thinking, which describes entities with "both consistency and fuzzy borders" (Tampio 2009, 394), offers the conceptual tools to do so.

In particular, the assemblage literature offers two concepts that are drawn on heavily throughout thesis. Firstly, the notion of emergence reflects the inherent dynamism and transitory nature of relational structures. The process of assembling is prioritised over resultant formation, as well as the potential for new configurations (Featherstone 2011, Li 2007, McFarlane 2011b). Secondly, understanding agency as distributed through an assemblage, rather than embodied in one element, points to the political salience of relations. Assemblage thinking, although disparate, does not generally subscribe to the Actor-Network Theory concept of nonhuman actants, but rather of agency as an effect of the interactions between humans and nonhumans (Bennett 2010, DeLanda 2006). In combining analysis of the political economy and political ecology of desalination plants with analysis of the political materiality of desalting technologies, I attempt to address an on-going disconnect in geographical enquiry between detailed analysis of particular socio-material configurations –like a desalination plant– and macro trajectories, like the neoliberalisation of nature. I develop the notion of the 'desalination assemblage' to conceptualise the multiple and heterogeneous processes, materialities and discourses that are brought into play through this most extraordinary technological adaptation.

The recent renewed interest in materiality and relationality in the social sciences, which, despite emerging from different fields and philosophies, is driven by a common desire for more progressive forms of relationality between humans and nonhumans, has been paralleled by increasing interest in connectivities in certain areas of environmental management. This is illustrated in a raft of emerging concepts calling for more integrated forms of environment and resource governance, like Integrated Water Resource Management, virtual water and the energy trilemma. The ‘resource nexus’ in particular, over the past decade has become an important new paradigm, which emphasises the interconnections, tensions and synergies between resource sectors that have traditionally been managed separately (Hussey and Pittock 2012, Olsson 2015). Nexus thinking presents itself as a radically new approach to integrated governance in response to interconnected socio-environmental challenges and constraints. In chapter three, however, I argue that the nexus discourse has become techno-managerial in style, linear in its analysis and reductionist in its recommendations. In particular, the concept of the nexus offers a way to identify and operationalize potential efficiencies between resource sectors, thereby discursively circumventing ecological crisis and overcoming barriers to accumulation. In this respect, relationality –or the connections between things– becomes the focus of economic innovation. In one sense, then, nexus thinking re-states what critical social science has been saying for a long time –that everything is inherently connected. But the particular conceptualisation of relationality has great bearing on the political work that a concept or theory does. In the case of nexus thinking, I argue, this is to re-enforce a market-oriented logic of environmental governance. One of the key contributions of this research is to insist that saying *how* things are related, or how they *should* be related, is an inherently political project.

The ocean bountiful?

The creation of drinking water from seawater by desalting is, of course, not a new idea. Crude methods of thermal distillation (i.e. the heating of salt water to create steam) have been used on ships for hundreds of years, and the first fixed desalination plant for municipal supply was installed in Egypt in 1912 –a very small plant by today's standards, producing 75 cubic metres per day (El-Dessouky and Ettouney 2002). Nor is seawater purification the only application of desalting technologies. Indeed, seawater accounts for only around 60% of total global installed capacity (Curcio et al. 2015). The other 40% of desalting capacity is used in the purification of brackish groundwater and surface water (around 20%), in wastewater treatment (about 5%), and for specialised industrial processes that require highly pure water –for instance, in the manufacturing of semiconductors (Lattermann et al. 2010). This research project does not consider desalination of brackish water or for industrial manufacturing. It is concerned with the ambitious –and in certain respects, utopian– efforts to tap the oceans; to remedy the social and ecological ills of scarce and contested terrestrial water by reversing the hydrological cycle on a scale large enough to sate the thirst of societies. President John F Kennedy once famously declared that to discover a way of doing so cost-effectively on a large scale would "dwarf any other scientific accomplishment" (Kennedy 1961b).

From the 1950s to the early 2000s the uptake of large-scale seawater desalination was largely isolated to the water-scarce and energy-rich Middle East and Arabian Peninsula (Lattermann et al. 2010). This research is particularly interested, however, in the more recent *global* profusion of large-scale seawater desalination plants in cities as diverse as Singapore, San Diego, London, Tel Aviv, Melbourne and Alicante –a phenomenon that has accelerated only over the last 10-20 years (Feitelson and Jones 2014). Whilst Kennedy's utopian vision of a desalinated future, free from scarcity was never realised, and few now talk in terms of desalination as a panacea for all water problems (Schiffler 2004), recent years have seen an extraordinary emergence of large facilities in cities across the world in response to particular urban water source challenges.

Although the drivers of desalination are always highly contextual –the governance decisions that led to desalination developments in San Diego were, for example, very different to those in Riyadh– proponents laud the desalination 'solution' for producing a rainfall and climate-independent source of water to address the combined challenges of increasing demand and reducing traditional supply. “Seawater desalination,” in a word, “offers a seemingly unlimited, steady supply of high-quality water, without impairing natural freshwater ecosystems” (Elimelech and Phillip 2011, 713). In this way, the desalination debate straddles multiple scales of environmental governance, from challenges of local water scarcity, to inter-regional and international water conflict, and climate change. A desalination plant can, therefore, be read as a crucible of trans-scalar discourses and environmental politics, a technological adaptation in which different forms of relationality are distilled and reconfigured.

The desalting industry

There are two broad methods of removing dissolved impurities from saltwater: thermal distillation and membrane. Thermal distillation, which, put simply, involves the separation of salt from water through the creation of water vapour, can be achieved through a number of processes, most notably Multi-Stage Flash Distillation (MSF), Multiple Effect Distillation (MED) and vapour compression (Khawaji et al. 2008). Until the 1990s MSF was the industry standard technology for municipal-scale desalination plants, and remains the most widely used technology in the Middle East (Al-Kharaghouli and Kazmerski 2013). Membrane desalination processes, by contrast, separate non-saline water from a saline brine reject with a physical barrier. Techniques include electrodialysis, membrane distillation, forward osmosis, and reverse osmosis. Reverse osmosis (RO) is by far the most dominant membrane technique. In the RO process, saline water is forced through membranes, usually in a spiral-wound configuration, trapping dissolved salt and allowing pure water through (images 1.1 and 1.2)(Fritzmann et al. 2007). The details of the RO process, which is used in the Carlsbad plant and will be used in Rosarito, are discussed more in chapter seven. RO technologies, which were pioneered in the US Federal Funding programmes (National Research Council 2008), overtook MSF as the industry standard in the 1990s, due to their energy efficiency compared to distillation processes (Malaeb

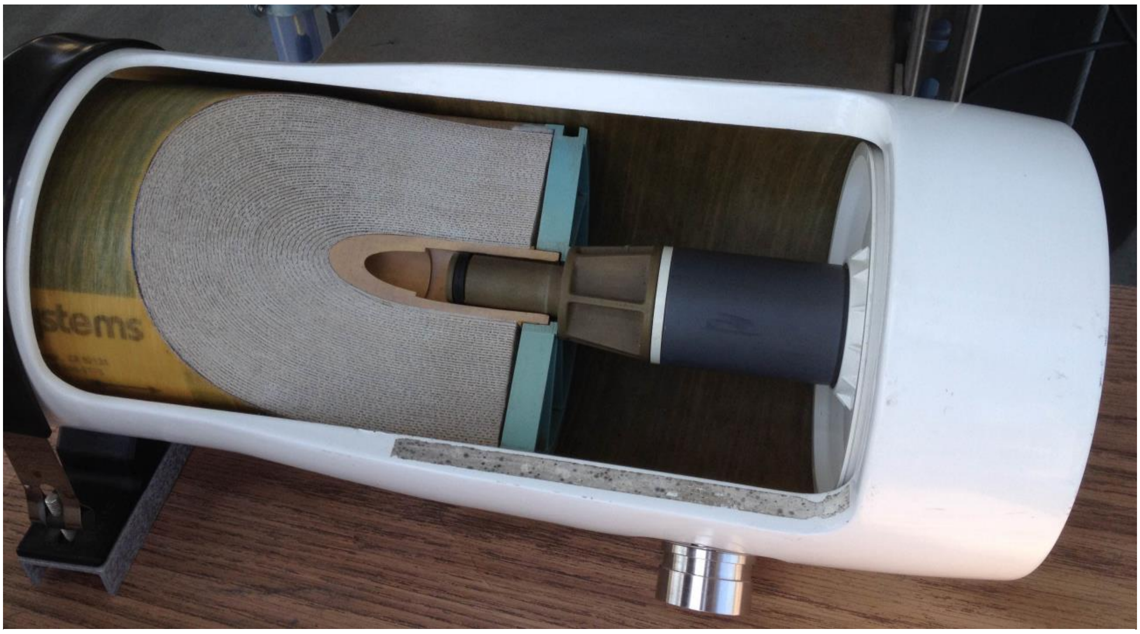

Image 1.1: Display model of the inside of a spiral-wound RO vessel. *Source*: Joe Williams (2015)

Image 1.2: Spiral-wound RO module at the North City Pure Water test facility, San Diego. *Source*: Joe Williams (2015)

and Ayoub 2011, Greenlee et al. 2009). Now, RO represents around 60% of the global desalting market (Ghaffour et al. 2013).

The geographical scope of the desalting industry, and its size measured in financial terms, number of facilities and total water production capacity, has grown hugely since the 1950s and has burgeoned particularly in the last 20 years (March 2015). The value of the global desalting market is now estimated to be in excess of $31 billion (Ghaffour et al. 2013). Since 2008 the industry has grown at around 11% a year, in terms of total global installed capacity (GWI 2013). Today, desalination plants with the combined global capacity to produce nearly 90 million cubic metres per day, provide potable water to more than 300 million people (IDA 2015). The industry analysts, *DesalData*, now monitor nearly 19,000 desalination plants in 150 countries. The largest of these are the Sorek reverse osmosis plant in Israel, which has a capacity of 627 mega litres per day, and the Ras Al Khair thermal distillation plant in Saudi Arabia, which produces 728 ML/day. With a capacity of just under 190 ML/day, the recently completed Carlsbad desalination facility in San Diego is smaller by comparison, but still produces 10% of the supply for the 3.3 million people in the San Diego County Water Authority's service area.

San Diego, although only having begun to develop its own desalting capacity very recently has been a hub of the desalination industry since the early years of the Federal funding programme (National Research Council 2008). The desalination sub-group of General Atomic (Reverse Osmosis General Atomic, or ROGA) was based in San Diego, and was very successful in attracting government funding. A number of pioneering technologies were developed in San Diego during this time in all aspects of membrane desalination, including chemical treatment, membrane development and membrane housing. Most importantly, this is where the spiral-wound configuration (image 1.2) was first developed. Desalination is an important economic sector for the county, and now employs an estimated 2,500 largely high-skilled workers (Eisberg 2010). San Diego is home to the headquarters and continental headquarters of some of the industry's biggest players, including Toray (of Japan), Siemens, General Electric, Hydranautics (part of the Nitto Denko Corporation), IDE (Israel Desalination Enterprise) and Avista Technologies.

What's all the fuss about?

Turning to the abundant oceans to meet expanding water needs, at face value, certainly seems like an attractive proposition. As proponents are quick to point out, this "new" source of water has "an essentially unlimited capacity," and, by circumventing many of the constraints of terrestrial supply, is "not subject to sustainability criteria" (Ghaffour et al. 2013, 198). Yet, the development of desalination is never uncontested, and a number of formidable barriers, both technical and social, have prevented the realisation of the ocean panacea (Cooley et al. 2006, March 2015). Chief amongst these is that of energy consumption. Indeed, because of the mechanical challenges involved in separating dissolved salt from water, "energy will always remain the crucial constraint" (Schiermeier 2008). Given that the oceans are, in all practical respects, inexhaustible, the main limiting factor on water production becomes one of energy availability. Significant efficiency gains have been achieved over the last 50 years –for instance the energy requirements to operate seawater reverse osmosis membranes has dropped from 20 kWh/m^3 in the 1970s to 2 kWh/m^3 (Peñate and García-Rodríguez 2012). Notwithstanding, the embedded energy within the desalting process, and consequences for greenhouse gas emissions and water price, has become the Achilles heel for the desalination industry.

This is reflected in California where the development of desalination has been challenged and contested fiercely by an organised coalition of environmental organisations. Indeed, I argue that the current debate on desalination cuts to the heart of divergent visions for California's water and energy futures. The Carlsbad and Rosarito desalination plants, then, provide an insightful heuristic vehicle for interrogating environmental politics. Whereas desalination developments in other states and countries have largely been contested on the narrow issue of saline brine discharge (Malaeb and Ayoub 2011), in California concern over the social and ecological costs of desalination has revolved around three inter-related issues: the energy and GHG problem; the seawater intake marine life impingement and entrainment issue; and the cost and financing issue (Cooley and Heberger 2013, Cooley et al. 2013, Cooley and Ajami 2012 respectively). These points of contestation structure the analysis of the politics of desalination in Southern California in chapter six.

Critical perspectives on desalination

The extraordinary emergence of water desalination in just a few short decades from fringe water source utilised only under the most extreme circumstances or for specific manufacturing functions, to a global industry, increasingly the focus of techno-managerial solutions to urban water stress, although long overlooked in geography and the social sciences, has lately attracted more sustained critical attention. By essentially reversing the hydrological cycle, causing water to flow from the sea to the land, the inclusion of desalted seawater in the supply of a neighbourhood, city, region or country reconfigures the social, political and economic relations of water (Feitelson and Rosenthal 2012). Critical perspectives on the desalination phenomenon can roughly be understood in three conceptualisations. Firstly, as a technological fix to water scarcity or stress (Fragkou and McEvoy 2016, March et al. 2014, McEvoy 2014, Swyngedouw 2013). Desalination provides the only water source option that is independent from precipitation and climate, and therefore provides a way of augmenting supply without addressing the socio-political drivers of scarcity. Although the desalination ‘panacea’ is often overstated by proponents of this technology, the capability to turn saltwater to freshwater certainly alters understandings of resource scarcity (March et al. 2014). Indeed, as I argue in chapter six, because desalination effectively turns energy into water, it not only reconfigures the politics of water scarcity, but of relative scarcities between resources.

Secondly, desalination is understood as a spatial-political fix. Seawater is, at the moment, essentially free and unlimited. In utilising this abundant and valueless raw material, desalination facilities produce ‘new’ water, free from the contestations and complex relations of use and ownership that beleaguer traditional water sources. In this sense, desalination becomes a way of maintaining or increasing supply by circumventing some of the contradictory relationships that characterise expansionist models of water governance (Swyngedouw 2013). Moreover, desalination may become enrolled to diffuse political tensions in transboundary water conflict, without addressing underlying causes of contestation (Aviram et al. 2014, Feitelson and Rosenthal 2012, Wilder et al. 2016). Chapters five and seven, which analyse the first ever binational seawater desalination project, advance this research by engaging the concept of the spatial-political fix in the context of transboundary water conflict between the United States and Mexico. Thirdly, desalination has been analysed as an economic or accumulation strategy (March 2015). For instance, Loftus and March (2016) argue that London’s Thames estuary desalting plant at Beckton –which, incidentally, has largely been unused since construction– is part and parcel of a movement towards big infrastructure developments in London geared to the financialisation of services and extraction of rent from high value land.

From a political ecology perspective, then, seawater desalination is understood not simply as a way of balancing water supply and demand, but as a technological solution to overcome the barriers to accumulation. Desalination is, therefore, borne out of the contradictory logics of the urbanisation of nature under capital, and embodies new forms of contradiction. Swyngedouw and Williams (2016) identify six central contradictions of desalination. These are the *energy and climate contradiction*, which concerns the energy intensity and associated greenhouse gas emissions of the purification process; the *environmental contradiction*, connected to the localised ecological impacts; the *governance contradiction*, which describes growing concerns about neoliberal environmental governance and water democracy; the *growth contradiction* relating to critique of growth-oriented modes of development and productivist logics of water governance; the *cost contradiction* from the rising cost of water and its implications for environmental justice; and finally, the *ownership*

Plant	Capacity (ML/day)	Owner/developer	Status
		Existing	
Carlsbad	189	Poseidon	Operational
San Nicholas Island	0.09	US Navy	Operational
Santa Catalina Island	1.23	City of Avalon and Southern California Edison	Operational
Santa Barbara	10.5	City of Santa Barbara	Idle
Gaviota Oil Heating Facility	1.55	Chevron	Operational
Diablo Canyon Power Plant	2.2	Pacific Gas & Electric	Operational
Morro Bay	2.27	City of Morro Bay	Idle
		Proposed	
Rosarito Beach Binational	379	NSC Agua	Permitting
Camp Pendleton	189/567	SDCWA	Design
Doheny	15/57	South Coast Water District	Design
Huntington Beach	189	Poseidon	Permitting
West Basin	76/227	West Basin Municipal WD	Permitting
Santa Barbara	10.5	City of Santa Barbara	Reactivation
Diablo Canyon	5.68	PG&E and San Luis Obispo County	Expansion
Monterey Peninsula	24/36	California American Water	Permitting
The People's Moss Landing Water Desal Project	45	Nader Agha	Design
Deep Water	95	Deep Water Desal	Permitting

Table 1.1: Existing and proposed desalination facilities for California. *Source*: Pacific Institute (2016) and project websites

contradiction, which refers to the potential disputes around the assertion of private property rights on currently 'free' seawater.

San Diego's changing water-energy-scape

In spite of California's troubled water history, and the somewhat precarious system of rights through which the heavily urbanised arid southern coast has historically secured supply, only recently have plans to turn to the Pacific to meet the water needs of a rapidly growing and urbanising economy begun to be realised. Until November 2015, when Poseidon started selling water to the San Diego County Water Authority from the Carlsbad desalination plant, the state's entire seawater desalting capacity amounted to less than 18 mega litres a day (table 1.1). The largest facility, located in Santa Barbara, has less than 6% of Carlsbad's capacity and has been idle since it was completed in 1992 (City of Santa Barbara 2016). Indeed, several major cities studied desalination throughout the 1990s and early 2000s when the energy efficiency of RO technologies improved dramatically, but decided to pursue alternative strategies. Most notably, the cities of Los Angeles and Long Beach water utilities conducted extensive R&D programmes, but both concluded that less costly and less energy intense water sources could be developed first (Bureau of Reclamation 2013).

The completion of the Carlsbad plant, after nearly two decades of development, however, may well mark the beginning of a period of large-scale desalination uptake in California. Certainly, the recent (and possibly still on-going) drought is raising the desalination profile again. San Diego sits well ahead of the curve in this respect. The imperatives to unlock the desalination panacea are perhaps most pressing in San Diego because of its particular geographical and historical context. With very little local surface water and almost no groundwater, San Diego has relied on water imported from the east through the Colorado River Aqueduct and from Northern California through the State Water Project to fuel its extraordinary growth since the 1940s (figure 1.2). As chapter five argues, the emergence of desalination in San Diego is deeply rooted in its historical reliance on long distance transfers, to the point where in the early 1990s the county was depending on imported water for 95% of its supply –around half of which it did not hold rights to. For the San Diego County Water Authority, which distributes wholesale water to 26 member agencies within the county, desalination has become an important component, at least discursively, of its aggressive supply diversification and localisation strategy (figure 1.3). By pursuing alternative water source options the SDCWA aims to reduce its heavy reliance on the Metropolitan Water District of Southern California, the country's largest urban water wholesaler that imports water from the Colorado River and Northern California for a population of 19 million people in Southern California's urbanised coastal belt (SDCWA 2011). Desalination has become enrolled as a technological fix for the intense disagreements that have historically characterised SDCWA's and MWD's turbulent relationship.

Figure 1.2: Map of the major aqueducts serving Southern California –the Colorado River Aqueduct, the California State Water Project (which both supply San Diego), and the Los Angeles Aqueduct.

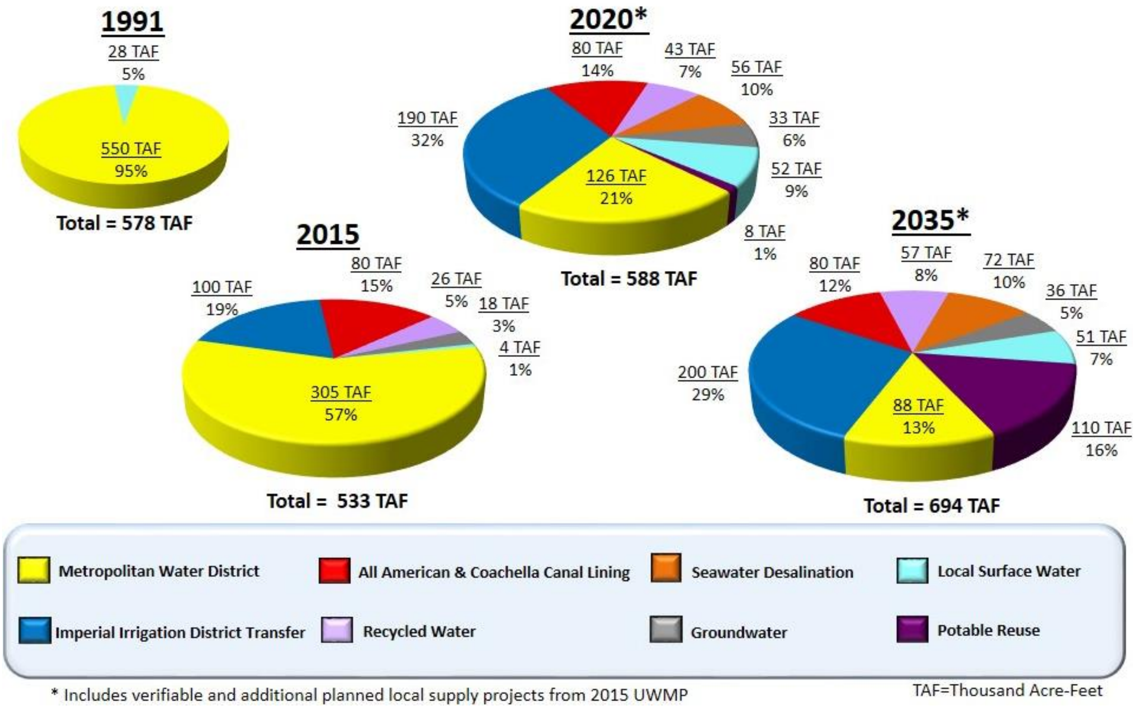

Figure 1.3: San Diego County Water Authority's supply diversification and localisation strategy 1991-2035. *Source*: SDCWA (2016d)

At the same time, the development of seawater desalination must be recognised in its broader context within changing paradigms of environmental and resource governance. Almost all water utilities and companies in Southern California are now pursuing diversification strategies to reduce reliance on transfers, some looking to desalination and others, like Los Angeles and Long Beach, investing more in conservation programmes, wastewater recycling and stormwater capture. This is understood to be part of cross-sector trends towards decentralised and alternative infrastructure planning (Coutard 2014). Indeed, these shifts in the water sector are paralleled in the transitioning energy sector in California away from large, base-loaded coastal thermoelectric fossil fuel power plants towards more renewable and distributed modes electricity generation. Furthermore, there is increasing recognition at both municipal and state level that governing the water-energy nexus is an increasingly pressing responsibility (CPUC 2016a, SDCWA 2015). Desalination in this context, then, is beset by contradictions between representing, on the one hand, an important supply technology for overcoming the intense challenges for the water sector in the face of increasingly contested traditional supply and climate change, and on the other hand, becoming increasingly the focus of discontentment and calls for more integrated and multi-benefit approaches to environmental governance that recognise the trade-offs between sectors.

The long and winding road

The substantive part of this thesis is structured in two parts; the first is theoretical, and the second handles the original empirical case study research conducted in 2014 and 2015. Each part consists of three chapters. Part one is intended to go further than simply setting up a theoretical framework that is then used to structure the empirical work. Chapters two and three in particular, engage –and in some small respects aim to advance– contemporary debates in geography and materialist social science. Chapter two develops a relational materialist approach to interrogating the desalination assemblage. It argues for a concept of political materiality and heterogeneity that integrates Marxian urban political ecology and assemblage thinking. Chapter three then mobilises these theories to critically examine the recent popularity of the water-energy nexus as an environmental management approach to understanding the tensions, trade-offs and potential synergies between sectors of resource governance. Chapter four lays out the research methodology employed during this project. It justifies the use of case study methodology, outlines the particular interest in San Diego and its involvement with planned binational water trading, and finally details the data collection techniques used.

Part two develops the empirical case study material in three distinct, but related modes of analysis. Although these three chapters engage somewhat with all of the three research questions outlined above, substantively, each chapter addresses one question. The chapter structure, therefore, roughly corresponds with the sequence of research questions. The chapters handle the concept of relationality slightly differently, focussing analysis progressively down, from the context of desalination in the development of the desert southwest, to regional environmental politics and the contestation of desalination in San Diego, and finally to the techno-politics of the desalting plant itself. Chapter five, titled 'Deserts of plenty,' tells the story of the historical emergence of desalination as a 'solution' for Southern California's troubled water supply. It makes three core arguments. First, that desalination represents first and foremost a political fix for San Diego's dysfunctional and increasingly contested access to imported water rights. Second, that at the heart of this political fix is an attempt, as Southern California continues to undergo a deep transition from agricultural to urban economy, to reconcile the inertia of modes of water circulation with the dynamism of Capital circulation. And third, that in the history of Southern California's resource development, water and energy are both co-produced and co-producing.

In chapter six, 'At the nexus of scarcity and opportunity,' I narrow the focus of analysis to consider the intense political disagreements that have arisen around the development of the Carlsbad desalination plant. The plant itself has been opposed fiercely by an organised collection of environmental groups. The energy intensity of desalination compared to other options has been a key point of contention. I argue, however, that although the environmental groups are often considered to be politically progressive, the arguments against desalination have tended to reinforce the techno-managerial and de-politicising discourse of nexus thinking.

Finally, chapter seven, 'The water factory,' focusses analysis still further down to the level of the desalting plant. The chapter attempts to build on Karen Bakker's (2003) work on water as the 'uncooperative commodity.' Although water, because of its particular biophysical characteristics, has historically eluded full privatisation, trends towards the neoliberalisation of nature and the privatisation of urban resource governance have seen it become increasingly a focus of capital investment. Desalination technologies, I argue, because of their specific material configurations are becoming efficacious in the market-disciplining of water, and the re-alignment of society's relationships with water towards the logics of accumulation.

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What's the 'matter' with social theory?

On nature, relationality, and the efficacy of urban infrastructure

The nature of relationality

This chapter is about the politics of nature and the nature of politics. It has two primary aims. The first is to outline a materialist theoretical framework that will give form and direction to the empirical analysis of desalination in Southern California, which forms the substantive work of this thesis. The second is to identify some shortcomings in current materialist theory that subsequent chapters will seek to remedy. As such, this research is positioned within a paradigm of renewed interest in materiality and materialist theory in the social sciences, which has emerged particularly strongly over the last decade (Braun and Whatmore 2010). Joyce and Bennett (2010) have described this as the 'material turn' in critical social theory. The re-insertion of the material into social theory is the outcome, I argue, of three interlocking imperatives. The first is ontological, the other two are political.

Spearheaded by, but by no means limited to, at first Actor-Network Theory (Latour 1993; Law 1992; Callon 1986) and later the so-called 'new materialism' literature (Coole and Frost 2010; Bennett 2010), the ontological starting point of contemporary materialist theory is a critique of Cartesian dualisms, which hold nature and society in distinct categories, as binary opposites. Society is instead understood as an effect, arising from the relations between things, human and nonhuman, that are themselves not inherently social. There is, therefore, no society without nature, and nature as a category becomes meaningless because there is nothing that is not nature. Relational materialism, then, stands in opposition to the pervasive anthropocentric concepts of society's 'domination of nature,' and of nature as that which is external and pristine. The second imperative is to provide a response to challenges that are unique to socio-ecological relations in the contemporary capitalist era, either in their scope and magnitude or because they are novel and emerging. These include, on the one hand, deepening ecological crises and the globalisation of environmental transformation, and on the other hand, new ethical concerns arising from technological developments like cloning, industrial livestock farming, the privatisation of genetic code, stem cell research and genetic modification (Braun 2006; Bakker and Bridge 2006). From this follows the third imperative, which is to develop a coherent and sustained posthuman politics. A non-anthropocentric politics would, it is hoped, provide a progressive framework through which we could integrate the nonhuman more fully into political discourse, to engage with an understanding of rights that go beyond simply human rights, and to encourage non-exploitative environmental praxis (Whatmore 2002). Such a project, Castree (2003) argued more than a decade ago, is in desperate need of development. A fully developed posthuman politics remains elusive.

The multiple relational theories that have mobilised around the material turn, whether inspired by Marx, Foucault, Lefebvre, Deleuze, Latour, Whatmore or Haraway, all share something in common. They all present highly relational and post-dualist concepts of nature, where interaction and process are emphasised over resultant formation. They also all claim to be progressive and political. Yet, I argue that difference lies in the particular ways in which the question of relationality is handled in each theoretical tradition, and therefore how the political moment is conceived. In Latour or DeLanda's notions of relationality, for instance, everything is seen to be infinitely connected, with little or no hierarchy between different forms of connection. In a sense, we are given a snapshot of relationality without history or direction. This 'ontological flattening,' has been criticised for overlooking important power relations, dehumanising humans and ignoring injustice (Fuller 2000). In political ecology, by contrast, politics –or the desire for change– flows from the concept of relationality. The history of capital is read as a process of the restructuring of human–nonhuman relations, consistent with logics of private property, productivism and accumulation. Certainly, everything is connected, but with historically produced structure. This means that the politics of relationality begins with the re-imagining of new progressive relational forms. These distinctions do not, however, imply that dialogue and concept sharing between relational materialist social theories is necessarily fruitless (Castree 2002, Kirsch and Mitchell 2004). The chapter is developed in four core parts, which are structured to build up a theoretical framework for understanding and interrogating the politics of seawater desalination in Southern California and Baja California.

1. Marxian dialectical concepts of nature and society
2. Urban Political Ecology
3. Assemblage thinking
4. Relational approaches to urban infrastructure

The chapter begins by grounding this research in a Marxian dialectical concept of nature, society and technology. Drawing particularly on contemporary Marxist scholars like David Harvey and Neil Smith, and on Urban Political Ecology (UPE), I argue that the dialectical approach offers the most appropriate starting point for engaging with the desalination question, which cannot be understood without reference to the historical and present economic development, and extraordinary urbanisation of Southern California (Henderson 1998). Nevertheless, I argue that Marxian interpretations tend to group disparate and diverse materialities into 'nature' as the means of production, or as the object of underproduction. As such, using a purely historical materialist language and framework tends to lead to incomplete or contradictory theorising. Assemblage thinking is therefore advanced as a useful set of conceptual tools and terminology to work through some of the theoretical challenges unresolved in Marxist thought. In particular, I draw on the related notions of emergence (McFarlane 2011b) and of distributed agency (Bennett 2010) as offering a productive language to represent the complexity and contingency of the socio-material world. Finally, the theoretical concepts advanced in the first three parts are engaged in a discussion on the socio-political efficacy of urban infrastructures. Infrastructures, which mediate and shape the urban metabolism, are conceptualised as relation-makers; as the machinery and technologies that reconfigure and transform human relations between each other, and relations with material nature (Graham and McFarlane 2015, Guy et al 2011).

On your Marx: groundings in dialectical materialism

The concept of nature in Marx's writing is the subject of fierce disagreement. There are two principle reasons for this. Firstly, Marx rarely handled the relationship between nature, society and economy explicitly. Indeed, Alfred Schmidt, in his foundational (albeit problematic) work on the subject, noted that theories of nature in Marx "appear at first sight to have purely peripheral significance" (Schmidt 1971, 15). Our subsequent interpretations must, therefore, be somewhat deductive. Secondly, as will be argued later, although making enormous contributions to our understanding of such matters, Marx nevertheless presented an incomplete and at times contradictory theory of nature, and as such is open to interpretation.

Nature and the labour process: Marx and his critics

Consider two of Marx's most cited passages on the relationships between humans and nature, the first from *Capital*, the second from the *Grundrisse*:

> *"Labour is, first of all, a process between man and nature, a process by which man, through his own actions, mediates, regulates and controls the metabolism between*

> *himself and nature. He confronts the materials of nature as a force of nature. He sets in motion the natural forces which belong to his own body, his arms, legs, head and hands, in order to appropriate the materials of nature in a form adapted to his own needs. Through this movement he acts upon external nature and changes it, and in this way he simultaneously changes his own nature. He develops the potentialities slumbering within nature, and subjects the play of its forces to his own sovereign power."* (Marx 1976, 283)

> *"Nature builds no machines, no locomotives, railways, electric telegraphs, self-acting mules etc. These are products of human industry; natural material transformed into organs of the human will over nature, or of human participation in nature. They are* organs of the human brain, created by the human hand*; the power of knowledge, objectified."* (Marx 1973, 706)

These passages are highly instructive and indicative of Marx's materialist theory. Principally, they place the materiality of nature at the heart of Marx's analysis of the production process. In this formulation the labour process is seen as a dynamic interaction between humans and nature, a relationship comprising: (1) *purposeful activity*, the work of humans; (2) the *object of that work*, which is nature, the raw materials of economic activity; and (3) the *instruments of that work* -tools, machinery and so on, which in themselves are the result of previous interactions between labour and nature –dead labour objectified in material commodities. For Marx, human interaction with nature is structured through the specific political-economic form of society at a given point in history –in his and our time, the *historically-specific* relations of capitalism (Burkett 1999; Foster 1999). In a word, "all production is appropriation of nature on the part of an individual within and through a specific form of society" (Marx 1973, 87). Here, then, is Marx's expression of the ultimate primacy of economic activity, rooted in the transformation of material nature (Burgess 1985).

This view of nature, however, where the interactions between humans and the material world are realised and mediated solely through the labour process, and where "we presuppose labour in a form in which it is an exclusively human characteristic" (Marx 1976, 283-4), is seen as problematic by many contemporary Marxist thinkers. Traditionally, historical materialist accounts of nature tend to belabour human's economic interaction with the material world. That is, interest in nature starts at the point of production and ends when a commodity is taken out of circulation. This, some have argued, betrays an anthropocentric conceptualization of the nature-society problematic, and an over-simplification of the complexity and vitality of socio-natural processes outside the realm of production (Appadurai 1986; Kopytoff 1986). Furthermore, the labour-centric concept of human and natural co-transformation largely ignores important metabolic exchanges in the spheres of reproductive and non-productive activities. This, according to Benton (1996, 167) leads to an "overall exaggeration of the potential transformative power of such labor processes, at the expense of any full recognition of their continued dependence upon and limitation by other non-productive labor processes." Such disagreements should, however, be understood in their historical context. Marx was, after all, primarily concerned with the contradictory development of capital as a specific form of social and material interaction (Clark and Foster 2010). Burkett (1999, 99) has argued, for instance, that "the critics who fault Marx for not ascribing value to nature should redirect their criticisms to capitalism itself."

The passages above also illustrate Marx's understanding of the dialectical relationships through which dynamic metabolic transformations unfold. Humans and nature are not separate interacting entities, but are co-constituted, physically and conceptually inseparable. Humans, as a part of nature, act upon our material surroundings, changing nature and therefore ourselves. Society's metabolism, which is analogous to the metabolism of the human body, describes an exchange or transformation of energy states (Fischer-Kowalski 1998; Fischer-Kowalski and Hüttler 1998). Material nature is socialised while human nature is simultaneously naturalised. For Marx, the development of capitalist social relations through the processes of primitive accumulation, forces a metabolic separation between humans and the land, the means of subsistent, production and reproduction. Marx described this as the *alienation* of both labour and nature under capitalism, the process by which labour and nature are commodified and internalised by capital (Foster 1997). This alienation does not imply a separation in real terms – humans still eat and excrete, labour and transform– but rather a socio-economic separation where interactions are mediated and structured through capitalist property rights and the wage relation. Thus,

> *"It is not the unity of living and active humanity with the natural, inorganic conditions of their metabolic exchange with nature, and hence their appropriation of nature, which requires explanation or is the result of a historic process, but rather the separation between these inorganic conditions of human existence and this active existence, a separation which is completely posited only in the relation of wage labour and capital."* (Marx 1973, 489)

John Bellamy Foster (2000, 170) developed these concepts to describe a *metabolic rift* where capitalism is "characterised by an extreme division of the population within society, which was rooted in no less an extreme division of the population from the earth." The dialectical approach and the related concept of metabolism are fundamental to understanding the Marxist view of nature, and its relevance to contemporary debates and challenges. Both themes are discussed in more detail in subsequent paragraphs.

Nevertheless, these excerpts betray the somewhat inconsistent way in which Marx handled questions of nature, even in his later works. In particular, I would like to highlight two contradictory positions discernible, captured clearly in the quotation from the *Grundrisse* where Marx talks about "human will over nature, or of human participation in nature." The first is that of the relational dialectic, where humans act on and transform nature "as a force of nature." In this respect, Marx and Engels were amongst the first philosophers to offer a conceptual basis to challenge the Cartesian dualisms, which solidified during the Enlightenment, holding nature and society as separate and opposing conceptual categories. The second position concerns what Clark (2001) has called the 'Promethean Marx.' Here, in contrast to the dialectical approach, nature is seen as external, a passive set of materials to be worked upon, exploited or preserved, and where the human condition can be improved through the progress of applied science and technology –in a word, the 'domination of nature' thesis. For indeed, Marx firmly believed that, if deployed through the appropriate social structures, the manipulation of nature through technological progress was fundamental to the transition towards socialism. Under this theorem, nature is seen as a realm 'out there,' a view inconsistent with the more subtle dialectical understanding of co-constitution.

These two divergent theories of nature sit (sometimes uncomfortably) together in Marx's work, and have left a legacy in subsequent scholarship. It is not unfair, therefore, to say that a fully coherent and concurrent Marxist theory of nature remains elusive. Indeed, many Marxist thinkers, notably of the Frankfurt School, have carried this contradictory position forward in their own work. Schmidt (1971), for instance, rather than addressing the antagonism, merely reproduces it by arguing that nature is both external, unformed material, and universal, encompassing all human activity. This has prompted some to accuse Schmidt and others of succumbing to a bourgeois conceptualisation of nature (Castree 1995; Swyngedouw 2004a). It is this conflict of theory that has led to confusion and disagreement over the Marxist concept of nature. Moreover, it is the view of capital's domination of external nature, which has been reproduced by some Marxist scholars, that has been the source of the fiercest post-structuralist critique. It is all too easy, when reading Marx, to leave this dual narrative unresolved. In the interest of clarity, then, the following paragraphs detail as lucidly as possible, the particular interpretation of Marxist thought adopted in this research.

On material dialectics and methodology

Broadly, Marx's historical materialist philosophy applied Hegel's dialectic of the mind to the socio-material world (Swyngedouw 2009). The principle aim of the dialectical mode of enquiry is to avoid reductionism in social theory and methodology, to excavate hidden processes by investigating not the characteristics of a thing *in and of itself,* but rather the contradictory relationships through which things are constituted (Whitehead 1920). Dynamism and change are emphasised as the eternal state of being, and contradiction as the primary driving force of change. In this sense, dialectical materialism advocates a highly relational understanding of the social and physical, and as such provided one of the first sustained and rigorous challenges to false binaries and dualisms (Foster and Burkett 2000). It is an approach that remains pertinent and effective today.

In contrast to other post-binary relational materialist philosophies, which prioritise the 'thing' as the analytical focus and then extrapolate to say something about the 'whole' (for example, the 'actor' in the 'network' of Latour's Actor-Network Theory), the dialectical thinker begins with the 'whole,' or as much of it as s/he can grasp, and proceeds to interrogate various parts and how they fit in (Ollman 2003). For Marx, Capitalism was the 'whole,' and his dialectical method examined how the various social, material and ideological relations together constituted capitalist society, in order to critically understand it. This does not imply that the 'whole' is understood as a totality or as something with meaning outside the relationships and processes that constitute it. Instead, the 'whole' is purely a matter of ontological focus, indeed, what "looks like a system at one level of analysis becomes a part at another level" (Harvey 1996, 52). Dialectical logic, then, develops "a system of categories, from the most simple and indeterminate to the most rich and concrete, by virtue of the contradictory imperatives of each successive form" (Castree 1996, 351). The categories Castree refers to, of course, do not exist *a priori,* but take form during the conceptualisation process. Marx is sometimes wrongly criticized for having an essentialist understanding of capital, that capital has an external essence or set of characteristics that gives capitalist society its structure. When read in the light of the dialectical approach, however, it is clear that Marx saw capital as a process arising from particular configurations of social and material relations. “Capital,” in his own words “is a general, eternal relation of nature” (Marx 1973, 86). As David Harvey puts it:

> *“When Marx argues that ‘capital does’ or ‘capital creates’ he is not arguing that a thing called capital has causal power, but that the process of capital circulation, understood as a whole, is at the centre of vital social transformations and for that reason has to be looked upon as embodying a powerful generative principle affecting social life.”* (Harvey 1996, 63)

The dialectical approach, then, offers a particular conceptualisation of relationality, one that is quite distinct from some of the post-structuralist traditions. For instance, under ANT’s ‘follow the actor’ methodology the part becomes the primary focus of study, be it a computer, a DNA sample or a scallop (Callon 1986). Thus, the scallop (or whatever), through its relationality with the things that surround it, and by the same reason the things that surround them, internalises the whole of the known universe. This is the *relational excess* or *absolute immanence* that Neyrat (2014) refers to, where “everything always stays inside.” Conversely, the dialectical approach, although presenting a radically relational view of nature where everything is connected and contingent, does not preclude externality from its ontology. The commodity, for instance, is brought inside the bounded (albeit porous) system of capitalism, circulates within it, and may then fall out. Indeed, the historical development of capital, through the processes of at first formal and then real subsumption, is one in which capital continually attempts to internalise things and processes, many of which are unsuitable for internalisation. In a word, to discipline and render commensurable that which is radically incommensurable. Dialectics, therefore, offers a conceptualisation of internal relationality where the external remains possible and significant.

Castree (1996), although noting the deep disparities and disagreements that persist in dialectical materialist thought, identifies two broad (albeit overlapping) approaches: dialectics as ontology and dialectics as methodology. This first position, which was most famously defined by Friedrich Engels in *Dialectics of Nature* (1934) holds that nature itself is dialectically constituted, that dialectics is not simply a way of describing the world, but also a way to understand how the world actually operates. Contemporary scholars to espouse variations of this 'strong' view include John Bellamy Foster and Brett Clark. Although I do not wish to disagree directly with this reading, this research does not make any such claims about the nature of things. Instead, I use dialectics as a methodological tool, a way of thinking through the complex and heterogeneous socio-techno-natural milieu out of which the desalination configuration emerges. In particular, I draw on the following principles (as identified by Harvey 1996; Ollman 2003; Merrifield 2002; Swyngedouw 2009). First, flows and relations are emphasized over things and entities -or rather, entities are argued not to exist outside the processes through which they are constituted. Second, transformation occurs through contradictory relationships between things, which together form complex and heterogeneous 'wholes' or *relational assemblages*, and not through linear causal relationships. The corollary of this being that object-subject and cause-effect become interchangeable –causality is not a one-way street. Finally, change is seen as the natural state of all things, and perceived stability, such as capitalist class relations, is the exception not the norm.

Dialectical research cannot be used to predict what future configurations will look like, or how new relations will be forged. Change, then, is seen as inevitable and unbounded, or as put by Clark and York (2005, 327), the direction of travel "is not predetermined; the future remains open." Here, dialectics differs again from other relational theories in that the door is left open for explicitly normative judgements about what the future should look like, how we should get there, and to whose benefit (Merrifield 2002).

The (under)production of nature and the contradictions of capital

In particular, dialectical thought is concerned with the dynamics of contradiction as the driving force of open-ended change, where transformation occurs through multiple and heterogeneous opposing forces. Geographers, over the last three decades have used these concepts of nature to theorise both how the geographical and historical development of capitalist relations of production are key to understanding material and social inequalities, and whether, why and how the logics of capital accumulation undermine the ecological basis of accumulation. Understanding capital as being constituted through, and emerging from, contradictory socio-material relations, I argue, is highly beneficial in avoiding the reductionist 'domination of nature under capitalism' binary reproduced by some contemporary eco-socialist scholars, such as James Gustave Speth (2008) and Joel Kovel (2007).

The substantive work of David Harvey (notably 1996, 2006, 2010, 2014) is, first and foremost, an attempt to elucidate and contest the contradictory historical and geographical development of capital, its production, circulation, accumulation and reproduction. The contradictions of capital are (in Harvey 2014) divided into the *foundational contradictions*, so called because they are constant in all capitalist forms; the *moving contradictions*, which are evolutionary and follow from the foundational; and the *dangerous contradictions*, which in the contemporary era may threaten the continuation of capital accumulation. According to Marx, Harvey (2006, 21) argues, "contradictions are rarely resolved" by capital, but are instead "nearly always displaced." For example, faced with the crisis of overproduction, where total industrial production cannot be absorbed by the consuming population, capital will invest its surplus by expanding into spheres that are not structured through capitalist social relations, either through expansion (colonialization) or intensification (privatisation and commodification of nature). Thus, according to the dialectical understanding, capital is astonishingly facile in successfully circumventing barriers to accumulation, but rarely addresses those barriers directly.

Concerning the question of capital's relation to nature, the language of contradiction has been used, most famously by James O'Connor, to describe the *second contradiction of capitalism*, or the *crisis of underproduction*. O'Connor (1991, 1998) argues that, because capitalism treats both human labour and nature as commodities despite neither being produced entirely through capitalist relations, the process of accumulation is vulnerable to external barriers. By relentlessly seeking to internalize and transform nature, capital undermines its own conditions of production –capital under-produces the material inputs it relies upon for its own metabolic reproduction. Capitalism does not resolve this crisis, but rather seeks to avoid it by expanding the frontiers of its material intake, or by increasing efficiency through technological development. This process is confounded by the imperative for compound growth, without which capital could not function, thus accelerating ecological transformation. To Harvey (2014, 246), capital faces a potentially fatal contradiction "from the accumulating environmental pressures arising from capital's exponential growth." Here then, the dialectical transformations of both humans and nature that Marx addresses in the excerpt from *Capital*, given structure by the particular relations of capitalism, under-produce nature and therefore systematically undermine the basis for future transformation and accumulation.

Given that visions for progressive and just change are hallmarks of the dialectical approach, concerns over the contradictory under-production of nature on the one hand, and capital's relentless compulsion for compound growth on the other, have begun to coalesce around political calls for zero growth or de-growth economics. Interestingly, the de-growth agenda, which can trace its genealogy back to the Club of Rome's *Limits to Growth* report (Meadows et al., 1972), initially emerged from the discipline of Ecological Economics. In its first phase, then, the discourse was distinctly unradical and somewhat apolitical. Tim Jackson (2010), for instance, although at times arguing persuasively for controlled transition to a zero-growth economy, insists that he is not anti-capitalist –a side-step that merely proves he does not understand capital. More recently, Marxist scholars have rallied around de-growth as a significant new critique of conventional economics (D'Alisa et al., 2014; Kallis 2011; Martinez-Alier et al., 2010; Schneider et al., 2010; Fournier 2008). Broadly, these authors all agree on the following principles: capital systematically degrades nature through its transformative capacity; the economy (globally speaking) cannot sustain growth indefinitely; the promises of absolute (as opposed to relative) economic-environmental decoupling are false; economic growth is socially unjust; and controlled, socially just de-growth is an ecological and social necessity. Notwithstanding the obvious absence of a strong signifier or political vision in this discourse, the de-growth agenda is becoming emblematic of the Marxist political interpretation of the ecological contradictions of contemporary capitalism.

Despite these contradictory relationships of under-production and growth, capital continuously develops in such a way as to create the conditions for its own reproduction. Put another way, the development of capital facilitates the further development of capital. To Neil Smith (1984; 32) "the development of the material landscape presents itself as a process of the production of nature." Human activity works on the materials provided by nature, producing a new material landscape that is both natural and social, or *second nature*. Furthermore, "the differentiated results of this production of nature are the material symptoms of uneven development." Geography does not produce economy by constraining or determining economic activity, but is itself co-produced as economies develop. Social inequalities in the relations of production, distribution and consumption, are hereby seen as reflected in and reinforced by the production of new natures, spaces and scales. Materiality is the embodiment of iniquity. The insatiable drive for capitalist growth and development is fueled in large part by the advancement of the capital-nature frontier as human ingenuity opens up new spaces of accumulation. Smith's understanding of capital's uneven production of nature, the geography and history of the development of capitalism, is presented as the dialectical alternative to crude and dualistic concepts of the domination of nature. This work has deeply informed the relational political ecology concept of nature, discussed next, and will be drawn upon heavily in the subsequent chapters of this thesis.

Political ecology in the urban century

Over a quarter of a century has passed since Margaret Fitzsimmons called for geographers to take the matter of nature more seriously, suggesting that urban studies, because the processes of urbanisation are a "reconstitution of the relationship between humans and the material world of everyday life", might prove fertile ground for new research (Fitzsimmons 1989, 108). So far this call has been most assiduously answered in the (now fully emerged) field of Urban Political Ecology (UPE). UPE, which was first delineated by Swyngedouw (1996), and later defined by Swyngedouw and Heynen (2003) and Heynen et al (2006), draws on a fairly diverse range of theoretical traditions. In engaging with this literature, I argue that one of UPE's major contributions is in its insistence that the study of relationality is important because the formation and re-formation of socio-natural relations, which is presupposed in the development of capital, is inherently a political project. Put another way, UPE is premised on the notion that understanding relationality, and importantly imaging new forms of relationality, actually matters.

As the name suggests, UPE attempts to open a two-way dialogue with Marxist Political Ecology by applying established concepts of unequal social power relations, alienation and marginalisation to the urban context, and moreover, to argue that processes of urbanisation are integral to the transformation of nature and to the re-assembling of socionatural relations. The first of these, we can safely say, has proved a fruitful endeavour, but the second only partially so. Initially used by Wolf (1972) to describe the ways in which capitalism structures human interaction with nature through land ownership, Political Ecology was later famously interpreted by as combining;

> *"…the concerns of ecology and a broadly defined political economy… encompass[ing] the constantly shifting dialectic between society and land-based resources, and also within classes and groups within society itself."* (Blaikie and Brookfield 1987, 17)

Notwithstanding this very broad remit, political ecologists have tended to focus overwhelmingly on rural ecological conflicts in the (still inexplicably yet pervasively named) Global South, despite there being "no particular theoretical reason why PE had its origins in studies in the South" (Blaikie 2008, 770). Despite gaining traction in other fields of study (geography, urban studies, posthumanism and so on), what we might call *traditional* Political Ecology has been somewhat unwilling to engage with UPE over the last two decades. This is illustrated in the virtual omission of the urban question, or at least peripheral handling of urban ecology, in recent and otherwise comprehensive overview volumes on political ecology (see Bryant 2015, Perreault et al 2015, Robbins 2012).

Given that political ecology has tended to overlook the significance of urbanisation in the (re)configuration of socio-natural relations (Heynen et al 2006), UPE by contrast, in placing cities explicitly as the central unit of analysis, distances itself from its parent discipline in two important ways. Firstly, and most importantly, where political ecology generally understands the growth of cities to be a more or less important development in the organisation of societies, UPE insists that the urban is *itself* "a process of socioecological *change*" (Swyngedouw and Heynen 2003, 899). The urbanisation of nature – the broad term used to describe the flows of resources, technologies, humans, waste, and the multiple ways in which these elements and processes combine to produce the urban landscape– is integral to, and conceptually and materially inseparable from, the historic development of capital. Capital produces cities to be places where it can most efficiently reproduce and expand itself (Harvey 1996). Through the related concepts of metabolism and circulation, which are explored in more detail below, the urban landscape is understood to be produced in such a way as to facilitate the accelerating flow of material commodities and the counter flow of money that Marx (1956) described as the metamorphoses of capital. The resulting assemblages of heterogeneous elements and relationships –what we call 'the city'– are then, the material expression of the logics of capital. Cities are landscapes of accumulation. In this sense, UPE is not interested in cities as such, but in the historical development of capital, and therefore the ways in which it produces humans and nature through the processes of urbanisation. By overlooking the centrality of urbanisation in the reconfiguration of socio-ecological relationships, traditional political ecology necessarily overlooks the very nature of capital.

Secondly, UPE is distinguished from political ecology more generally by its theoretical dynamism and range of concepts (Zimmer 2010). Drawing particularly on the work of David Harvey and Neil Smith, UPE is ontologically rooted in a Marxist dialectical concept of nature and society. In understanding the city as a hybrid (Swyngedouw 1996), however, UPE has perhaps fittingly adopted a somewhat hybrid theory of urbanisation, engaging with poststructuralist philosophers like Lefebvre and Foucault, posthumanist scholars such as Latour, Haraway and Whatmore, and Science and Technology Studies (STS).

Nature and the city

The premise of the UPE literature, that the city is the best place to study nature, might initially seem perverse to some. More specifically, the city can be seen as a sort of laboratory, where social and environmental processes combine in dynamic, dialectical and highly uneven ways to form new configurations of social-nature (Heynen et al. 2006). The conceptual starting point of UPE is to reject dualisms and arbitrary distinctions between rural and urban. If there were such a distinction, where would the boundary line lie? Cronon (1991) argued persuasively in his seminal work, *Nature's Metropolis*, that it is wrong to draw a boundary line between the abstraction called *city* and the abstraction called *nature*. Nature is, in a sense, a useless term because it implies that there is something that is not nature. Instead, we should emphasis *country* and *city* as a set of co-constituted and dialectical relationships, structured by capital. What we call cities are, therefore, not distinct entities, but are rather "dense networks of interwoven sociospatial processes that are simultaneously local and global, human and physical, cultural and organic" (Swyngedouw and Heynen 2003, 899). Moreover, the material flows that move through the porous, contested and historically-specific socionatural urban fabric are not simply reflective of society's consumption and domination of nature, but rather a complex and variegated process of the *urbanization of nature* (Swyngedouw and Kaika, 2000). The city, then, is not merely a thing that sits in the landscape, but a process of constant material and social transformation that unfolds dialectically through the mechanisms of urbanization (Kaika, 2005). From this, I argue, UPE embarks upon two political projects: one normative, the other ontological. The first rests on the assumption that questions of ecology and sustainability are fundamentally political, and that political transformations are inherently ecological (Heynen et al. 2006). Thus, processes of urbanisation are saturated with unequal relations of social power. One of the principle aims of UPE, therefore, is to excavate these relations and to ask who wins and who loses in the formation of given urban socionatural configurations.

Secondly, UPE scholars insist on a radically relational concept of urbanisation, drawing on posthumanist notions of nonhuman agency and materiality. Donna Haraway's notion of the cyborg has been particularly influential. A cyborg is a combination of human and machine elements that together make a (dis)functioning organism, "a hybrid of machine and organism, a creature of social reality as well as a creature of fiction" (Haraway 1991, 149). In this sense, cyborg is used as an ontological strategy for exploring the interface between technology and the body. Haraway's (1991; 150) is "an argument for *pleasure* in the confusion of boundaries and for *responsibility* in their construction" [emphasis in original], and so offers a strong challenge to traditional, masculinist and capitalist ways of viewing reality. The cyborg has been adopted by urban ecologists, notably Gandy (2005, 28) who argues that "urban infrastructures can be conceptualized as a series of inter-connected life-support systems." The modern home, for example, “has become a complex exoskeleton for the human body with its provision of water, warmth, light and other essential needs.” These connections and networks extend beyond the body and home through urban space to produce a “multi-layered structure of extraordinary complexity and utility.” Bruno Latour’s (2005, 71) concept of nonhuman agency, where “*anything* that does modify a state of affairs by making a difference is an actor,” has also figured in the UPE literature.

The urban metabolism

Arguably UPE’s greatest contribution is the development of Marx’s concept of metabolism, and the closely related concept of circulation. Metabolism is used as both an ontological foundation, a way of conceptualising material and social exchange in relational and post-dualist terms, and as the starting point for a potentially transformative and egalitarian urban politics (Heynen 2014; Keil and Boudreau 2006). Indeed, the particular form that metabolic exchange takes place, which in capitalist cities centres primarily around the production, circulation and consumption of commodities, always raises profoundly political questions about how urban configurations emerge (Gandy 2004). Thus;

> *“[T]he city and urbanization more generally can be viewed as a process of de-territorialization and re-territorialization through metabolic circulatory flows, organized through social and physical conduits or networks of ‘metabolic vehicles.’ These processes are infused by relations of power in which social actors strive to defend and create their own environments in a context of class, ethnic, racial and/or gender conflicts and power struggles.”* (Swyngedouw 2006, 106)

The urban metabolism, then, is not unique to capitalism, but the form it takes, the social relations, technologies, discourses and ideologies that co-evolve with material flows are given structure by the historical development of capitalist relations. The political question, which is all too often forestalled in other relational materialist traditions, is explicitly left open: how might we formulate and enact different praxis of metabolic exchange in order to create more just forms of urbanisation? In emphasising dynamism and potential over torpidity, the principle aim of UPE has been to "articulate urban metabolism as a dynamic process by which new sociospatial formations, intertwinings of materials, and collaborative enmeshing of social nature emerge and present themselves" (Heynen 2014, 599).

Closely related to the concept of metabolism is that of circulation. In the UPE literature the term takes on a twofold meaning, considering the inextricable dual flows of material commodities and capital through urban space (Swyngedouw 2006). Again, this notion is developed from Marx's work on the metamorphoses and circuits of capital in its various forms, explored in great detail in the second volume of *Capital* (Marx 1956). Here, the circulation of productive capital, which takes the form of commodity flows (C), is opposite to that of money capital (M). Thus, the movement C-M-C is accompanied by the opposite movement M-C-M. The flow of commodities through the urban landscape, be it water, cars, food, clothing, waste, electrons, or photons carrying information, form one direction of a double movement, completed by the counter flow of capital. Together, the movement of commodity and capital form the basis of accumulation and urbanization in modern capitalist cities. Circulation is enabled and lubricated by locking a portion of total capital into the material landscape as *fixed capital*. These nodes and conduits, be they roads, bridges, pipelines, houses, cables, skyscrapers, factories and machinery, or desalination plants, give form to the urban landscape and facilitate the flow of commodities and money.

Herein lies one of Harvey's (2014) foundational contradictions: capital's imperative to remain as mobile as possible, on the one hand, and its need to fix in place to allow growth and reproduction on the other. According to Harvey fixed capital gradually transfers its value to other commodities during use to the point when, at the end of its lifetime, contains no value at all. Thus, capital, which Marx defines as *value in motion*, "continues to circulate as value while remaining materially locked within the confines of the production process as a use value"

(Harvey 2006, 209). This has been demonstrated empirically in the UPE literature by Cooke and Lewis' (2010) analysis of Chicago's Michigan Avenue Bridge, which acts as a 'metabolic vehicle' for capital, driving corporate-commercial development in the area, and by Gandy (2002) in his study of highway building in New York City.

Through the language of metabolic circulation, UPE attempts to illuminate how unequal relations of social power and exclusionary practices, as structured through the social relations of capitalism, are reflected by and articulated in the materiality of the urban landscape. The political project of metabolism, then, is to insist on the possibility of egression. By this I mean that UPE adopts an expressly political view of relationality, in that the urban is inherently political and inherently relational. Or rather, the process of forming new relations is innately political. Put another way, the particular materialist conceptualisation adopted in UPE is one in which the capitalist imperative of growth and internalisation is by no means the only, or inevitable, form of relationality.

Neoliberalism and the urbanisation of water

The imperative of internalisation by capital should be understood as a process of the realignment of human and ecological relations consistent with, and directed towards the logics of capital accumulation. This has broadly proceeded through two related processes: extensive strategies and intensive strategies (Bakker 2003, Foster 2000, Harvey 1996, Moore 2015, Smith 1984). On the one hand, extensive strategies involve the expansion of capitalist relations *over* space, through processes like colonialism or the establishment of private property rights. Karl Marx called this process *primitive accumulation*, and David Harvey, *accumulation by dispossession* (Harvey 2005). To this end;

> *"The need of a constantly expanding market for its products chases the bourgeoisie over the whole surface of the globe. It must nestle everywhere, settle everywhere, establish connections everywhere."* (Marx and Engels 1992, 6)

On the other hand, intensive strategies refer to the deepening of capitalist relations *within* space. This has involved, to highlight a few examples, the commercialisation of spheres of reproduction, the financialisation of housing, or the fostering of consumption by the injection of credit.

A growing body of literature, led by critical geographers and political ecologists, recognises that these extensive and intensive strategies are achieved through a dynamic transformation of nature. "Capitalism," Moore (2015, 2) argues, "is not an economic system; it is not a social system; it is *a way of organizing nature*." Much of this work has focussed on the neoliberalisation of nature –or the nature of neoliberalism (McCarthy and Prudham 2004), as what Castree (2008) calls the current 'shell' of the capitalist mode of production. Indeed, the transformation of nature-society relations consistent with the market logics of privatisation, (de/re)regulation, commercialisation and corporatisation are key hallmarks of the neoliberal era. Neoliberalism is then, at its heart, an environmental project, and one in which the objectives of economic liberalisation are advanced through the reshaping of socio-ecological relationality (Heynen et al 2007, Heynen and Robbins 2005, Himley 2008, Mansfield 2007). As Bakker (2013) notes, the broad processes that we understand as the neoliberalisation of nature have involved a double movement of, firstly, the increasing private ownership and management of nature and resources, and secondly, the use of market logics and market proxies in the governance of nature. Attention has been drawn to the extension of capitalist relations into nature via, for example, payment for ecosystem services, carbon trading, mineral extraction in indigenous lands, land grabbing, and the privatisation of urban infrastructural services.

The political ecology of urban water has received a great deal of attention in UPE scholarship. Particularly notable studies include Erik Swyngedouw's work in Guayaquil (2004a) and Spain (2015), Matthew Gandy (2015) in a variety of urban contexts, Maria Kaika (2005) in Athens, Alex Loftus (2007, 2009) in Durban, Antonio Ioris (2007, 2012) in South American cities, and Karen Bakker's (2013) work on privatisation. The use of water as a vehicle for interrogating the heterogeneity, economics, and power relations of the historical and contemporary urban condition is discussed in greater detail in the next chapter. Here, however, I highlight one strand of this work, which considers the political importance of materiality –a conceptual theme that runs through this thesis. Water presents a particularly intriguing entry point for analysis, in part because, as Loftus (2009, 956) has observed, "capital has actually found it remarkably difficult to profit from water privatisation." This is due to the particular material characteristics of water, which render it in many respects unsuitable as a vehicle for surplus value and accumulation. The market has, in a word, historically struggled to discipline water (Bakker 2003, Bear and Bull 2011, Castro 2013, Page 2005, Swyngedouw 2005). Particularly useful in grappling with the political economy of water is Karen Bakker's notion of the 'uncooperative commodity.' She writes;

> *"Understanding why water is such an 'uncooperative' commodity, persistently characterized by externalities and hence market failure, requires reference to its biophysical characteristics; in other words, to its 'materiality'… The use of the term 'materiality' implies an acknowledgement of the corporeality of our economies, of their embedding in natural processes. The term 'materiality' also refers to an understanding of nature as a subject of political economic processes, whose specific biophysical characteristics shape the social relations of production, simultaneously enabling and constraining its own production."* (Bakker 2003, 31-32)

At the heart of this concept of the materiality of water, and its political significance, is the notion of barriers to accumulation. These can roughly be divided into three characteristics of water: density, volume and fluidity. Water is heavy and difficult to transport. Sites of collection, storage, treatment and consumption, are therefore, geographically constrained and contingent. This limits opportunities for trading on an open market. Water must also be mobilised in large volumes, and crucially, at relatively low cost in order to sustain sanitary cities, industrial production and agriculture. Herein lies a deep tension between water as the general preconditions of production and reproduction, and water as the object of production and bearer of surplus value. Water is a flow resource, transient, technologically challenging to store and transport. Externalities, such as pollution, are rapidly diffused and difficult to contain. As water flows, it passes through multiple functions and forms of ownership, not all of which are easily commensurable under the capitalist rubric. Any attempt to commodify water, then, can only establish the social relations of capitalism in a particular phase of the hydrological cycle –hence, the 'commodity phase' of water (Page 2005).

Together, these material characteristics present a number of significant obstacles for capital. First, the necessity for large infrastructures and long-term fixed capital investment is contrary to capital's imperative for accelerating circulation and turn over (Harvey 2006). This also leads to the formation of natural monopolies, which reduce opportunities for competition. Second, capital's usual strategy for achieving growth through increasing either price or supply is often not viable in the case of water, where the political and ecological imperatives are generally towards limiting use and maintaining price (Swyngedouw 2005). Third, many areas are simply not profitable to provide with water services, particularly outside affluent urban centres. This has resulted, in places where privatisation has been poorly governed, to the cherry-picking of profitable areas and resulting uneven geographical distribution. Finally, there is limited scope for 'adding value' to water in the production process. Water is, after all, either safe or dangerous. At least in North America and Europe, water is also almost always delivered through centralised conduits. It would be neither feasible nor ethical, therefore, to deliver varying qualities of water to different customers, based on price differences.

Although interesting work has been conducted on, for instance, the use of water meters to introduce market logics to the water sector (Loftus 2006), insufficient attention has been paid to the technologies mobilised in the market-disciplining of water. Chapter eight, in which the desalination plant is conceptualised as a 'water factory,' addresses this gap.

On heterogeneity and assemblage

Of all Marxian approaches to conceptualising society and nature, UPE (and the major theorists it draws from –Harvey, Smith, and so on) certainly presents the most subtle and theoretically rigorous account. Significantly, UPE has for the most part, managed to escape the binaries and simplifications that other Marxist notions of nature reproduce. Here, then, is the field's greatest contribution, in that it promotes a decentred and post-dualist ontology, which nevertheless prioritises politically performative concepts of relationality, social power, marginalisation and the potential for alternatives. This, I argue, has been achieved through sustained engagement with non-Marxist and post-structuralist theories. UPE has drawn on philosophers as varied as Lefebvre, Foucault, Gramsci, Latour and Haraway (Gandy 2005, Keil 2003, Loftus 2012, Swyngdouw 2006). To many urban political ecologists, Marx is necessary, but not *wholly sufficient* to conceptualise the socionatural processes of urbanisation.

Some have argued, with limited success, that Marxist theory shares significant ontological common ground with post-structuralist and post-humanist theories (Castree 2002; Gareau 2005; Perkins 2007; Rudy 2005). Without wishing to simplify too much, these authors all argue that, although there has been sharp disagreement between these disparate traditions, the differences are generally over-stated at the expense of commonalities. To a greater or lesser extent, they agree that 'strong' interpretations of theory are largely incompatible, but 'weak' readings of the same theories are open for productive assimilation. In a word, the shortcomings of various traditions may be healed by incorporating other approaches. Although such arguments can be compelling, there is always a danger of watering down theory to the point of banality. In general, UPE research has not attempted such an ontological fusing. Rather, the approach has been more one of theoretical hybridisation, and in particular, concept-borrowing. Differences of theory are not denied as such, but UPE scholars have effectively mobilised certain concepts and language from the likes of Latour, Lefebvre and Foucault. Studies that rely too heavily on purely Marxian notions of the production of nature, without engaging posthuman or more dispersed notions of materiality have a "tendency to move too rapidly from the concrete to the universal, so that diverse materialities become conflated into the unitary category 'nature'" (Bakker and Bridge 2006, 11). In this research, then, I advance some of the ideas from assemblage thinking as useful handles to grasp the complexity and contingency of the desalination phenomenon in Southern California.

Principles of assemblage

Ironically, the concept of assemblage is itself somewhat assembled. By this I mean that it has multiple influences and as a result, is not easily definable –hence, *assemblage thinking*, not *assemblage theory*. Despite this conceptual slipperiness, the language of assemblage is gaining traction in geography and across the social sciences. Recent work on assemblages is influenced by two principle, and quite distinct, theoretical orientations. The first is derived from the work of Giles Deleuze and Félix Guattari. Deleuze and Guattari's notion of assemblage is expressly metaphysical. It is, first and foremost, an attempt to redefine political subjectivity. Using the metaphor of a garden, rather than a tree, the singular and coherent political body (the proletariat as the convocation of the Left, for instance) is rendered manifold and constellatory –the political 'multiplicity' (Deleuze and Guattari 1987). An assemblage can denote something very small, like a local conservationist movement, or vast, like capitalism. In each case, however, assemblage emphasises incoherence (to a greater or lesser extent), conflicting movements and permeability over homogeneity and fixity. This does not preclude the notion of structure –indeed, every assemblage is given structure by the interactions of its constituent parts– but rather rejects essentialism. One may, therefore, talk in terms of the capitalist assemblage as a collection of people, things, practices, discourses and ideologies, but not of a transcendent force of capital. An assemblage is;

> *"…every constellation of singularities and traits deducted from the flow –selected, organised, stratified– in such a way as to converge (consistency) artificially and*

naturally; an assemblage, in this sense, is a veritable invention." (Deleuze and Guattari 1987, 406)

Assemblage never describes an end point or a beginning, but rather a condition always in the middle, constantly changing, re-assembling –hence, a *Thousand Plateaus*. To Tampio (2009, 394) "[t]he brilliance of the concept of assemblages is that it describes an entity that has both consistency and fuzzy borders," a vision of the Left which is not necessarily united around a common identity, but rather forms a collection of "semi-coherent political entities that express and work for the ideals of liberty and equality." An assemblage, although not fully coherent, is nevertheless a profoundly geographical construct. Assemblages are "produced in the strata, but operate in zones where milieus become decoded" (Deleuze and Gattari 1987, 503). They are territorial, but dynamic and mobile, not spatially fixed and hierarchical (Allen and Cochrane 2007; McFarlane 2009).

The Deleuzian metaphysical understanding of assemblage has more recently been materialised in the social sciences to describe the connections between disparate socio-material elements. This 'new' assemblage literature, exemplified by the likes of Colin McFarlane, Manuel DeLanda and Jane Bennett, draws inspiration from the second wave of Actor-Network Theory scholarship, sometimes referred to as after-ANT (e.g. Farias and Bender 2010; Hetherington and Law 2000; Latour 2005). After-ANT furnishes materialist concepts like nonhuman agency and heterogeneity, which are mobilised through the language of Deleuze and Guattari as an alternative post-dualist framing (Anderson and McFarlane 2011). In effect, and despite some clear differences, the 'network' broadly translates and morphs into 'assemblage' (McFarlane 2009). Although intellectually disparate, in essence current scholarship on assemblages seeks to understand how social-material amalgamations, such as cities, or indeed techno-political configurations like seawater desalination plants are "enacted into being in networks of bodies, materialities, technologies, objects, natures and humans” (Farias 2010, 13). Very broadly, this literature has solidified around two key concepts.

The first is that of emergence. Although Featherstone (2011) points out a tension in some assemblage thinking between conceptualising assemblages as relational processes or as constituted ‘things,’ there is nevertheless general emphasis on flux, contingency and dynamism, and to uncovering the multiple movements that together constitute an effect. The authors cited here are all concerned with the process of assembling, rather than the assemblage as resultant formation. Assemblage thinking is therefore, more than anything, interested in uncovering the “hard work required to draw heterogeneous elements together, forge connections between them and sustain these connections in the face of tension,” and in analysing “how the elements of an assemblage might -or might not- be made to cohere” (Li 2007, 264). Following on from this, Colin McFarlane, along with others, has argued that the contributions of the assemblage literature, be they conceptual, descriptive or methodological, imply a normative commitment to explore how these social-material networks are produced, to whose potential benefit, and to how they might be imagined differently (McFarlane 2011a; Anderson and McFarlane 2011). This is the ‘history-potential relation’ that describes both the ‘depth’ of assemblages, how the historically and geographically contingent processes of assemblage formation produce particular trajectories, *and* the potentialities of new configurations to emerge from the old (McFarlane 2011b).

The second broad theme in the new assemblage literature concerns distributed agency. In the interests of clarity, some distinctions are necessary before jumping into the murky waters of material agency. Although conceptually related, the assemblage interpretation is not that of the strong theory of nonhuman agency espoused in ANT (Callon 1986; Latour 1993; Law and Mol 1995) and some of the New Materialism literature (Bennett and Joyce 2010). Whereas the ANT approach attributes agential capacity to particular actants or actors, the assemblage conceptualisation contends that an action or movement is never the outcome of a single actor.

Rather, effect emerges through the intersection of human and material elements. In a word, there is no causality without relationality. To DeLanda (2006) assemblages consist of human, material, technical, social and natural parts, which, through close interaction co-develop into networks of greater or lesser coherence. All parts of an assemblage, human and material alike, play roles that fall somewhere along a continuum from purely expressive to purely material. Parts cannot be understood purely in terms of their place in a whole, they may have other properties that are not realised in that whole. Relations between parts are *contingently obligatory* in that they are not given or predetermined, but arise through coevolution.

Particularly influential in this framing has been Jane Bennett's notion of vital materialism. To Bennett (2010, 31/34), a "theory of distributive agency…does not posit a subject as the root cause of an effect." Instead, there are "always a swarm of vitalities at play." According to this concept, therefore, an assemblage "owes its agentic capacity to the vitality of the materials that constitute it." Human agency is not only distributed in the tools and technologies that are intended to produce certain effects, but also in the disruptive capacity of seemingly excluded elements (Bennett 2005). Agency is hereby seen as *distributed* and *composite*. The political importance of nonhuman agency, nevertheless, is often overstated. Moreover, doing so raises very difficult questions about intentionality and accountability, which are sometimes inadequately addressed or overlooked in the assemblage literature. Notwithstanding the important contributions to post-human politics made by Bennett and others, I therefore prefer to talk in terms of material efficacy, rather than agency.

Heterogeneity, metabolic assemblages and methodology

While some have argued that the breadth and malleability of assemblage thinking is precisely its strength (Anderson and McFarlane 2011), others (notably Brenner et al. 2011) contend that this conceptual slipperiness leads to weak theorising and confusion, particularly over whether assemblage refers to a research object, a methodology or an ontology. In an effort to avoid vagueness and confusion, this section clarifies my use of assemblage in this research.

The assumption of society's heterogeneity is the foundation from which assemblage thinking proceeds –i.e. that the 'social' is non-homogenous. Yet, this axiomatic term is rarely defined, and often takes the form of a buzzword. The standard definition, that "heterogeneous" describes a body or substance that is "diverse in kind or nature" (Oxford English Dictionary), is generally accepted. The mathematical definition, however, goes further, denoting those constituent parts which, through their diversity, are incommensurable. This is a subtle, yet vital distinction. With reference to the complexity of socio-material interactions, the former definition is apolitical, in that it is purely descriptive, while the latter holds the kernel of a politicised notion of assemblage. By this I mean that merely stating that something is socially and materially diverse is not particularly profound or indeed interesting, but insisting that this diversity carries a particular set of implications, is potentially disruptive. Take, for example, recent attempts in the field of Ecological Economics, to attach specific market value to 'environmental services,' such as wetland storm barriers or carbon sequestration in tropical rainforests. Complex ecological and social processes are simplified, categorised, commodified and expressed in monetary units, and may therefore be traded and speculated upon in the market. Indeed, one could argue that the historical development of capital –the extension of capitalist social relations into new territories, processes and practices– constitutes an attempt to render commensurable that which, because of its heterogeneity, is radically incommensurable. Adopting the politicised interpretation, therefore, implies an understanding of assemblage, which by definition is constituted through its incommensurability, that contests capital's imperative for internalisation and equivalence.

Assemblage thinking, mobilised in this way is useful because it "offers the possibility of grasping how something as heterogeneous as nation states, for instance, or regional political formations, hold together *without* actually ceasing to be heterogeneous" (Allen 2011, 154). In thinking through the implications of this for notions of distributed, or nonhuman agency, Kirsch and Mitchell's (2004) adaptation of Marx's theory of dead labour is particularly insightful. They argue that the intentionalities ossified in commodities, technologies and other forms of metabolised nature through past labour can influence, and even direct, current human activity. Thus, it is the metabolic process between humans and material nature (the forging of new relations) that distributes agential capacity throughout the assemblage. For example, it is not the five wide-diameter pipelines, which transport water hundreds of kilometres to San Diego from the Colorado River and Northern California, that compel some to dump up to 2,000 litres of water on their lawns every day, but rather the social relations that work through, and connect with, those technologies. According to Kirsch and Mitchell, then;

> *"[T]here is social intentionality in turning relationships into things; there are reasons for putting networks [or assemblages] together, even if those reasons themselves are highly structured by and determined within the contested relationships that constitute capitalism as a social totality."* (Kirsch and Mitchell 2004, 700)

In this way, agency can be understood as being distributed through heterogeneous assemblages, without attributing individual agency to particular objects. The contribution of assemblage thinking here is to demonstrate that while material elements may embody the intentions of those who made or mobilised them, the particular manner in which they are assimilated into an assemblage may have disruptive or unintended effects (McFarlane 2011a).

Moreover, although process and relationships are emphasised, assemblage thinking does not necessarily preclude discussion of structure in exploring the particular forms assemblages take (Marcus and Saka 2006). Indeed, Robbins and Marks (2010) distinguish between what they call 'symmetrical assemblages,' propounded by the likes of Latour, and 'metabolic assemblages,' which adopt a more Marxian approach. Although related to more widely accepted interpretations, in that heterogeneity, distributed agency and emergence are still key themes, metabolic assemblages are nevertheless framed and shaped by identifiable socio-economic forms, such as feudalism, capitalism or communism, which change over time. This understanding, then, "inevitably differs from other forms of assemblage in its necessary privileging of some important, established categories of labour processes and capital flow" (Robbins and Marks 2010, 189). In this way, the language of assemblage can be mobilised to ask questions about social power, marginalisation and environmental justice that are forestalled in more symmetrical forms (McFarlane 2011c). McGuirk and Dowling (2009), for instance, use assemblage to explore the heterogeneity and diversity of practices, and the multiple pathways of neoliberal restructuring in Sydney's real estate sector.

I am not trying to argue that Marxian political ecology and assemblage thinking are entirely compatible, nor that a full synthesis is possible or desirable. It is true that they are both highly relational materialist social theories, and that they therefore share some important features, especially in emphasising process, change, heterogeneity and indeterminacy. Put another way, there is common agreement that everything is in a constant state of change, and that change is open-ended. But there are important differences and incompatibilities, most importantly, as I have argued, concerning the particular way in which relationality, externality and the political moment are handled. To attempt an uncritical integration of the two would probably lead to conceptual vagueness and overall weak theorising. If these two perspectives are to be brought into dialogue, McCann (2011, 145) has argued, "they must be brought together carefully, recognising their provenance and situatedness, compatibilities and incompatibilities, and their capacities and limits." Nevertheless, as the field of urban political ecology demonstrates, critical and deliberate concept sharing can be theoretically productive.

My particular use of assemblage is largely descriptive and methodological. The language and image of assemblage is particularly powerful for post-dualist discourses because, unlike some other concepts, it does not inadvertently reproduce the same binaries it seeks to discredit. This research, then, is aligned most closely with Robbins and Marks' (2010) notion of the metabolic assemblage. I begin with a dialectical understanding of contradictory socionatural metabolic processes, but also draw on assemblage notions of heterogeneity and material efficacy. My particular mobilisation of assemblages, then, is intended to emphasise the complexity, the histories and potentialities, and the heterogeneity of the desalination technological node, within a broadly neoliberal, growth-oriented and accumulation-driven trajectory.

Infrastructure and the re-shaping of socio-ecological relations

If the flow of water through cities 'lubricates' the economy (Swyngedouw, 2005), then energy 'fuels' the economy (Huber, 2013). The technologies through which this is achieved are the condition of urbanisation. Infrastructures transcend and link together spaces of production, distribution and consumption; they connect the raindrop to the kitchen tap, the aquifer to the garden hose, the coal mine to the light switch, and the photon in a ray of sunlight to the kettle. Gandy's (2004, 373) argument that the flow of water "implies a series of connectivities between the body and the city, between social and bio-physical systems, between the evolution of water networks and capital flows, and between the visible and invisible dimensions to urban space" could equally apply to energy and its production, distribution and consumption technologies. Infrastructures are, in a sense, relationship creators; they are efficacious in the forming and reforming of social and material interconnectivities. It is now well understood that infrastructures act as mediators, being both shaped by and creating geographies and territories (Barry 2013, Bouzarovski et al 2015, Moss 2014), in the configuration and consolidation of state power (Bouzarovski and Bassin 2011), the transformation and urbanisation of nature (Kaika and Swyngedouw 2000), in the metabolising of resource flows (Monstadt 2009), and in forming relationships between people and between people and the environment (Amin 2014, Kaika 2015). The intentionalities embedded in infrastructure, ossified in material form, influence and shape human action (Bouzarovski 2010). Similarly, the social relations that coalesce through infrastructures often produce unintended or unpredictable effects (Bennett 2005). It follows, then, that we must begin to conceptualise agency, or the capacity to act and influence things, as a relational flow, circulating through infrastructural technologies and the ways in which humans use and interact with them.

As heterogeneous socio-material assemblages, spaces where different elements, technologies, flows, cultures, capital and social intentionalities are drawn together in a process of mutual constitution and reconfiguration, urban infrastructures are at once palimpsests of old and new forms of urbanism, and technologies of transformation (Graham and McFarlane 2015). Understood also as "site[s] of multiple, overlapping, or nested forms of sovereignty, where domestic or transnational jurisdictions collide" (Easterling 2014, 15), the governance of environmental and social transitions is inherently a process with infrastructure at its heart. Given the centrality of these technologies to urban transitions, infrastructures are also necessarily integral to discussions on the future trajectories, forms and politics of cities (Coutard and Guy 2007, Goldman 2011, Hodson and Marvin 2009). Yet, the importance of infrastructure for transitions in often overlooked (Bulkeley et al 2014). Much of the discussion on infrastructure concerns notions of 'path dependency,' which describe the condition whereby, because of the longevity and behaviour-influencing capacity of technical systems, cities are locked into particular cycles of consumption and distribution. Others, however, stress openness, dynamism and potentiality of urban systems (Soja 2000). Urban infrastructures, which form the primary mediators between material resources and urban populations, are for instance, deeply implicated by resource pressures, notions of scarcity and climate change, and the transformation of technical networks has become part and parcel of strategies of adaptation and mitigation (Bulkeley and Broto 2012). Moreover,

> *“In a period of resource constraint and climate change the world’s largest cities are beginning to translate their strategic concern about their ability to guarantee resources into strategies designed to reshape the city and its relations with resources and other spaces.”* (Hodson and Marvin 2010, 478)

In particular, because of their critical importance to the functioning of cities, water and energy networks have become the focus of ‘sustainable’ transitions (Moss 2001, Monstadt 2007). The remainder of this chapter is concerned with how the historic and contemporary development of water and energy infrastructure, understood as socio-technical assemblages, shape the practices, institutions, politics and economics of urban resource governance.

Building the compartmentalised city

The compartmentalised city describes an ideology of development, which became prominent under nineteenth century visions of modernity, based on the notion of an ordered, cohesive city, rationalised and structured through standardised and universally accessible infrastructure networks. Graham and Marvin (2001) have called this the ‘modern infrastructural ideal.’

“Water,” as Jamie Linton (2010, 3) asserts, “is what we make it.” This has been, since the industrial revolution and particularly from the mid-nineteenth century on, to engage water in what Goubert (1986) as called a ‘double-edged conquest’. The first movement, the human conquest of water, saw water become the subject of scientific and technological knowledge, and therefore increasingly an industrial and commercial product. The second movement was the conquering of humans by water; the functioning of industrial society became wholly dependent on abundant, reliable and cheap freshwater. Deepening understanding of the virtues of water and its potential uses combined with rapidly developing technologies to control and manage it. In Europe and North America, the desire to control and subjugate water became modernity’s Promethean Project, with engineers and technocrats as its heroes (Kaika 2005). Great public works –dams and reservoirs, canals and pipelines, sewers and fountains– stood as monuments to progress, growth and national identity, as well as catalysts for the drastic re-forging of the relationships between the city and nature (Worster 1985, Kaika 2005). Water use in industrial, commercial and domestic sectors burgeoned as a result of this conquest on both sides of the Atlantic. The making of what Gandy (2004) calls the 'bacterialogical city' and Melosi (2000) the 'sanitary city' was driven by the chaos of nineteenth century urbanisation. Most sizeable urban settlements experiencing unprecedented growth, faced water crisis (Melosi 2000). Water quality was poor, its quantity inadequate, its supply expensive and unreliable, and waste removal systems were archaic. A series of devastating disease epidemics, culminating in the cholera outbreaks of the 1830s and the establishment of causal links with contaminated water, provided the impetus for a water revolution (Goubert 1986, Koeppel 2000, Melosi 2000).

The resulting great infrastructural works of the nineteenth and twentieth centuries encompassed *supply* –the capturing of water from beyond the boundaries of the city, its purification and delivery to homes and industry (Koeppel 2000, Gandy 2002); *removal* –through great sewerage and treatment works (Gandy 1999, Karpouzoglou and Zimmer 2016, Laporte 2000); and *drainage* –an often overlooked aspect of urban water infrastructure (Karvonen 2011). The emphasis of these developments was on large, standardised state-led technological 'improvements', designed to homogenise and bind together urban space through equal access to abundant and clean water. Value was placed on cleanliness, order, purity and beauty and became concomitant with moral discourses on spiritual righteousness and bodily cleanliness (Laporte 2000). The modernist conquest of water, however, was not simply a response to health issues, but constituted "a new socio-spatial arrangement that could simultaneously ensure a degree of social cohesion at the same time as protecting the political and economic functions of the modern city" (Gandy 2004, 365-366). According to this dual conquest –humans over water and water over humans– the logics of capital accumulation and the Promethean urge to tame water can be seen as being locked into a concatenation of growth, whereby the economic imperatives to control water resources compel societies to become increasingly reliant on abundant fresh water.

During a similar period, the cities of Europe and North America underwent a similar process of networked provision of energy and energy services. To Hughes (1983) the electrification of, in the first instance cities, and then entire landscapes, represents one of the greatest social, technical, scientific, economic and cultural achievements of industrial society, and was central to what has been called the 'second industrial revolution' which took place in the late 1800s. Because of the size, scale and complexity of electricity networks, they became the important focus of studies on Large Technical Systems (LTS), particularly in the 1980s (Joerges 1988, Levy-Leboyer 1988, Hughes 1983). The places, structures and technologies of electrification, the "electrical sublime", are to Nye (1994, 23) the "amalgamation of natural, technological, classical, and religious elements into a single aesthetic." Houses, factories, shopping centres and cities are not passive spaces that become 'electrified' through technological development, but form instead the social terrain in which electricity is incorporated into everyday activities. These are the 'unforeseen transformations' latent in every technology (Nye, 2006). The roll-out of standardised electricity infrastructures, along with compatible appliances became vital mediators of urban living.

The development of networked distribution of water and energy was central to what Gandy (2002, 37) calls the "rationalization of public space." The modernist project of urbanisation was, through the deployment of technology and infrastructure, architecture and planning, to cleanse and make healthy the stagnant city. The role of networked infrastructure was to facilitate the rapid circulation of water, energy and other material elements, and therefore also the rapid circulation of capital, through urban space. Otter (2004), for instance, argues that these technologies of clarity can be split into two groups. 'Negative' technologies, like clean water supply, sewers, refuse collection and centralised abattoirs, freed urban residents from the moral horrors of uncleanliness and disease; whilst 'positive' technologies, such as electricity and lighting, 'facilitated lucidity' and made urban workers more productive. At the same time as reconfiguring the material flows through cities, the development of networked infrastructures also transformed the social relations of water and energy:

> *"Finally, fresh water was carving out a kingdom for itself, a kingdom both visible and invisible, subterranean and manifest, public and private, intimate and social. A water-devouring economy was gradually set in place."* (Goubert 1986, 115)

> *"…..electricity is an enabling technology that is not always noticed. It quietly became central to the functioning of the modern city, to the 'industrialization' of the home and modernization of the factory, and to the improvement of the farm."* (Nye 1990, 26)

Nevertheless, this process of rationalisation was also based on a rigid separation of socio-material flows. Through the establishment of categorised infrastructural networks and associated distinct institutional and governance structures with specialised scientific knowledge, the urbanisation of water and energy in the modernist era became sharply divided.

Unbundling the compartmentalised city

So far, water and energy infrastructures have been discussed in relation to their capacity to homogenise urban space, to bind it together physically and socially through the provision of standardised, monopoly-based services, consistent with meta-visions of progress. The following paragraphs move beyond this paradigm to consider how infrastructures *differentiate* urban spaces, and to what extent they might be considered to be connected to broader processes of social fragmentation and economic neoliberalisation. Graham and Marvin, in their seminal book *Splintering Urbanism* (2001), argue that since the 1960s, the ideals of equal, affordable access to urban services based on fostering social cohesion, characteristic of the 'modern infrastructural ideal' have been eroded, resulting in the fragmentation of urban space. This splintering has been driven by the confluence of a number of processes, notably post-Fordist economic and political restructuring, the movement away from monopoly control, the decline of the welfare-state and rise of consumerism, and the development of new technologies that facilitate service differentiation and reduce the conditions for natural monopolies. These trends have combined with 'glocalisation' process, which have increasingly seen city-regions as self-contained centres of connectivity competing to attract global capital (Swyngedouw, 2004b), to produce 'pepperpotted' infrastructural developments that overwhelmingly favour high-value users. This has led to the emergence of, on the one hand, what Graham and Marvin call *premium networked spaces*, where users are hyperconnected, plugged into flows of materials, communications and capital; and on the other hand, spaces of marginalisation and disconnection. According to the splintering urbanism thesis, infrastructures are now implicated in the fragmentation of urban space, rendering the coherent, incoherent.

The notion of fragmenting infrastructure very much parallels broader movements of neoliberal governance, understood as "an historically specific, unevenly developed, hybrid, patterned tendency of market-disciplinary regulatory restructuring" (Brenner et al 2010, 330). In these processes of economic and political restructuring, realised through market-based policies like privatisation and deregulation that prioritises growth over social goals, cities function as the crucible of change (Peck and Tickell 2002, Harvey 2005). Indeed, because networked urban infrastructures are the conduits for so much of the material flows that sustain cities, and through which cities are constituted, they are also necessarily at the heart of political and economic restructurings (Guy et al 2001). For urban infrastructures, the introduction of market mechanisms has been achieved through the 'unbundling' of monopolies and the introduction of the principles of competition, albeit to varying degrees (Rutherford 2008). The water and energy sectors of many cities globally have undergone privatisation, commodification, the break-down of monopoly provision, the commercialisation of services, and a drive towards full-cost pricing (Bakker 2005, Hess 2011).

Although highly influential, the *splintering urbanism* thesis and the notion of infrastructural unbundling have received criticism from urban theorists and scholars working on infrastructure. Critique centres around three themes. First, a rejection of meta-theory and an unwillingness to accept splintering urbanism as a 'general rule.' To Coutard and Guy (2007), *splintering urbanism* offers a useful 'middle-range' theory, provided that it is not applied too generally, but that it is guilty of 'universal alarmism'. They argue that neoliberal infrastructural developments *potentially* but not *necessarily* contribute to differentiation. Second, challenging the assumed link between technological and institutional infrastructure fragmentation and neoliberal restructuring. This theme will be interrogated more in the next chapter, which argues that calls for greater integration and infrastructural re-bundling championed by the nexus framework, imply the opposite. Third, objection to the existence of a 'modern infrastructural ideal' and the associated implication that integrated infrastructure services support integration generally (Coutard, 2008). The unbundling thesis has, for example, been criticised for having a Global North bias, in that it focusses on industrialised cities in Europe and North America. Some have argued that in post-colonial cities, infrastructures have always been fragmented (see for example Kooy and Bakker (2008) on Jakarta, and Zérah (2008) on Mumbai). In general, these critiques all point to the need for more context-specific understandings of how infrastructures contribute to, or undermine urban cohesion and shape social relations (Coutard 2008).

Conclusion

This chapter lays out the conceptual foundation, and the key theoretical and methodological concepts that inform the analysis of the politics of seawater desalination in Southern California. Principally, it argues that the extraordinary emergence of large-scale desalting infrastructures in San Diego and Baja California must first and foremost be understood as the outcome of the historic development and urbanisation of capital in the American West (Henderson 1998). The competitive relationships between states (within and between the USA and Mexico), the convoluted transition from agrarian to urban-centric economies, and the contradictory relationship between capital's treatment of water as the general means of production and as vehicle of accumulation, give structure to Southern Californian metabolic interaction with water (and energy), out of which new and extraordinary water-energy configurations emerge. The Marxian dialectical concept of nature, particularly notions of the production of nature and society's circulatory metabolism, it is therefore argued, is an essential starting point for understanding the desalination phenomenon.

Yet, these concepts alone are insufficient to grasp the complexity, contingency and heterogeneity of the processes currently unfolding. The multiple trajectories that are brought into play, through two national contexts, include the disruptive and facilitatory 'acting' of technologies, chemicals, fish and other materialities, are not adequately theorised through an exclusively historical materialist account. Assemblage thinking, is therefore introduced as a set of conceptual tools and terminology with which to grasp such complexity, whilst maintaining the broad categories of accumulation, commodification and production. In the study of urban infrastructures, the need for a conceptual framework that integrates notions of political economy and structure with notions of openness, dynamism and heterogeneity, is brought clearly to the fore. Networked infrastructure are places where history, money, power, nature, and imaginaries fuse. They draw together all manner of material flows and shape resource practices. Infrastructures are *relationship creators*; they mediate the metabolic exchange of energy and materials that constitute the urban, and are at the centre of the re-configuration of social and natural interconnectivities. The political intentionalities embedded within infrastructures are hugely powerful in shaping and re-aligning these relations in a manner consistent with particular logics –namely, the social relations of capitalism. Yet at the same time, the technologies and materialities that are drawn together in infrastructure networks also have disruptive capacities. Infrastructures are, then, at the heart of how cities are produced, and how they might be imagined differently. Nevertheless, the position occupied by networked infrastructures, in the way they intersect different forms of relationality, is not fully understood. This thesis represents a small attempt to address this, mobilising the particular notions and politics of nexus thinking, which are handled more comprehensively in the next chapter.

I have not argued for a full integration of structural and post-structural traditions. Indeed, I have outlined significant differences between them, which largely centre around their divergent handling of the question of relationality. I have argued in this chapter for an expressly politicised notion of socio-ecological relations. Symmetrical notions of assemblage or network insist on universal internalisation, a conceptualisation where everything is infinitely connected, and where relations may be re-ordered but not exceeded. Here, the political moment is in the insistence of the fundamental heterogeneity of the social and material world. This is by no means a superfluous project, given that capital has historically developed on the assumed separation between things and people. Nevertheless, the Marxian materialist political economy and political ecology approach goes further. Radical heterogeneity is merely the starting point of politics. Although concerned with internal relations, political ecology is interested in the moment of egression (i.e. the point at which internal relations are exceeded) and the resultant new formation. There is, therefore, no politics without relationality, and equally no relationality without politics.

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The urban resource nexus

On the politics of relationality and the fallacy of efficient integration

Nexus thinking and the end of the compartmentalised city

There is nothing particularly natural about the city. Nor indeed, is the city unnatural. Cities are what we produce; our images of the world wrought in concrete, steel and stone, pulsing with a myriad of co-constituted organic and inorganic elements; the material realisations of our concept of the human place in nature. We understand this now full well. The modernist image of the city as a distinct sphere, held in opposition to nature, had been comprehensively dismantled in urban scholarship by the turn of the century (Cronon 1991, Harvey 1996, Heynen et al. 2006, Latour 1993). So too had the promises of the functional modernist city of coherence and abundance (Norgaard 1994). In the era of planetary urbanism and ecological crisis we start to see another set of binaries disintegrate: the decline of the compartmentalised city. The material flows that constitute and sustain cities –water, electricity, gas, oil, food, information and a multitude of other commodities– that have traditionally been conceptualised and managed separately, are increasingly being understood as inexorably interconnected, contingent and co-producing. This shift is illuminated in a plethora of emerging concepts, including nexus thinking, diversification, the energy 'trilemma,' Integrated Water Resource Management and virtual water, that, although differing in scope, all emphasise socio-ecological relationality and material interconnectivity. Where previous modes of environmental governance banished externalities to the realm of 'bad nature,' I argue that through these emerging notions and practices of integrated governance, certain externalities are systematically internalised by a new logic of capital accumulation. Particular relationalities, or the connections between certain things, become, in a word, the new frontier of capital.

This chapter offers a critical conceptual engagement with nexus thinking. The concept of the resource nexus has emerged over the past 5-10 years as a powerful framework for understanding the relationships, and critiquing established distinctions between categories of environmental governance that have traditionally been managed in separation (Andrews-Speed et al. 2015, Bazillian et al. 2011, Hussey and Pittock 2012, Olsson 2013, Olsson 2015, Verma, 2015). In essence, the literature reviewed in this paper concurs on the following point: the challenges facing our water, energy and food systems, that together provide the basic material flows upon which all human action is predicated, form a set of complex, and above all *inter-related* problems. The key governance challenge, then, is to mitigate negative interactions and optimise positive interactions (Kurian and Ardakanian 2015). Notions around resource scarcity, limits to growth and planetary boundaries pervade the nexus discourse (Andrews-Speed et al, 2015). Nexus thinking seeks to offer;

> *"…integrated approaches to resource use that emphasize longer-term social and ecological sustainability while offering operational means to internalize externalities, foresee and mitigate unintended consequences, and above all, strengthen resilience through outcome-oriented open learning and institutional change."* (Scott et al. 2015, 16)

Fundamentally, nexus thinking represents an effort to build resilience to insecure resource access, increasing competition between sectors and deepening ecological crises in the context of a changing global climate (Beck and Walker 2013, Rasul and Sharma 2015, Waughray 2011).

Also known as the 'stress nexus,' the concept of a resource nexus emerged from techno-managerial environmental governance circles in response to tensions between water and energy sectors. The California Energy Commission's report on the embedded energy in California's water supplies, and the need for greater coordination between sectors to address shared challenges, provides one of the first examples (Klein et al. 2005). The nexus has since grown to become the new buzzword of resource governance (Cairns and Krzywoszynska 2016). Over the last few years the number of academic publications specifically concerned with the nexus framework has burgeoned; a multitude of international conferences have been arranged on the topic; and a number of high profile events have raised public awareness, notably the Bonn 2011 Conference and UN World Water Day 2014 and 2015. Nexus thinking has now become a central discourse for Sustainability and is seen by many as a core concept for achieving the UN Sustainable Development Goals (Biggs et al. 2015, Mabhaudhi et al. 2016, Rasul 2016, Yillia 2016). Proponents attempt to identify and eliminate tensions and trade-offs between resource sectors, and to highlight synergies and shared goals between them (Scott and Pasqualetti 2010, UNESCO 2014, Pittock, 2011). Although some have questioned the true novelty of these ideas (Rees 2013, Allouche et al. 2015, Muller 2015), nexus thinking certainly presents itself as a radically new approach to integrated resource governance in response to interconnected socio-environmental challenges and constraints (Kurian and Ardakanian 2014). Developing nexus approaches is now a key research agenda across multiple disciplines (Faeth and Hanson 2016).

The nexus discourse so far has developed along a technocratic and reductionist path. The contested relationships, processes and technologies, through which resources become enrolled in nexus interactions –what we might call the political production of the nexus– are drastically overlooked in existing scholarship (Rees, 2013). This chapter, then, offers two core contributions. First, I argue that the politics of scale (Swyngedouw 2000) have been insufficiently handled in nexus thinking so far. This represents a significant gap, given that questions about the interconnections between resources and material flows are inherently profoundly geographical. The chapter focusses on the urban nexus, and in particular interfacing water and energy infrastructures, as a key geographical scale of existing, emerging and contested nexus interactions. Specific attention has been paid to cities in the literature (Kenway et al. 2011, Villarroel Walker et al. 2014), but a comprehensive understanding of the urban nexus is yet unformed (Moss et al. 2016).

Second, I argue that the technocratic language and core concepts of nexus thinking are, in current form, profoundly de-politicising. In particular, I challenge an emerging consensus in the literature, which posits that integrated management of water and energy will necessarily lead to more sustainable management of both. Fundamentally, this is a call for purely efficiency-based techno-managerial solutions to tensions and trade-offs between energy and water, and one that is entirely consistent with market-based approaches to environmental governance. The concept of 'integration' has become a panacea for the negative aspects of the nexus, an ultimate solution that forestalls more politically informed discussions. This assumed logic ultimately implies that the serious challenges posed by the nexus framework do not in fact require real political change.

Dimensions of the water-energy nexus

Expressed in its simplest (and most simplistic) form, the water-energy nexus considers the embedded energy in water systems and the embedded water in energy systems, or succinctly "*energy for water* and *water for energy*" (Perrone et al. 2011, 4229). Moreover, it is when "water and energy rely on each other that the most complex challenges are posed" (Hussey and Pittock 2012, 32). The water-energy nexus concerns the energy required to capture, treat, distribute, use and dispose of water, and the water required to extract, produce, distribute and use energy. This physical, quantifiable, metric of the nexus has attracted most attention from scholars

(Chang et al. 2016, Kahrl and Roland-Holst 2008). As such, much of the literature is concerned with the technologies through which water and energy are brought together. It is these *nexus technologies*, then, that form the starting point of this discussion. A *nexus technology* simply refers to a technical configuration that draws together water, energy, land, and atmosphere, creating or reconfiguring interactions between them. Particular attention is often paid to large infrastructures and technologies –this is what Scott et al (2011) have called the 'pumps and turbines' approach to energy and water coupling, that lies at the heart of this conceptualisation of the nexus.

Energy is required in every stage of water capture, production, extraction, transportation, treatment, distribution, consumption and disposal. Nexus interactions are implied in every aspect of the water system, from the type of shower head installed in your bathroom and the amount of tea you drink each day, to the specific water mix of a given region (i.e. the various sources of water and their respective energy-intensities), and its distribution and treatment infrastructure. Kenway (2013) distinguishes between *direct* links, which describe the respective water-energy intensities of production, distribution and disposal, and *indirect* links, which concern the act of consumption. Although the former is generally given priority in the literature, often being assumed to be more important, end use is nevertheless highly significant. Cohen *et al* (2004) have, for instance, estimated that even in San Diego County, California –a region that relies on energy-intense inter-basin transfers from Northern California and the Colorado River for the majority of its water– *consumption* accounts for 57% of total embedded energy per unit of water.

A common concern is the high energy intensity of alternative freshwater sources, that are emerging as traditional sources deplete and competition between uses increase (Schnoor, 2011). Desalination of seawater and brackish water has received particular attention, along with long distance inter-basin transfer (Clayton *et al*, 2014; Siddiqi and Anadon, 2011; Scott and Pasqualetti, 2010; Lofman, 2002). Both represent significant attempts to expand water consumption in the face of dwindling traditional sources and growing demand, and both are highly energy intensive, albeit with a degree of regional variation. Others have focussed their attention on the energy intensity of existing water practices and technologies, arguing that increasing efficiency in the water sector will relieve pressure on energy resources. Stillwell *et al* (2010), for example, are concerned with reducing the energy consumption of established wastewater treatment infrastructures. The central argument of the *energy for water* literature is that, because of the technological feats water-stressed communities are compelled to achieve, levels of embedded energy in water supply are rising, but, it is also precisely the scarcity of water, and competition for it, that places additional strain on energy supply (Klein *et al*, 2005).

Similarly, large amounts of water are required in the extraction, processing and conversion of energy, in almost all of its forms (Tan and Zhi 2016). In the USA, for example, the energy sector is the fastest growing water user nationwide, with demand expected to increase 50% between 2005 and 2030, and growth largely concentrated in areas already experiencing high levels of competition amongst water users (Carter, 2011). Water is consumed in the extraction, production and refining processes of combustible fuels. Demand is set to rise as alternative fuel types, including hydraulic fracturing and oil from tar sands, replace traditional sources (King *et al*, 2008). Biofuels, such as corn ethanol and palm oil, which have become a popular option for countries wishing to reduce greenhouse gas emissions and reduce reliance on imported fossil energy, are particularly water intense (Bazilion et al. 2011, Gheewala 2011). Although embedded water in biofuel production varies according to context –Chiu et al (2009) have calculated a range of 5 to more than 2,000 litres of water per litre of fuel produced– the expansion of the biofuel industry nevertheless significantly increases energy related water use (Damerau et al. 2016). Here then, an alternative energy option, praised for its ecological credentials, is likely to contribute to water stress over the coming decades.

Much of the nexus literature is concerned with the water requirements of electricity generation, both hydroelectric and thermoelectric. Thermoelectric power plants, the fuel inputs for which include coal, oil, gas, nuclear, and to a lesser extent biomass, require vast quantities of water for cooling. Almost all thermoelectric plants use one of three types of cooling system: o*pen-loop* or *once-through* systems withdraw huge amounts of water, circulate it through the power plant and return 95% to the source; *Close-loop* or *re-circulating* systems withdraw 30-50 times less water than open-loop, but more than 75% is consumed in the process and not returned to the water body; finally, *dry cooling* systems use air flow instead of water for cooling, but cause a dramatic drop in plant efficiency, so are not widely used (Feeley *et al*, 2008; Sovacool, 2009; Wolfe *et al*, 2009). In terms of mitigating the negative effects of the water-energy nexus, the type of cooling system in a power plant embodies many tensions and trade-offs. For example, by switching from open to close-loop, power plants can reduce their vulnerability to drought and water scarcity, but in doing so, increase their water consumption overall (Koch and Vogele, 2009). Overall, thermoelectric plants are responsible for around 40% of freshwater *withdrawals* in the USA –higher even than agriculture- but only 3% of freshwater *consumption* (Fthenakis and Kim, 2010; Wolfe *et al*, 2009). Hence, electrical power generation is severely affected by constraints on water supply, and as a sector, is amongst the most vulnerable to negative implications of the water-energy nexus.

The recent academic and policy interest in nexus thinking has been fuelled, in large part, by the confluence of two trends: the increasing concern over water and energy supply on the one hand, and the deepening of linkages between the two on the other. Alternative sources of water developed to mitigate inadequate or insecure supply, like sea and brackish water desalination, wastewater recycling and inter-basin transfer, tend to increase the water-sector's energy consumption. At the same time, new sources of energy, particularly biofuels and hydraulic fracturing, are often associated with increased water demand from the energy sector. This may lead to a growth concatenation, a cycle of deepening nexus interactions.

Governing the nexus concatenation

The nexus literature, although by no means coherent, conceptualises the multiple interactions between resource sectors under four core categories. Firstly, as *tensions*. The interdependencies between resource circulations are revealed as structural tensions when developments in one put increased pressure on others, and where stresses and insecurities in one simultaneously become stresses for others (King et al. 2013). The interactions and dependencies between sectors are "acutely articulated under conditions of resource scarcity" (Scott and Pasqualetti 2010, 655). That is, as concern over supply intensifies and competition between each grows under conditions of real or perceived scarcity, the centrality of one to the other becomes more stark (Malik, 2002). For instance, water availability is becoming an increasingly important consideration for thermoelectric power plant siting. Water constraints can translate into electricity constraints through reduced electricity output, plant closure or rising prices (DeNooyer et al. 2016). Moreover, the (mis)management of the on-going drought in Venezuela provides a particularly vivid illustration of what Beddington (2009) has called the 'perfect storm' of resource tensions. In a country that relies on hydropower for two thirds of its electricity supply, historically low reservoir levels are causing power shortages and associated widespread blackouts, as well as reduced agricultural productivity, leading to the implementation of emergency government measures, inflation and economic crisis, and political unrest (Bakke 2016).

Secondly, failure to adequately manage these tensions can lead to 'questionable trade-offs' between sectors (Hussey and Pittcock 2012). *Trade-offs* occur when changes in one sector carry negative implications for another sector. For instance, as discussed earlier, the promotion of biofuels as a sustainable alternative to fossil fuels may present benefits for energy security or reducing carbon emissions, but the conversion of agricultural production from food to energy may also be associated with rising food prices, accelerated land use conversion, and increasing water demand for irrigation. The vicious cycle of resource governance trade-offs has led to what Webber (2008) has called a 'catch-22 situation' in decision making.

Third, *maladaptations* are similar to trade-offs. An adaptation to a particular problem becomes a maladaptation when it inadvertently increases vulnerability to that problem. The extraordinary emergence of seawater desalination as an alternative urban water supply provides a good example. Often touted as a climate-proof, drought-resistant and rainfall-independent source of freshwater, large-scale desalination is considered by many to be a viable adaptation strategy to climate change. Yet, by increasing reliance on industrialised energy inputs, often in the form of fossil fuels, desalination may actually exacerbate the problems it is intended to solve, and as such, represent a form of climate 'maladaptation' (Barnett and O'Neill 2010, Cooley and Heberger 2013, Rothausen and Conway 2011).

Fourth, *synergies* may occur when adaptations benefit more than one sector. The overwhelming consensus of the nexus literature is that we should understand better the tensions between sectors, avoid negative trade-offs where possible, and seek out and capitalise on synergies between them. As might be expected, synergies are found in both supply-side and demand-side solutions (Pittock 2011). On the demand-side, emphasis is generally placed on efficiency, with numerous studies espousing the potential for synergies in conservation (see for instance, Bartos and Chester 2014, Scott and Pasqualetti 2010, Stillwell et al. 2011). Recommendations for conservation are almost exclusively efficiency based, for example the use of 'green' household appliances such as efficient household hot water systems (Brazeau and Edwards 2013). Through the multiple linkages, it is argued, savings in one sector translate as savings in the other, thus counteracting tensions and trade-offs. On the supply-side, a broad range of technological solutions has been proposed. Suggestions include the co-production (here used in a technical, rather than conceptual sense) of electricity, heat and water (Santhosh et al. 2014); the use of low-grade excess heat energy from power stations in District Heating

(Morandin et al. 2014); energy recovery from wastewater treatment (Stillwell et al. 2010); and the use of off-peak wind energy for brackish water desalination (Clayton et al. 2014).

Policy and institutional reform, it is generally agreed, should be implemented to overcome what Waughray (2011) calls 'structural problems' in management. Indeed, the underlying narrative of the scholarship reviewed thus far is almost unanimous: that tensions and negative trade-offs should be avoided, and synergies amplified, through policy and institutional *integration*. Many of these authors, however, are fairly non-specific on what an integrated water-energy policy framework would actually look like. More detailed visions have been proposed by the likes of Goldstein et al (2008), who have argued that institutional boundaries should be softened through data sharing and free movement of information between the two sectors; Scott et al (2011), who call for greater recognition of the multi-scalar politics of the nexus; and Sovacool (2009) who has suggested the designation of 'electricity-water crisis areas' as a potential policy tool. Nevertheless, generally the idea of integration has become a catholicon for the negative aspects of nexus interaction, unquestioned and never problematized, but one that is consistently ill-defined.

Fundamentally, the call for integration through policy change and technological development is a call for the eradication of inefficiencies. The message that permeates the nexus discourse, that integration will necessarily lead to greater sustainability –the implication being that inefficiency is the root of our water and energy problems– is no more than an assumption. It is moreover, an assumption that should be challenged. The few examples of historically integrated resource management tend to contradict the argument that such practices are more sustainable. For instance, in California the City of Los Angeles and the agricultural land of the Imperial Valley are both served by agencies that manage both water and energy supply (the Los Angeles Department of Water and Power and the Imperial Irrigation District). This institutional structure has certainly not helped to foster more sustainable practices. Indeed, these agencies were formed precisely to promote expansionist consumption by delivering cheap and abundant water and power, thereby facilitating the techno-social entrenchment of unsustainable resource practices that now present barriers for energy and water transitions (MacKillop and Boudreau 2008).

This really brings us to the key point of this chapter. The assumed logic resonating through the nexus literature, that the primary response to tensions and trade-offs should be to integrate, overlooks the deeper challenges and contradictions of water and energy consumption, and ultimately deflects some of the more difficult questions posed by the concept of the nexus. It has been argued by some that fundamentally, the nexus framework presents neither new or novel approaches to sustainability, nor does it imply any need for radical change (Rees 2013, Allouche et al. 2015, Muller 2015). Perhaps this point lies at the heart of the recent success of the nexus framework. The argument is, after all, compelling: water and energy are essential ingredients to the functioning of economies and societies; there are indeed multiple linkages between them, despite being managed separately; and these linkages do embody many tensions and trade-offs. The solution, *'integration, integration, integration'* is, at first glance, an obvious one, and indeed difficult to disagree with. We are, then, presented with a set of severe challenges that seem to jeopardise our very security and quality of life, and *at the same time* a ready-made solution, which tells us that real change is not in fact needed. The important question is thus forestalled: what type of politics and imaginaries are being reproduced, if inadvertently, by the current nexus discourse? And how might the debate look if we were to challenge some of those prevalent assumptions and conclusions?

The urban nexus: on scale and geography

The coupling of energy, water, food and other resources, as a physical and political phenomenon, is situated firmly in place. In other words, the nexus has a distinct geography, but one that is as-of-yet poorly understood. A comprehensive understanding of the resource nexus necessarily considers the inter-relations at all spatial and political scales, from the technologies and practices of personal hygiene, through geographically and historically specific urban production and consumption infrastructures, to the geopolitics of supranational struggles for control of resources (Scott et al. 2011, Hussey and Pittock 2012)(table 3.1). Indeed, because "water and energy pervade every aspect of ecosystems, human systems and economic activity, the connections between water and energy are everywhere" (Kenway et al. 2011, 1984). Moreover, the physical interactions between water and energy are often separated geographically from the social and ecological effects of those interactions. For example, Bartos and Chester (2014) point out that because Arizona is a net exporter of electricity, through the embedded water in that electricity, the state concurrently exports water. Thus, Scott et al (2011, 6628) have argued that there is not only a "dissonance between scales of water-energy coupling and levels of institutional decision-making," but also a dislocation between energy and water use and negative impacts of the nexus.

	Nexus technology	Household	City	Regional	National	Supra-national
Energy for water	Appliances, baths and showers	✔				
	Rainwater collection	✔	✔			
	Sewerage treatment	✔	✔	✔		
	Water recycling	✔	✔	✔	✔	
	Groundwater pumping	✔	✔	✔	✔	✔
	Desalination		✔	✔	✔	✔
	Inter-basin transfer		✔	✔	✔	✔
Water for energy	Appliances, baths and showers	✔				
	Domestic heating and cooling	✔				
	District heating	✔	✔	✔		
	Thermo-electricity		✔	✔	✔	
	Biofuels			✔	✔	✔
	Fossil fuels			✔	✔	✔
	Hydroelectric		✔	✔	✔	✔

Table 3.1: The scales and technologies of the water-energy nexus

So far, substantive research on the resource nexus have focussed disproportionately on the national or state level: for example Spain (Hardy et al. 2012), Mexico (Sanders et al. 2013), Australia (Kenway et al. 2011), China (Kahrl and Roland-Holst 2008), India (Malik 2002), the Middle East and North Africa (Damerau et al. 2015, Siddiqi and Anadon 2011). These issues have, however, received most attention in the United States, and particularly in semi-arid and rapidly urbanising states like California (Kenney and Wilkinson 2011, Klein et al. 2005, Larson et al. 2007, Lofman et al. 2002) and Texas (Clayton et al. 2014, Stillwell et al. 2011). Tan and Zhi (2016) have identified a US dominance in data on water and energy coupling, and call for a more international perspective. With the exception of a small number of research projects (Duan and Chen 2016, Scott and Pasqualetti 2010), very little attention has been paid to nexus interactions across national or administrative boundaries. A more thorough understanding of the scalar politics of the resource nexus is needed to address questions around the uneven geographies of the nexus and the just governance of resources.

This chapter is concerned particularly with cities as an important scale of analysis for future nexus thinking research. This is both consistent with a growing interest in urban analysis within nexus thinking (Kenway 2013, Scott et al. 2016), and echoes calls from critical urban scholarship for greater understanding of the interconnectivities and contingencies between urban material flows and associated infrastructures (Broto and Bulkeley 2013, Moss et al. 2016). The importance of the urban scale to nexus thinking revolves around two key points. Firstly, as sites of high population density, and therefore of intense metabolic transformation, of production and consumption, and of the forging of new socio-material relationships, cities are where different material flows and resources are bound most tightly together, often in new and extraordinary ways. As Scott et al (2016, 114) put it, “urbanization drives the nexus.” Interconnected resource pressures are concentrated in urban areas (Hake et al. 2016). As was noted earlier, many of the technological responses to resource insecurity merely transpose pressure into another sector. Seawater desalination is a good example of this, where the question of water scarcity effectively becomes one of energy security. Kenway et al (2011) have argued, then, that studying cities as an important scale of nexus interactions can help to identify ‘root causes’ of resource tensions. Furthermore, the production of urban space is concomitant with the displacement of nexus burdens. The resource tensions and trade-offs driven by urbanisation are felt disproportionately both within cities and beyond their geographical boundaries, creating new socio-ecological vulnerabilities. Urban analysis, therefore, is integral to understanding the uneven geographies of the resource nexus.

Secondly, the pace of urban change and the scale of resource flows through urban space, offer significant potential for the formation of new modes of resource governance (Kenway 2013). Moreover, the technologies and infrastructures through which water and energy in particular are urbanised are central to the (re)shaping of the urban metabolism (Villarroel Walker et al. 2014). In other words, programmes for integrating water, energy and other resource management in cities may act as catalysts for broader change. Nevertheless, much of the literature so far that specifically handles the urban resource nexus conceptualise cities in fairly reductionist input and output terms, often using models that inevitably overlook complexity (for recent examples, see Chan 2015, Chen and Chen 2016, Fang and Chen 2016, Kenway et al. 2015, Lu and Chen 2016). Such formulations view water, energy and other resources as externally related. That is, cities are seen merely as black boxes; places where separate materials flow together, interact and are expelled. Input/output models of the resource nexus view water, energy and food as related, but distinct categories, and ultimately reinforce binary conceptualisations of cities, nature and society. I argue, however, for a more political understanding of urban infrastructural connectivities, one that emphasises the complex material and social hybrid relationality and contingency that characterises the contested development of the resource nexus.

More critical and theoretically rigorous interpretations of nexus thinking are, however, starting to emerge in urban scholarship. Most significant contributions are being made in the Science and Technology Studies literature, which place urban infrastructure as the central ambit of analysis. Using particular infrastructural configurations as an analytical lens, or entry point, for teasing apart the contradictions and relations of the resource nexus is, of course, highly appropriate, and an exciting new area of research (Moss et al. 2016). Coutard (2014) and Derrible (2016), for instance, recognise a contemporary trend in urban water and energy provision towards decentralisation, integration, and localisation through the deployment of alternative technologies. Coutard (2014, 92) calls this the "post-networked city," to describe "the forms of organization of urban spaces associated with the hybrid assemblage of a myriad of emerging infrastructure configurations." Infrastructures are the key conduits of resource flows through urban space, shaping behaviours of production and consumption, and as such are central to any debate on resource sustainability or justice. Infrastructures are the technologies that draw together water, energy, food and so on, and (re)shape their interactions.

The panacea of integration and the new hegemony of ecological modernisation

Recent burgeoning interest in nexus issues has gone hand in hand with an emerging and overwhelming political consensus on how nexus interactions should be managed. This is expressed in the assumed logic of the panacea of integration. The consensus holds that efficiency is the key to sustainable management of the nexus. Integration has become a buzzword of the discourse, ostensibly uncontroversial, yet politically loaded nonetheless. Indeed, despite a veneer of scientific impartiality, the suggested mechanisms through which this should be achieved are saturated with political meaning. Yet, this distinct *nexus politic* is rarely acknowledged explicitly. I contend that the project of integration infers an underlying alignment with neoliberal modes of resource governance. In doing so, I make a distinct argument about the changing logics of ecological modernisation and capital accumulation. The process of neoliberalisation of urban resource governance, particularly in 'networked' North American and European cities, has typically been understood as one of infrastructural and institutional unbundling (Graham and Marvin 2001, Rutherford 2008). Albeit in a non-linear sense (Coutard

2008), unbundling denotes a process whereby infrastructures are, broadly speaking, divided and transferred to private ownership in order to encourage the development of competition and market forces in resource allocation. This creates a fragmentation of uses across space, and a multiplication of contracts and 'service providers,' which are key hallmarks of the neoliberal process.

By contrast, the calls for integration are, in effect, a call for infrastructural re-bundling. Whether this be a physical bundling of urban infrastructures, as envisioned by Karaca et al (2013), or coordinated governance between sectors, the term 'integration' expresses a distinct underlying political project. The use of 're-bundling' to conceptualise the integration of water and energy governance, however, does not signal a return to what Graham and Marvin (2001) call the modern infrastructural ideal of universal centralised networked supply. In other words, re-bundling does not reverse the neoliberal project of un-bundling. Re-bundling the water-energy nexus, then, describes the political project of, firstly, framing resource connections in a particular way, and secondly, making claims about how these connections should be governed and re-configured. As such, the process of re-bundling water and energy through integration is conceptually consistent with the un-bundling of infrastructures and service provision.

The call for integration centres around two primary recommendations: one, the potential for greater efficiency through technological development; and two, need for institutional and policy reform. Such 'solutions,' I argue, go hand in hand with calls for ecological modernisation through market-based mechanisms. In the first instance, the call for efficiency-driven technological 'fixes' represents a strongly market-led approach to managing the contradiction between, on the one hand the need to mitigate tensions between water and energy, and on the other the economic imperatives for sustained growth in both sectors (Castree 2008). Proponents argue that innovations such as water-saving shower heads, the co-location of water desalination facilities with power plants, the use of renewable energy in water transportation, or the development of dry-cooling systems for thermoelectric generation, reduce the interdependencies between water and energy, and therefore mitigate the negative implications of the nexus. The technological solution, however, does not resolve these contradictions, but rather diminishes them as an obstacle to continued growth. In other words, the application of technology becomes a method of governing the resource nexus based on the logics of the market.

In the second instance, the argument for integration through institutional and political restructuring does not *necessarily* denote neoliberal proclivity, but it does leave the policy door wide open to market-based reform (Brenner et al. 2010). The capacity of the neoliberal movement to restructure various social and natural relations, to subject them to the play of the markets, has been highly dynamic and adaptive (Peck and Tickell 2002, Harvey 2005). The restructuring and re-scaling of the institutions and practices of environmental governance has been an important frontier of this process (Heynen and Robbins 2007, Himley 2008). Indeed, the reconfiguration of human-environment relations lies at the heart of the neoliberal project (McCarthy and Prudham 2004). The emphasis on efficiency-based restructuring that characterises the emerging nexus consensus, therefore, indicates a clear preference for the use of market proxies in the co-management of resources (Castree 2008).

The fact that the current nexus literature presents its arguments in the very particular, and politically loaded language of efficiency-through-integration, suggests that the discourse is rapidly becoming assimilated into a market-environmentalist ideology. This carries two very significant implications. Firstly, if a consensus is allowed to form, which tells us that inefficiencies are the root problem and integration is the primary solution, then more critical interpretations are precluded, or easily ignored. By reducing social and environmental sustainability to the issue of technological and institutional efficiency, the complex challenges facing cities and societies are, to use Murray Li's (2011) term, 'rendered technical.' Political discussions on the deeper implications of resource connectivities are, then, effectively forestalled. Nexus thinking becomes a discursive tool for the de-politicisation of nature (Wilson and Swyngedouw 2014). Secondly, the burgeoning popularity of the nexus concept illustrates a broader trend towards the increasing internalisation of environmental externalities into the processes of urbanisation and capital accumulation. In the nineteenth and twentieth centuries cities were built on the logic of sharply delineated material flows, and economies functioned on the assumed separation between them (Melosi 2000, Nye 1990, Otter 2004). The greenhouse gas emissions associated with urban water infrastructure, or the impact of power plant cooling systems on waterways, for instance, have historically been externalised. Under the nexus framework, and related concepts like Integrated Water Resource Management, such elements are internalised by the practices of environmental governance and the parameters of economic activity.

Conclusion

The burgeoning popularity of the resource nexus concept should give us cause to pause. After all, doesn't nexus thinking tell us what we already know? Surely we don't need a new discourse to tell us that it requires energy to move and treat water, water to transform and use energy, and a lot of both to produce and consume food? Excavating and understanding socio-material relations and interdependencies has long been central to social science theories of materiality. Nor are these ideas particularly novel in techno-managerial environmental governance circles. Some of the success of the concept is due simply to the fact that the arguments put forward by proponents are, in many cases compelling. As concern over resource scarcity grows, and ideas of natural limits to growth resurface in the popular imaginary, understanding the tensions and contingencies *between* sectors, and not just within them, becomes ever more pertinent. In part, however, the popularisation of the nexus framework is enabled by, on the one hand the universal appeal of its underlying message, and on the other the uncontroversial nature of its recommendations. The principle of integration is presented as a panacea, but its effect has been, I have argued, to draw attention away from the more fundamental tensions at play. The question we must continuously ask is, therefore, what is the political performativity of nexus thinking? And whose interests are served by a movement towards infrastructural re-bundling implicit in growing calls for technological and institutional integration?

Nexus thinking should be understood in the context of a broader movement towards integrated environmental governance where connections are emphasised over categories, sustainability and security are contingent, and resilience is diffused across multiple spheres. Nexus approaches are also inextricably linked with emerging paradigms of urban infrastructure reconfiguration towards ecological modernisation through alternative 'bundled' technologies and multi-benefit planning. These trends, I have argued, are consistent with broadly a neoliberal ideology, where the complex and multiple challenges of urban sustainability are reduced to the 'solvable' problem of technological and institutional inefficiencies. A politicised and progressive concept of integration, therefore, is sorely needed. Furthermore, the explicit focus on the connected flows between resource sectors suggests an emerging logic of capital accumulation where the linkages between traditional categories are increasingly internalised. This is not to suggest that socio-ecological connectivities are universally internalised by the nexus approach, but that through the project of integration and re-bundling, specific, and most importantly, *measurable* connections are quantified, valued and placed under the umbrella of 'sustainable development.' Particular relationalities, in other words, become a new frontier of economic expansion.

That said, this really comes down to a question about the politics of relationality, about how things are connected and with what consequences. The implications of more integrated concepts of environment and society raise serious questions about politics, about fair and just management of resources, and about our collective future. Given that 800 million people still suffer from malnutrition worldwide, around the same number do not have access to adequate clean water and 2.4 billion lack adequate sanitation, and 1.2 billion people live in homes without electricity (UNDP 2015), and with many of these marginalisations manifested explicitly at the urban scale, the intersecting challenges of energy, water and food in the twenty-first century could hardly be more critical.

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Pipes, Politics and the Pacific

Researching desalination in Southern California and Baja California

A research imperative

California is a land of contradiction. It is, on the one hand, a "culture and society built on, and absolutely dependent on, a sharply alienating, intensely managerial relationship with nature" (Worster 1985, 5), and an incubator for some of the more progressive environmentalist movements in the US, on the other, where conservationist groups wield significant political influence. It is a land where individualistic dreams of the good life are fused with capitalist state-building, imperial in scope and ambition, and written into the landscape as mega-infrastructures: hydropower dams that can light up entire cities, wide diameter pipelines that carry water hundreds of miles, and twelve-lane highways that dissect valleys and traverse mountains (Starr 1990). Where twentieth century capitalism produced both rural irrigation district and city as dialectically co-constituted, but where those same capitalist structures threaten the future of the West in the twenty-first century as competition between agricultural and urban water users grows (Henderson 1998). In California, the usual distinctions between nature, society and technology are radically undermined. Furthermore, many of the ways in which the materialist social sciences handle these conceptually sit slightly uncomfortably in the Californian context. This is highlighted in the case of large-scale seawater desalination, which is emerging from complex and historically-weighted entanglements of past and present logics of capital circulation, state and private technological vision, the interactions between water and energy governance, the efficacy of nonhuman elements with disruptive or facilitatory trajectories, and the politics of drought and climate change. The study of the political ecologies of water and energy in California, then, could scarcely be more starkly illustrative of the re-configuration of socio-material relationalities under contemporary capitalism.

The principal theoretical and epistemological aspects of research *methodology*, pertaining particularly to dialectical materialism, assemblage thinking, infrastructure studies, and nexus thinking, are handled in the previous two chapters. The purpose of this chapter, then, is to detail and justify the research *methods* used. In outlining and justifying the methods and data collection techniques employed for this research project, the objectives of this chapter are threefold. The chapter begins by framing the rationale for case study research as the basis for representing complexity and fundamental contexualities that are the bedrock of good social science research. Secondly, I summarise the imperatives behind the particular focus of this research, namely large-scale ocean water desalination in the context of the San Diego–Tijuana metropolitan region. Finally, the technicalities of this research, including data collection techniques –which utilised primarily expert interviews, site visits and archival research– as well as justification for these methods and research timeline, are outlined. Primary data for this project was collected during two three-month periods of fieldwork conducted in San Diego in 2014 and 2015. In addition to extensive document analysis and triangulation of data, the substantive original research utilised expert interviews and archival data.

On case study methodology

Urban political ecologists have tended towards a case study based methodological approach, choosing to mobilize and theorize the concepts of *metabolism* and *circulation* through the study of the unfolding of particular phenomena in particular cities. The most significant contributions to this literature include: William Cronon's (1991) momentous environmental history of Chicago and the Great West, *Nature's Metropolis*, in which he argues strongly for the conceptual fusing of city and country; Matthew Gandy's (2002) historical analysis of the materiality of New York City, *Concrete and Clay*; Erik Swyngedouw (2004) on water and social power in Guayaquil, Ecuador; Maria Kaika (2005) on the socio-political relations of water, focussing on Athens, in her book *City of Flows*; and Mike Davis' (2006) work, *City of Quartz* in which he shows how socio-ecological relations in Los Angeles combine to produce highly exclusionary socio-spatial configurations. In a very broad sense, the strength of high quality case study research, like the examples above, is twofold. Firstly, in its ability to represent diversity, complexity and contingency between actors and factors, not merely as details colouring otherwise coherent transitions, but as central to the unfolding of inherently situated socio-material relations. Secondly, to *build up* theory by creating an essential dialogue between the abstract and the material. Put another way, abstract theories of, say, the neoliberalisation of nature, the consolidation of state power, or the marginalisation of vulnerable populations, are used to structure understanding and interpretation of complex socio-materialities, but also flow from rigorous analysis of those context-specific relations. As Castree notes;

> *"Case study research in human geography…shows the world to be persistently diverse… Yet it shows that this diversity arises out of multiscaled* relations *such that it does not emerge* sui generis*."* (Castree 2005, 541)

Although many of the UPE case studies take a particular aspect or flow of urban nature (water, food, waste, for example) as the methodological starting point, a number of influential studies take urban infrastructure, the key technological nodes, pathways and mediators of the urban metabolism, as their analytical entry point (Cooke and Lewis 2010; Gandy 1999; Kaika 2006; Kaika and Swyngedouw 2000; Monstadt 2009). The study of urban infrastructures is an essential part of UPE case study research, given that these technologies are *relationship makers* (as was argued in the previous two chapters), in that they are key sites of transformation in shaping the contemporary urban condition, and that they link geographical scales from the individual and household, to the urban, national and supranational.

Case study methodology is, of course, well established in the social and political sciences, and is particularly valuable when the researcher is asking 'how' and why' questions that go beyond the search for predictive general rules and universal laws (Yin 2009). Indeed, because these methodologies are concerned precisely with uncovering and highlighting the multiple contingencies that are always at play in the unfolding of phenomena, case study research by its nature, cannot be used to predict behaviour or future trajectories. As such, the detailed analysis and careful examination required to produce high quality studies is important for understanding the complexities of contemporary phenomena, like urbanisation. For disciplines like UPE, and economic and political geography more generally, which valorise complexity, case studies are invaluable in producing the kind of context-specific knowledge that can account for multiple, contradictory and contingent processes. Indeed, Flyvbjerg (2006) has argued that there are no context-independent forms of knowledge, and because the social sciences will almost certainly never be able to produce predictive theories, then specific, context-dependent knowledge should be valued for its theory-building potential. In case study research, multiple data sources are often preferred over single sources. These might include any combination qualitative data, such as expert or public interviews, focus groups, psychogeographies, video or photograph data, discourse analysis or archival work, as well as a variety of quantitative data types. The particular data sources used for a given study will, of course, reflect the type of information the researcher requires to answer particular research questions. In general, however, a number of sources are used to enhance overall data richness. In this type of research, then, extrapolation proceeds through analytical induction, where analysis of certain parts is used to make propositions about the whole, rather than through statistical inference (Peck 2003).

Research sites are selected precisely because they are unusual or exemplary, not because they are statistically representative. Although complex causal relations may be present in many places, such phenomena are often particularly lucid in extraordinary cases, and therefore enhance the analytical or explanatory potential of the study. Thus, the "validity of the extrapolation depends not on the typicality or representativeness of the case but on the cogency of the theoretical reasoning" (Meyer 2001, 347). All of the UPE studies mentioned above were chosen for their explanatory and theory-building capacity, not for being typical or standard. Indeed, as has been noted by George and Bennett (2005), case study research is strong precisely were representative statistical methods and modelling are weak. To fully embrace this methodological potential, some have argued that UPE can go even further. For instance, Lawhon et al (2013) and Karpouzoglou and Zimmer (2016) have argued that, because UPE has traditionally (although by no means exclusively) focussed on cities in industrialised countries, in applying theoretical concepts to contexts in the Global South, has sometimes overlooked the situatedness of urban phenomena within particular socio-cultural conditions. Here, then, is a call for greater appreciation of the diversity of urban contexts under study.

Peck (2003) has also argued for a deepening of case study research. This, he suggests, might be achieved through greater willingness to engage in difficult or awkward studies and to confront the theoretical challenges they throw up; more transparency and clarity in methodological design; more cross-regional and transnational studies, which naturally highlight important contradictions and tensions in the way we handle issues of scale; and more critical self-reflection by researchers. The analytical gaze of this research project, which includes the inter-state politics of the Colorado River, multi-scalar disputes over water and energy governance, and the planned development of the world's first ever 'binational' seawater desalination facility, certainly represents an attempt to take seriously the call for extraordinary and challenging case studies in social research.

California: a place for political ecology

As I outlined in the introductory chapter of this thesis, California presents a remarkable study location for any researcher interested in the contradictory historical development of capital, society-nature relationality, or the role of technology in shaping both. The complex and extraordinary social relations and materialities that create and sustain California as the land of abundance, of possibility, sunshine and pristine nature in cultural representations both within and outside the Golden State, have emerged from successive boom and bust cycles of various resources, the irrigation of vast stretches of desert, and the construction of mega infrastructures (McWilliams 1999). The expansionary tendencies and *material primacy* of capital are indeed writ large in the history of California (Starr 1990). This most unusual of states has long been the study of environmental historians and political ecologists. Whether it be the extension of capital over the land, the rise of agribusiness and the growth of seasonal migrant labour (Henderson 1998, Mitchell 1996, Stoll 1998, Walker 2004), the gold rush of the 1880s and other mineral extraction (Isenberg 2005, Rawls and Orsi 1999), or the troubled story of water in the arid West (Hundley 2001, Kahrl 1982, Reisner 1986, Worster 1985), the ecological histories of California are multiple and remarkable. This thesis, then, represents a very small contribution to a vast scholarly project. Nevertheless, the empirical focus of this thesis, which is currently understudied in the literature, and the theoretical approach, particularly the engagement of nexus thinking, constitute a departure from previous work.

Within the field of political ecology and critical geography, there have been many attempts to understand and interrogate California's extraordinary history from dialectical Marxian perspectives. Several deserve particular mention. Donald Worster's (1985) *Rivers of*

Empire and Marc Reisner's (1986) *Cadillac Desert*, both tell the history of the American West through the tumultuous, and in their eyes, ultimately ill-fated saga of the Promethean project to control and put to work water to build a desert civilisation. Worster draws on Karl Witfogel's (1957) notion of the *hydraulic society*, to describe the American West as;

> *"…a social order based on the intensive, large-scale manipulation of water and its products in an arid setting…… increasingly a coercive, monolithic, and hierarchical system, ruled by a power elite based on the ownership of capital and expertise."* (Worster 1985, 7)

While Worster is concerned with formations of social power, Reisner presents a more environmentalist critique of nature and society in the West. The great dams and pipelines, monuments to the progress of a nation, he argues, were built under a model of development based on state subsidised, cheap and abundant water, that will ultimately cripple the ability of future generations to realise alternative futures. To Reisner (1986, 503) "the cost of all this… was a vandalization of both our natural heritage and our economic future, and the reckoning has not even begun." Both seminal works are drawn upon heavily in this research, and are cited throughout the thesis. Political ecology studies of California that do not engage solely with water or energy, but have nevertheless been influential in this research include George Henderson's (1998) *California and the Fictions of Capital* –a momentous work that combines a literary critique of nineteenth and twentieth century novels on California, and an historical and geographical analysis of the uneven development of capital in Californian agriculture and the dialectical coproduction of cities and agribusiness. *The Conquest of Bread* by Dick Walker (2004) tells the history of California's growth from isolated backwater to the most advanced agricultural region on earth and centre of global capital. And Don Mitchell (1996) in *The Lie of the Land*, presents a radical Marxist critique of the exploitative labour relations in Californian agriculture.

Here, I highlight two critiques –or observations– of this body of the Political Ecology and California Studies literature. The first is that studies so far have tended to be fairly bounded in terms of spatial focus. That is to say, Californian PE work has generally focussed on the state of California, or particular areas of California, and has therefore overlooked the complex scalar politics between states and transnational politics with Mexico, with which California shares a long border. This research attempts to fill part of that gap in two methodological respects. Firstly, it focusses on a border city, and one that is increasingly understood, along with its Mexican counterpart, as forming the single San Diego-Tijuana Metropolitan Region. Indeed, San Diego and Tijuana, although separated by a wall and fence, are both growing rapidly and face many of the same water and energy challenges. Chapters five and seven, in particular, expand on the inter-state theme. Secondly, one of the two projects that are the focus of the substantive empirical analysis for the research, will be the first ever 'binational' seawater desalination plant.

The second observation is that critical urban and UPE studies in California have tended to draw disproportionately on the cities of Los Angeles and San Francisco. Davis (2006) and Gandy (2014) on Los Angeles, and Walker (2007) and Brechin (2006) on San Francisco, are particularly highly cited examples. San Diego, by contrast, which although being the eighth largest city in the United States and being home to the largest military industrial complex in the world, has received very little critical attention. Historiographies of San Diego's water and energy supplies have been published in the past (Engstrand and Crawford 1991, Mirvis and Delude 2013), but from critical political ecology or urban studies perspectives, this region is significantly under-studied. Chapter five, which considers the historical emergence of desalination in San Diego, represents the first attempt at such a project.

Data collection

The original data used in this research was collected during two periods of fieldwork conducted by the researcher. Each period of fieldwork lasted three months, meaning the total time spent in the field was six months. The first period was conducted from September to November 2014, the second from June to August 2015. During these fieldwork periods, the researcher resided in San Diego County. The substantive data collected during fieldwork periods utilised interviews with experts and archival data. The majority of data was collected within the City of San Diego and San Diego County. Several interviews were, however, conducted outside of San Diego County, however, across the US-Mexico border in Tijuana, and also in Orange County and Los Angeles County. And the researcher spent a week in August 2015 in Washington D.C. to visit the National Archives. The remainder of this chapter provides detail on the specific methodologies utilised for this research.

Research sites

The specific research case study of San Diego was chosen for three primary reasons. First, as outlined above, although this is the eighth most populous city in the United States, San Diego has received very little critical attention from a political ecology perspective, or indeed from critical social sciences more broadly. Second, San Diego has very unique resource and ecological circumstances, even by the standards of the arid West. The region has almost no local water or energy resources, and has historically relied on long distance imports of both. The paradigmatic shifts, then, towards localised and diversified water and energy resources, which are taking place throughout the West, are particularly intriguing here. San Diego sits at the end of all the water distribution pipelines and has, as a result of the historical development of water rights and mega infrastructures in California, struggled to establish autonomy in resource governance. The County Water Authority's investment in large-scale ocean water desalination represents an important aspect of this effort. Thirdly, the region's geographical location on the Mexican border, and the deep economic linkages between San Diego and Tijuana, make this an ideal case for studying the politics of inter-state and binational resource governance. The planned development of the binational desalination facility at Rosarito Beach is unprecedented in the water treatment sector globally. These factors combined make the San Diego–Tijuana region the most extraordinary and illuminating region to study the political ecologies of desalination in North America. The empirical material collected during the course of this research focusses on two large-scale seawater desalination plants.

Carlsbad Desalination Project. The Claude 'Bud' Lewis Carlsbad Desalination Plant –so called after the late former mayor of the City of Carlsbad for his work in the initial stages of the project– was completed in November 2015, nearly two decades after the plant was first proposed. Located in northern San Diego County, the facility can now produce 189 mega litres a day – around 10% of the total demand within the San Diego County Water Authority's service area. It is currently the largest desalting plant in the Western Hemisphere, and has double the capacity of the next largest –the Tampa Bay plant in Florida. Initially conceived as a public venture, the Carlsbad plant was ultimately delivered as a Public Private Partnership, led by a venture capitalist firm, Poseidon Resources, based in Connecticut. Poseidon are also planning to build a facility of similar size 90km north along the coast in Huntington Beach, Orange County. That project is still mired in the permitting and contract stage. The Carlsbad plant, although now operational, became the focus of considerable contestation in the decade leading up to its completion, and was fought by environmental groups throughout the permitting and construction process.

Rosarito Beach 'binational' desalter. Rosarito Beach lies south of Tijuana, about 25km from the US-Mexico border. The desalination plant there is still in the development stage. The project has experienced some set-backs in the last year, but it could be operational by 2019. When complete, it will have double the capacity of the Carlsbad plant and will be able to produce around 380 mega litres a day. Although contracts have yet to be signed, under current plans, Tijuana will purchase 50% of the water produced, 25% will be piped directly across the border to the Otay Water District in South San Diego County, and 25% will be marketed to other US off-takers, possibly through a paper transfer (rather than a physical transfer of water) of Colorado River rights. As Mexico currently holds a storage right in Lake Mead, a paper transfer could be negotiated between the desalination consortium and off-takers as far north as Nevada. Indeed, water districts in the Las Vegas Valley have previously considered financing coastal desalination in exchange for Colorado water.

The Rosarito plant, similar to Carlsbad, was initially proposed as a public venture between four US water wholesalers and four Mexican authorities. The project was then taken under private control by a new company, NSC Agua, who are now almost entirely owned by a Cayman-based desalination company, Consolidated Water. The project has since undergone a further phase of restructuring, and will now be delivered through a PPP between NSC Agua and the Baja State Government.

Despite a number of significant similarities between the Carlsbad and Rosarito developments, the two projects emerged from very different political circumstances. The Carlsbad project began as a city-level initiative to reduce the reliance of Carlsbad and neighbouring water districts on imported water, and therefore increase local resilience to reductions imposed by water wholesalers. By contrast, the idea for a binational project at Rosarito emerged from the large water wholesalers on the Colorado River, effectively as a way of 'freeing up' over-allocated water in the Lower Basin and reducing tension between right-holders. The two projects, then, tell very different stories in the overall narrative of the governance of desalination for San Diego. As such, this thesis does not handle them in a simple comparative manner, but rather puts them two work in parallel to engage different complexities of water and energy governance in San Diego. Overall, more attention is given to the Carlsbad site, particularly in chapter six, for two core reasons. Firstly, as California's flagship desalination development, the Carlsbad plant has been at the focus of sustained political disagreements for over a decade. Much of the information relevant to the Carlsbad plant is in the public sphere, and there are more well-informed experts willing to discuss the project. By comparison, there has been far greater uncertainty and far less civil society engagement with the Rosarito plant, which is at a much earlier stage of development. Secondly, and related to the first point, given that construction has not yet begun and there are still significant uncertainties associated with design, contract structure and stakeholders, access to verifiable data on the Rosarito plant was somewhat limited. The two cases, then, are both highly important in the overall story of desalination in Southern California, but for very different reasons.

Data Sources

Expert interviews. A total of 36 interviews were conducted over the course of fieldwork with experts from civil society groups, industry and business, academia, and government. An anonymised list of all participants and dates of interviews is provided in appendix I. Participants were initially contacted by email, and on rare occasions by telephone, and asked to participate in the study. Interviewees were provided with an information sheet, which gave an overview of the research and its scope, before they agreed to participate. Participants were selected and approached based on: 1) their particular area of expertise or knowledge of pertinent issues; 2) their professional position and ability to articulate the perspectives of a given organisation; and 3) their role in the unfolding of the desalination story in Southern California. The snowballing technique was used to make additional contacts with potential participants, with the final question of every interview being "who else should I talk to." Every interview was recorded using a portable dictaphone, with the consent of the participant. The recorded interviews were then transcribed in full, and coded. The social science coding software, *Atlas Ti*, was used to organise interview content by theme.

In researching issues as contentious as desalination, water and energy in California, challenges of fact-checking and triangulation are inevitable. The participants interviewed for this research, however, represent a comprehensive range of expert opinions on the topic of desalination. Although some groups were more difficult to access –most particularly the business leaders involved in the desalination projects– I was eventually able to access multiple (and contradictory) perspectives. Roughly equal numbers of participants from civil society, government and industry were interviewed. A growing network of professional connections was particularly important in contacting some of the more aloof participants. For instance, during the course of communication with one participant, who edits one of the desalting industry's weekly publications, the interviewee expressed interest in writing a piece on my research. This participant put me in contact with another leading expert, and the publication of the article prompted another to respond favourably to my request for an interview.

The only perspective that is conspicuously missing from the data is that of the regional Mexican government of Baja and Tijuana. Individuals and institutions were approached on multiple occasions, but such was the political sensitivity and transitory phase of the binational Rosarito desalting project at the time of fieldwork, that very little headway was made. Indeed, a Mexican Commissioner of the International Boundary and Water Commission (IBWC) (the collaborative U.S.-Mexican government body that applies the binational water laws), who had been approached on my behalf by another participant, was unwilling to speak to me because of the political sensitivity of the project. Although this lack of representation is regrettable, it does not greatly detract from the arguments presented in this thesis, which are more focussed on the governance of desalination in San Diego.

Archives and historical analysis. Chapter 5 of this thesis situates large scale seawater desalination in historical context. It tells the story of San Diego's water supply, considering the various conflicts and disputes within the region, between regions, between states, and between countries, that created the technological, economic and political milieu, from which the desalination assemblage emerges. Much of the information in this chapter is based on archival research. All of the archival work for this project was conducted by the researcher during the second phase of fieldwork, between June and August 2015. Collections were viewed at four locations. First, San Diego State University, which is a public research university, maintains an archive of local and regional history. Second, the San Diego History Centre, located in the City of San Diego, is a civil organisation dedicated to celebrating local history. The Centre owns a research library. Third, the City of San Diego Public Library has an extensive collection of publications and documents at its central branch. Fourth, the National Archives in Washington DC holds extensive records of California's water supply, and some information on the 1950s and 1960s federal desalination research programmes.

Although the collections viewed from these archives was invaluable in piecing together the complex history of San Diego's water story, some of the richest historical data, particularly concerning the development of desalination technologies, came from expert interviews. The history of desalination in the United States really begins in the 1960s, meaning that many of the early engineering pioneers are still able to give first-hand accounts. Moreover, given that San Diego was, and remains, a hub of the industry, a number participants were interviewed for this study who had been involved in desalination for decades. These participants were able to provide insights which are certainly not contained in archives or document repositories.

Document analysis. Extensive online document analysis conducted between 2013 and 2016. Entire PhDs could be written about water and energy in California based exclusively on data and information freely available online. Government organisations at the federal, state and county level are required to publish annual reports, policy documents, minutes from meetings and hearings, and data. Similarly, utilities, water wholesalers and other public institutions also make vast amounts of information publically available. The data contained in these publically available documents was integral to the project as sources of information, for triangulation with other data sources, for identifying key stakeholders, institutions and potential interviewees, and for analysis of broader policy context.

Civil society groups and businesses are more selective with publications, and there is, moreover, disparity between institutions over the kinds of information made available to the public. The well-established environmental organisations (such as the California Coastkeeper, the Natural Resource Defence Council, the Sierra Club, and the Surfrider Foundation) publish lots of policy-related documents, comments on specific projects and policies, and blogs. Businesses, by contrast, publish relatively little –but again, there is disparity between businesses. For instance, the developer of the Carlsbad plant, Poseidon, make very little information available, other than the targeted contents of their website. But the parent company of the Rosarito developer, Consolidated Water, which is traded on NASDAQ, makes certain information available for the benefit of its shareholders in the form of annual reports, public conference calls and online presentations. Where an institution does not publish material itself, however, information regarding that group is often available from other sources. For example, although Poseidon is not forthcoming with details on its protracted permitting hearings, many of their communications are published as records by the permitting agencies.

Water treatment and desalination, because it is a rapidly developing field and new technologies are subject to fiercely guarded intellectual property rights, is naturally an industry in which certain information comes with a price. As such, certain industry information was financially unobtainable for this project. For instance, the *DesalData* database maintained by Global Water Intelligence, and the weekly publication *Water Desalination Report*, both require subscriptions costing several thousand pounds a year. Although access to such data would have bolstered some elements of this thesis, there is sufficient information in the public sphere and secondary literature (or accessible through the University of Manchester library) to address the questions engaged in the research.

Site visits. In researching the political materialities of infrastructure, it is evidently highly desirable for the researcher to visit and tour the sites of those infrastructures. Over the course of fieldwork, the researcher visited a number of the places and projects discussed in the next three chapters. These included: most impressively, the Hoover Dam and Lake Mead at Boulder, near Las Vegas, where the researcher took a tour of the dam and hydroelectric power plant in September 2014; the nearly completed Carlsbad Desalination Project, where the researcher was given a personal tour of the plant (after much negotiation) in August 2016; the City of San Diego Pure Water wastewater recycling test facility, which is currently operating as a pilot plant for the $3 billion project; and several storage reservoirs within San Diego County. Unfortunately, after a number of requests, the researcher was not able to secure a tour of the Rosarito Beach site that will accommodate the planned binational desalination plant.

From theory to practice…

The remainder of this thesis –the substantive case study chapters– are structured as follows. Chapter 5, *Deserts of Plenty*, situates the extraordinary emergence of desalination in historical context. In chapter 6, *At the Nexus of Scarcity and Opportunity*, I consider the politics of desalination. The chapter focusses mainly on the various contestations around the Carlsbad plant, and questions what this means *politically*. Chapter 7, *The Water Factory*, is about the techno-politics of reverse osmosis desalination. It conceptualises these technologies as being efficacious in the market-disciplining of water. These chapters are structured so as to progressively focus down the analysis: the first considering the role of water and energy in the development of capital in the West; the second interrogating regional environmental politics; and the third focussing on the material politics of a particular technology. Each chapter addresses the desalination question in a different manner, engages different aspects of the politics of relationality, and answers distinctly different questions.

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Deserts of plenty

The historical emergence of desalination in Southern California

"Uncle Sam took up the challenge in the year of thirty-three
For the farmer and the factory and all of you and me
He said roll along Columbia, you can ramble to the sea
But river while you ramblin' you can do some work for me."
Woody Guthrie (1941)

"And it never failed that during the dry years the people forgot about the rich years, and during the wet years they lost all memory of the dry years. It was always that way."
John Steinbeck (1952, 9)

San Diego, CA, 1991

The State of California is entering its fifth year of severe drought. In the urbanised coastal South water agencies are beginning to exhaust local supplies and demand for imported water ramps up. In San Diego, which unlike its neighbours in Orange County and Los Angeles does not sit on top of groundwater aquifers, the County Water Authority imports 95% of its supply from the Metropolitan Water District of Southern California (hereafter 'MWD' or 'Metropolitan'). MWD, the largest wholesaler of non-agricultural water in the USA, serves a population of roughly 19 million across six counties with water imported from the Colorado River and Northern California. For the first four years of drought Metropolitan had drawn on its stored capacity in order to meet demand, without introducing any cutbacks or drought savings measures. By the end of 1990, however, with little in the way of winter storms or snow pack to ease the situation, it became clear that business-as-usual was no longer an option. In November of 1990 the Board adopted a five-stage shortage allocation plan called the Interim Interruptible Conservation Plan, outlining incrementally deeper cutbacks. Stage 1, which called for a 5% voluntary reduction by member agencies, was implemented at once.

Less than three months later, MWD enforced Stage 5: mandatory reductions of 20% for municipal and industrial users and a 50% cut for agriculture. For San Diego, which still supported a fairly large agricultural sector, this meant an overall cut of 31% to 95% of total supply. At the beginning of March 1991 the Board moved to introduce and implement a further level to the plan, Stage 6, which sanctioned 30% cuts to municipal and industrial water and 90% to agriculture. This would have resulted in an overall loss of 50% of San Diego's supply, a decision that the SDCWA were virtually powerless to challenge. Only unexpectedly high rainfall that month, which would become known as Miracle March, prevented the 50% cut. It wasn't until 1992 when the drought finally broke that Metropolitan lifted the shortage allocation. The majority of the other large MWD member agencies have significant local sources of water and generally tend to maintain a surplus of preferential rights to imported water, and were therefore far better equipped to absorb the shocks of drought allocation. In San Diego, which relied so heavily on MWD water and had for decades been importing far more water than it had legal rights to, the severity and rapidity of these cuts were, in the words of one participant, a "major wake-up call" (Water Resources Director, interview 24/06/2015).

This period is now considered a significant turning point in the governance of San Diego's water supply. Following backlash from (in particular) the San Diegan business community, the County Water Authority embarked on an aggressive, and in many respects highly effective localisation and diversification strategy aimed at reducing reliance on the MWD. This has been accompanied by similar efforts from all of SDCWA's member agencies to move away from single-source imported supply. This is the discursive shift out of which the seawater desalination 'solution' emerges. It is, above all in San Diego, a political fix to the problems that beleaguer long-distance transfers –increasing competition under conditions of reduced reliability, a dysfunctional and entrenched system of water rights, and growing appreciation of the ecological implications of moving large amounts of water between basins. Although current developments in ocean desalting are intimately linked to broader contemporary paradigmatic shifts in water governance, interest has recurred periodically in Southern California for over half a century, usually associated with a particular techno-political configuration, energy regime, or in response to drought. Indeed, SDCWA and MWD first started to consider desalination seriously and systematically in 1964/5. Since then there have been a number of unsuccessful attempts to further the desalination agenda. This chapter places desalination in its historical context and excavates the particular socio-material configurations, or assembled actors and factors, that have confluenced around this particular technology in the last two decades.

The water and energy history of San Diego, as a metropolitan region, roughly mirrors those of many other North American cities, discussed in chapter two. In the 1800s individual (and sometimes collective) supply was replaced by small and poorly regulated private companies, which serviced particular areas and customers. Amid discontentment with the quality and adequacy of water, and the cost and reliability of energy, the early 1900s marked the beginning of a period of public ownership, universal access and networked connection, where municipal government assumed ownership of infrastructure and responsibility for supply (Mirvis and Delude 2013). During this time, abundant and relatively cheap access to water and energy became central to the functioning of the economy, and both per capita and total consumption burgeoned. This was followed by a process of privatisation in the electricity and gas sector towards the end of the twentieth century. Water remains, however, largely in public hands. Indeed, in Southern California, where those few areas still supplied by private water companies experience higher rates and poorer quality, there is still very little appetite for such restructuring. In San Diego the principle challenge since first settlement has been to contend with the absence of local supplies of both energy and water. Although substantial, the problem of importing energy presented comparably fewer obstacles (Engstrand and Crawford 1991). This chapter is not about the importation of energy. It tells the story of San Diego's water supply, and of the particular ways in which energy is manifest in its development.

By situating the desalination phenomenon in its historical context, this chapter represents the first attempt to tell San Diego's water story from a critical perspective. Existing studies of the region are all local historiographies, in that they are not intended to advance theoretical understanding. Furthermore, the great works of Californian environmental history and political ecology have generally overlooked the intriguing history of San Diego. The arguments presented in the chapter are threefold. Firstly, that desalination in Southern California is primarily a technological solution to increasingly contested terrestrial water supply, allowing water agencies to circumvent the intense political disputes and supply insecurities that characterise long distance transfers. These tensions are historically produced and arise from the very particular praxis and technologies of water governance in the West. Secondly, and in relation to the first point, it is argued that the complex and peculiar system of water rights in the American West, through which San Diego establishes its claims to waters that flow far beyond its borders, now presents significant obstacles to further transformation. The inertia of this mode of water governance, which became entrenched during the agrarian development of the desert Southwest, offers resistance to the dynamic transformation of economic processes, particularly in the metabolic shift towards a more urban economy (Henderson 1998). Desalination is understood, then, as a political fix that is emerging at a stress point between two increasingly incompatible forms of capitalism and related forms of metabolic transformation. Thirdly, it is argued that energy is manifest in San Diego's water history. The understanding of nexus interactions presented in this chapter goes beyond the somewhat *ad hoc* linkages of the technocratic nexus literature, where water and energy are connected only through the external relations between them. Instead, a dialectical view of water and energy as historically co-constituted and co-evolving is put forward.

Establishing the transfer paradigm

In November 1947, after more than two decades of struggle to overcome substantial technical and political hurdles, San Diego County finally realised what had been dismissed by one of the nation's most respected hydraulic engineers in 1924 as 'wild dreams' (Freeman 1924): it successfully took delivery of water transported by pipeline nearly 500 kilometres from the Colorado River. Residents and industries of San Diego finally had a secure supply of water that would at first supplement, and then far exceed, its overstretched and unreliable local supply. A prosperous future seemed set for this beachhead desert community.

This marked the beginning of a period, lasting for half a century, in which the transfer paradigm ruled as *the* model of water governance, fuelling extraordinary levels of urban growth and allowing the expansion of military and civilian industry, making San Diego the country's eighth largest city today and a node of global capital accumulation. The transfer paradigm represents a particular, primarily state-led, vision for water and energy, one that couples the two in historically and geographically specific ways. Indeed, a report published by the San Diego Water Utilities Department in 1980, which was largely ignored at the time because it argued for a re-imagined and unified approach to the region's water and energy future, noted that in San Diego imported supply from MWD had become favoured "to the virtual exclusion of all other alternatives" (SDWUD 1980, vi). The first half of this chapter tells the story, illustrated in Figure 5.1, of how water transfers became entrenched, and how in turn this logic of techno-natural governance created the conditions for the contemporary water crisis.

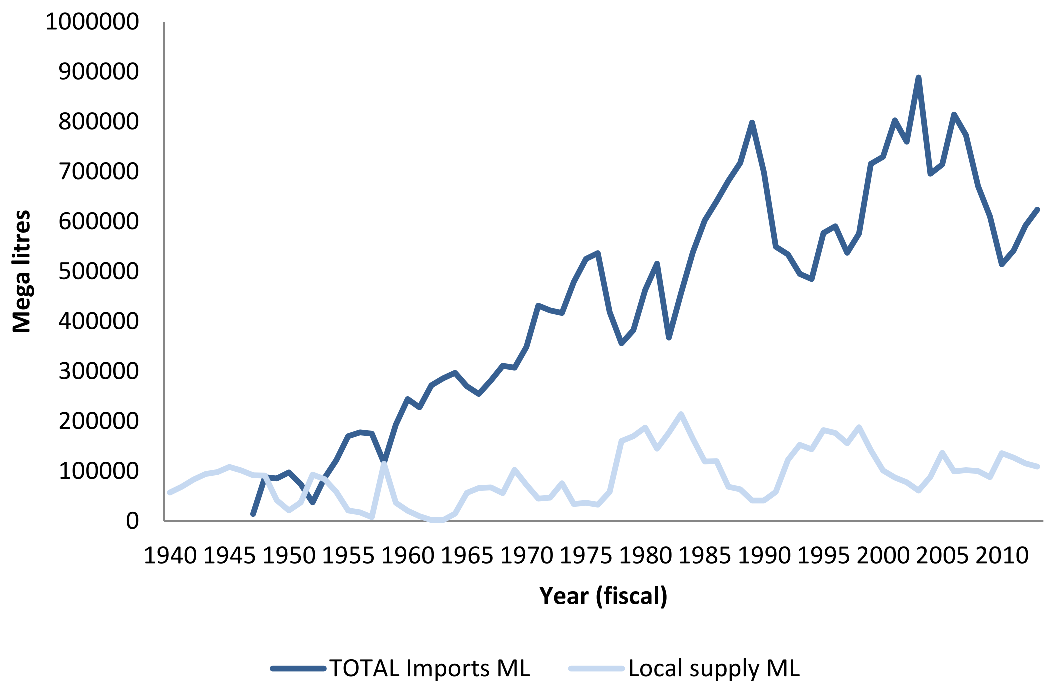


Figure 5.1: Growing reliance on imported water in San Diego County 1940-2014. *Source*: SDCWA annual reports 1946-2015

Outgrowing local supply

The history of San Diego's modern water system really begins in the 1870s with the establishment of private water delivery companies. This period also marks the beginning of two significant trends pertinent to the eventual emergence of the desalination 'solution.' First, as the economy and population grew beyond the capacity of locally available water to support, an expansionist logic of water governance, predicated on importing new waters became entrenched. Second, the cyclical dynamics of crisis became the major catalyst for development. Prior to that, from Spanish colonialization in 1769 and the establishment of the early missionaries, through the 1821-1848 rancho system of water allocation under Mexican rule, to the period of early American settlement from 1848, economic and population growth in the region remained fairly slow (Mirvis and Delude 2013). Developments of locally available water supply had been limited to artisanal wells, some small gravel dams and levees, and gravity-fed wooden flumes supplying irrigation water. Residents of the Old Town drew water from wells

Image 5.1: Construction of the San Diego Flume 1889. *Source*: San Diego History Centre (2016)

sunk in the sandy bed of the San Diego River. Vendors with barrels would deliver to those who didn't have wells, or were unable to collect water themselves.[1] The first networked water works were started in 1873 by local businessman, Jake Vandyke, who dug 14 wells next to the river and routed the water by ditch and tunnel to the oil-powered Old Town Pump Station, where it was transported to a small reservoir on 5th Street, and from there gravity-fed to the town.

Through the 1870s and 1880s the City grew rapidly and by the mid-1880s the water supply was in crisis. Demand rose to nearly 6,000 m^3/day in 1888 and residents complained about the poor quality and foul smell of the river water. Visitors from Los Angeles were even warned to take bottled water with them because of rumours that the local water carried typhoid. Inconsistent supply and water pressure was also fast becoming an issue, although the San Diego Water Company (1889) insisted at the time that this was due not to scarcity, but rather to the pipeline being too small to keep up with demand. In response, San Diego took the first of many steps towards the transfer paradigm, and the San Diego Flume Company was

[1] This description is informed by a collection in the San Diego Public Library called 'San Diego's early water resources: Recollections of pioneer settlers,' compiled in 1923.

established to import water from the Cuyamaca Lake in the mountains to the east. The 60km flume, which transported water by gravity at 3km per hour, was completed in 1889 (Image 5.1). On 22nd February the City held a grand opening ceremony to welcome the arrival of mountain water. Large crowds gathered as jets of water were sent high into the air. People were heard to remark on the purity and softness of the new sweet-tasting water. Few knew at the time that the water was not in fact delivered by the flume, but had come from the usual source on the San Diego River, and the pressure for the jets came from the same old pump station. It was not until a few weeks after the ceremony, when work on the flume was finally complete, that San Diego took delivery of its first imported water.

The 1880s marked the beginning of the rapid and comprehensive development of locally available supply within San Diego County. Figure 5.2 shows the expansion of reservoir capacity. Following the successful completion of the Cuyamaca Flume, the Southern California Mountain Water Company was established in 1894 to develop the southern system, the San Dieguito Mutual Water Company in 1918 to build the Hodges Dam, and the San Diego County Water

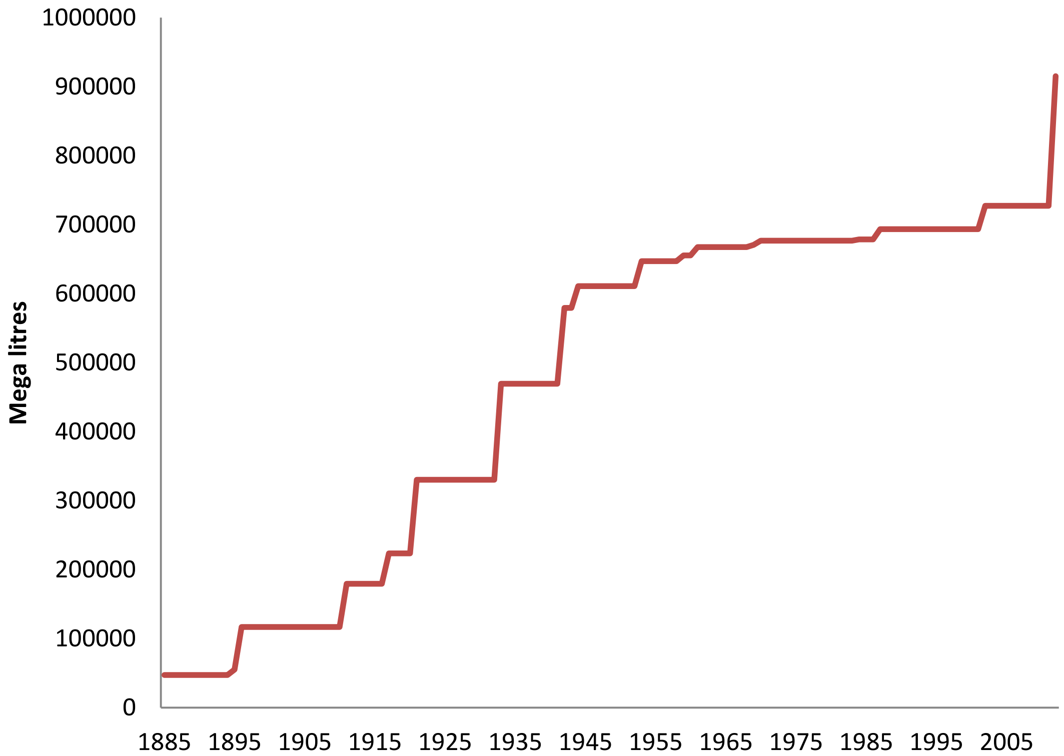


Figure 5.2: Reservoir capacity in San Diego County. *Source*: SDCWA (2016a)

Company in 1920 to construct the Henshaw Dam (Mirvis and Delude 2013). This period was, however, marked by disputes between companies, municipalities and land owners, and by the 1910s the tide was turning towards public ownership of water infrastructure, a process that would accelerate following the establishment of the SDCWA. Indeed, a report by the Southern California Mountain Water Company noted that;

> *"…the history of all water companies engaged in supplying San Diego has been one of turmoil, misfortune and difficulty…which [has] rendered the supply of water for many years in the past decade, not only bad in quality, expensive in development, but inadequate in quantity, all of which retarded the growth of the town and checked general progress."* (SCMWC 1910)

From 1913, after purchasing the entire Mountain Water Company's southern system, the City of San Diego took increasing responsibility for its residents' water supply. The primary strategy during this period was twofold. First, to continue developing a 'comprehensive reservoir system,' which would store surplus water in wet years, mediating the regions variable climate (San Diego Water Committee 1916). Second, to re-establish the historic Pueblo rights to all the waters of the San Diego River, dating back to Spanish colonisation, and to secure surplus waters from neighbouring basins. The recommendations of two major reports conducted in the 1920s illustrate the urgency associated with these endeavours:

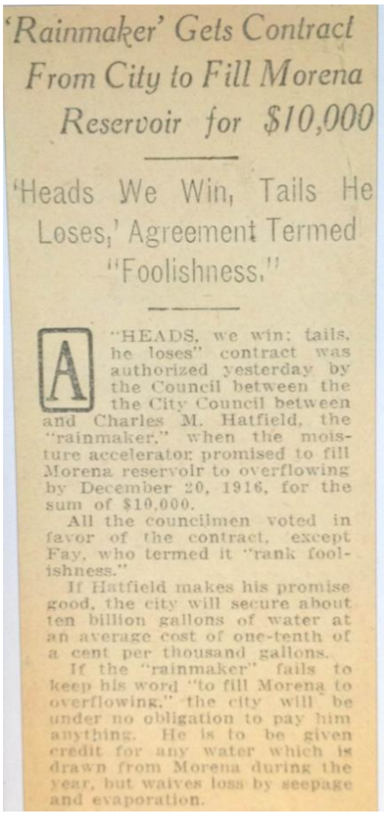
> *"…the water problems of the City of San Diego have been difficult to solve in the past, they are more difficult at present time, and it will be impossible to properly solve them in the future, unless the City regains its water rights which it has unwisely allowed to pass to adverse ownership."* (San Diego Board of Water Commissioners 1922, 2)

> *"…the San Diego River, in addition to the fullest development of sources now owned by the city will become insufficient before many years, and…the time will surely come when San Diego will have to stop growing in an attractive way because of lack of water. It is*

> *in my judgement largely a case of now or never, about obtaining the surplus waters of the Santa Ysabel."* (Freeman 1924)

The City's expansionist strategy to secure additional water in the county was not, of course, uncontested. Most notably, this resulted in a Supreme Court battle between the City and a group of farmers in the La Mesa area to the east from 1935-37. This dispute, although not as fierce or prolonged, resembled in some respects the water wars between Los Angeles and the Owens Valley, popularised in Roman Polanski's 1974 epic, *Chinatown*. During the 1920s the City had been buying up riparian land in the La Mesa Irrigation District and began extracting water at the Riverview Pumping Station. As the water table dropped, farmers downstream complained that their wells were running dry and collectively sued the City. The City, by contrast, claimed exclusive rights to the river water, invoking its historic Pueblo status under the legal doctrine of Prior Appropriation. The City was ultimately victorious in establishing its claim.

Perhaps no episode expresses the anxieties around water during this time as well as the curious tale of Charles Hatfield, the rainmaker. Hatfield was the last, and most successful, of a group of pseudoscientists-come-showmen who travelled across the American West in the late nineteenth and early twentieth centuries attempting to make it rain. Techniques varied, but the process generally involved evaporating some form of secret chemical mixture at strategic times in strategic locations in order to encourage the conditions for precipitation. After gaining notoriety throughout California, Hatfield was commissioned in 1916 by the City of San Diego, again in the grips of drought and desperate for a quick solution, to use his techniques to fill the Morena Reservoir for the sum of $10,000. A contract was unanimously agreed by council members, except for one, who described the whole affair as 'rank foolishness' (Image 5.2). And so, Hatfield got to work on his apparatus. Shortly after, it began to rain. And it kept on raining. Soon, the reservoir was not only full, but overflowing. The resultant flooding killed twenty people and caused $4 million of damage to property. Hatfield then requested payment. The City



'Rainmaker' Gets Contract From City to Fill Morena Reservoir for $10,000

'Heads We Win, Tails He Loses,' Agreement Termed "Foolishness."

A "HEADS, we win; tails, he loses" contract was authorized yesterday by the Council between the the City Council between and Charles M. Hatfield, the "rainmaker," when the moisture accelerator promised to fill Morena reservoir to overflowing by December 20, 1916, for the sum of $10,000.

All the councilmen voted in favor of the contract, except Fay, who termed it "rank foolishness."

If Hatfield makes his promise good, the city will secure about ten billion gallons of water at an average cost of one-tenth of a cent per thousand gallons.

If the "rainmaker" fails to keep his word "to fill Morena to overflowing," the city will be under no obligation to pay him anything. He is to be given credit for any water which is drawn from Morena during the year, but waives loss by seepage and evaporation.

Image 5.2: News article on Charles Hatfield. *Source*: photograph by Joe Williams (2015), San Diego Public Library display

refused because, upon successfully filling the reservoir, he had been unable to stop the rain. A protracted court battle ensued. Finally, the City agreed to honour the contract, on the condition that Hatfield took responsibility for the claims for damages from local landowners. Charles Hatfield duly left town without collecting his fee (Jenkins 2005, Hundley 2001).

Colorado River and the urbanisation of Southern California

After comprehensively developing the capture and storage potential of locally available waters by the end of the 1930s, the engineers and water managers of San Diego faced a problem: find additional water from further afield, or risk constraining the growth of the City and surrounding agricultural districts. The solution, which only a few years earlier had been widely disregarded as fanciful, was to look east to the Colorado; to bind the development of San Diego to that of the West's mightiest river and to the other cities and states that laid claim to its waters. The taming of the Colorado was absolutely central to both the acceleration of urbanisation in

Southern California, and to the agricultural conquest of the desert (Henderson 1998, Worster 1985).

> *"To some conservationists, the Colorado River is the preeminent symbol of everything mankind has done wrong –a harbinger of a squalid and deserved fate. To its preeminent impounder, the U.S. Bureau of Reclamation, it is the perfection of an ideal… One could almost say, then, that the history of the Colorado River contains a metaphor for our time. One could say that the age of great expectations was inaugurated at Hoover Dam –a fifty-year flowering of hopes when all things appeared possible. And one could say that, amid the salt-encrusted sands of the river's dried up delta, we began to founder on the Era of Limits."* (Reisner 1986, 126)

Serious efforts to connect San Diego to additional water supplies first began in 1926, when the City applied to the California Division of Water Resources for the right to divert water from the Colorado River, a request that was officially recognised in 1931 under the Seven Party Agreement. A public information pamphlet published by the County Water Authority in the 1960s highlights the importance of this moment in history:

> *"If you live in San Diego County, you are enjoying a future that was prepared for you beginning in April, 1926, when the City of San Diego filed a request…for 112,000 acre feet [138,150 ML] per year…of water from the Colorado River, 300 miles away."* (SDCWA, no date, 1)

At the time, of course, San Diego had no viable way of accessing this supply. Much depended on the monumental Federal and State infrastructure projects on the Colorado during the 1930s and 1940s, and the success of the American New Deal in rejuvenating economic activity in the arid West after the Great Depression. With the exception of the 1926 filing, San Diego had very little to do with the initial Colorado negotiations, which were largely handled at the State and Federal level, and the Metropolitan Water District of Southern California.

Image 5.3: The Hoover Dam. *Source*: Joe Williams (2014)

Image 5.4: Hydroelectric power plant, Hoover Dam. *Source*: Joe Williams (2014)

The full allocation of the Colorado River began in earnest in 1922 with the signing of the Colorado River Compact, and its ratification by all seven of the basin states, except Arizona. The Compact divided the river into the Upper Basin states of Colorado, Utah, Wyoming and New Mexico, and the Lower Basin states of, Arizona, Nevada and California. Based on average precipitation and streamflow in the years leading up to 1922, available supply was divided equally between the Upper and Lower basins, each receiving 7.5 million acre-feet (9.3 million ML) a year, with a further 1 million AF (1.2 million ML) to be made available to the Lower Basin. The principle challenge for engineers in taming the Colorado was dealing with the highly seasonal flow. Baseflow for nine months of the year is only about 20% of the flow during the snow melt period of Spring and early Summer, so the full utilisation of Colorado water resources required the development of flood water storage capacity, and of conveyance pipelines.

The Boulder Canyon Act of 1928 then provided for the Federally-funded development of these engineering projects, most notably for the construction of the Boulder Dam, which would later be named the Hoover Dam (Images 5.3 and 5.4). The purpose of this Act was threefold. First, to control floods, improve navigation and regulate the variable seasonal flow of the river. Second, to provide for storage and delivery of water for beneficial uses within the United States. And third, to generate electrical energy "as a means of making the project…a self-supporting and financially solvent undertaking" (Boulder Canyon Act 1928, 12). The Boulder Canyon Agreement also allocated annual apportionments to each state. In the Lower Basin, California was to receive 4.4 million AF (5.4 million ML) plus half of any surplus supply, Arizona would receive 2.8 million AF (3.5 million ML), and Nevada 300,000 AF (370,000 ML). The addition of some further guaranteed contracts for Colorado water in California and a treaty for water delivery to Mexico, however, meant that right from the outset, the Lower Basin share of water was over-allocated by perhaps 2.5 million mega litres a year (Colorado River Board of California 1944). Moreover, streamflow in the decade leading up to the signing of the compact was above historic average, meaning that projected yield at the time was somewhat optimistic (Bureau of Reclamation 2016).

1	Palo Verde Irrigation District	3,850,000 AF pre-1922 Colorado River Compact rights
2	Yuma Project	
3	Imperial Irrigation District (IID) and Coachella Valley Palo Verde ID	
4	Metropolitan Water District of Southern California and Los Angeles	550,000 AF
5	MWD and LA San Diego (City and/or County)	550,000 AF 112,000 AF
6	IID and Coachella Valley Palo Verde ID	300,000 AF
7	Other agricultural use	

Table 5.1: California's hierarchy of Colorado water rights, as laid down in the Seven Party Agreement 1931. *Source*: adapted from Pyle (1937)

The California allocation was further divided in the Seven Parties Agreement of 1931. Under this agreement water was allocated according to the legal doctrine of Prior Appropriation, where those who establish a 'beneficial use' of water may claim that right indefinitely. The upshot of this 'first in time, first in right' framework is that those parties with the earliest established use of Colorado River water have a stronger claim than those that were made later. The strongest rights were, and remain, those claimed before the 1922 Compact. The hierarchy of rights laid down for California in 1931 are shown in Table 5.1. In California, the oldest and strongest rights are all held by the historic irrigation regions of the Imperial and Coachella Valleys and Palo Verde, with the coastal urban areas maintaining more precarious access. Indeed, the first sustained diversions of Colorado River water date back to 1856 and the cultivation of the Palo Verde Valley, whereas established claims for urban water did not begin until the 1920s. The 1926 rights held by San Diego for 112,000 acre-feet a year, before it was annexed to Metropolitan, were therefore comparatively weak and vulnerable. Even the Metropolitan Water District of Southern California, which now supplies water to cities in some of the most populous and economically productive counties in the US, including Los Angeles, Orange County and San Diego, holds only fourth and fifth tier post-1922 rights. This effectively means that in years of reduced streamflow, during drought when available stored supply is reduced, or when competition between states squeezes allocation, those with the lowest priority rights experience the most severe cutbacks.

This brief sketch of the history of Colorado River water allocation is given in order to illustrate two points, which it is argued, are fundamental in understanding the emergence of seawater desalination in urban Southern California. Firstly, that the annual yield of the Colorado's Lower Basin has historically been over-allocated. Throughout the 1930s and 40s, when entitlements were often not fully claimed and demand was still below yield, this did not create any significant issues. As demand increased, however, and new claims and uses were established, this particular and peculiar system of water rights created the conditions for fierce, prolonged, and in many cases still unresolved disputes over access to water. Secondly, this entrenched mode of allocation developed out of, and reflects, a particular logic of capital accumulation, one that positions irrigated agriculture as the primary form of socio-natural metabolic transformation. The Great West was, after all, settled as an agrarian economy. The continuing transition to an urban economy in Southern California, and its associated urban metabolic transformations, now poses many economic challenges for the region. This is not to suggest that the 'urban' and the 'rural' represent distinct spheres of accumulation in California –indeed, they are historically (and remain) co-constituted. Rather, I argue that the resistance of the system of water rights to change, even in the face of profound economic transformations throughout the twentieth century, now begins to threaten capital accumulation in the Southwest. Henderson for instance, argues that in California;

> *"…the city is no longer just a core economic space that seeks to articulate with, shape, or control surrounding economies, but a material, infrastructural space that competes with and perhaps displaces those surroundings by virtue of core and periphery competition over the same spoils."* (Henderson 1998, 204)

Put another way, the challenge now facing many coastal cities in Southern California arises from a disconnect between the inertia of modes of water circulation vis-á-vis capital circulation. One of the key contentions of this chapter, therefore, is that seawater desalination in the contemporary era, because it avoids both the problem of over-allocation and of allocation inertia, emerges at a stress-point between two competing, and increasingly incompatible, forms of capital accumulation.

Connecting San Diego to the Colorado

By the end of the 1920s it was widely accepted that San Diego County would, at some point, exhaust its local supplies of water, and that connection to the Colorado River for supplementary supply was both feasible and desirable. Two importation options were considered in detail (figure 5.3). The first was to bring in water through the Metropolitan Water District via the Colorado River Aqueduct, which was completed in 1941, north of the Salton Sea and south through Los Angeles. The second option was to connect San Diego to the Imperial Irrigation District south of the Salton Sea, and to route water along the Mexican border via the All American Canal. Initially, the All American Canal route was favoured by hydraulic engineers as the most viable long term option (Ready et al. 1937). In the mid-1930s, however, it was thought that the high growth rates experienced in San Diego in the preceding two decades would slow, and that Colorado River water would not be needed until around 1960. Indeed, a report by the Municipal Employees Association in 1937 projected that demand for the entire metropolitan region would only reach 340,000 m^3/day by 1960. Actual demand in that year grew to more than double this figure. Water managers in the 1930s could not, of course, have predicted the effects

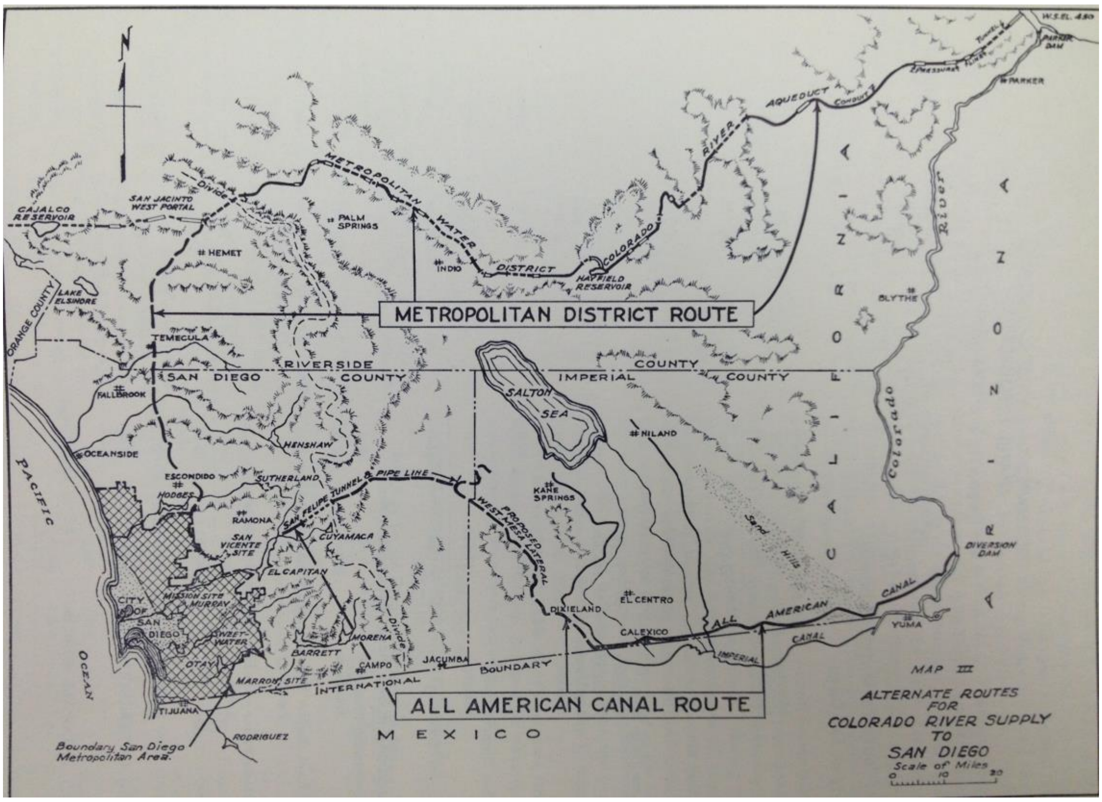


Figure 5.3: Two route options for importing Colorado River water. *Source*: San Diego Municipal Employees Association (1937, 13)

of the Second World War and the development of the world's largest military-industrial complex within San Diego County.

At the time, San Diego, with its large and sheltered harbour, hosted the US Navy Pacific Fleet. North County is also home to the US Marine Corps at Camp Pendleton. Before the War the main industry in the region had been tuna packing, but within a matter of a few short years military-oriented industry, housing and population burgeoned. By 1944 the military and its associated industries were using half of the metropolitan region's water supply (SDCWA 1945). A military publication aimed at persuading the Federal Government to assist San Diego in its quest for more water, conceded that "[T]he burden which has been placed on the City in its endeavour to handle this situation has been enormous" (US Navy 1941). Hydraulic Engineer, Fred Pyle (1945), insisted that the annual safe yield of the County's reservoirs was being 'greatly overdrawn,' a situation that had not yet resulted in critical shortages only because rainfall in the late 1930s and early 40s had been 158% above average. Other authorities suggested that San Diego was withdrawing double its safe yield.

As a result of the pressures of accelerated growth during WWII, the water problem in San Diego, which had until then been something of a desert backwater, became an issue of national defence. “San Diego’s problem,” announced the Chamber of Commerce (1951, 6) “is the Nation’s problem.” By the mid-1940s it had become crucial for San Diego to accelerate its plans to import Colorado River water. Under pressure, the Federal Government commissioned the Navy to build a 110km pipeline (now called the First San Diego Aqueduct) to connect the Metropolitan Water District’s Colorado River Aqueduct with San Diego’s distribution system. Work began in 1945, but when the War ended the Navy moved to abandon construction. San Diego managed to negotiate the aqueduct’s completion after agreeing to reimburse the Federal Government $14 million. The decision to bring in water through MWD, rather than via the Imperial Valley, therefore, was made under conditions of wartime crisis, where the primary imperative was to secure rapid connection to additional supply. This, in effect, locked San Diego’s development into a particular pathway, and began what would become a fractious relationship with the MWD and its other member agencies.

During this time it was decided that a county-wide institution was needed to pool the various rights within the county and negotiate on behalf of the City of San Diego and the various surrounding metropolitan areas and irrigation districts. The San Diego County Water Authority was therefore established under a Special Act by the Legislature in 1944, with the primary remit of importing and delivering Colorado River water, “the only remaining source of water outside San Diego County still available for its use” (SDCWA 1946, 40). The SDCWA, which initially comprised five cities, three irrigation districts and one public utilities district, has now grown to include a total of 24 member agencies, mostly in the populated coastal region, supplying 80% of all water used in the county (figure 5.4). The first task of the newly created Authority was to negotiate its annexation to Metropolitan. In doing so, the two agencies combined their fourth and fifth tier entitlements, giving San Diego preferential rights to slightly more water than it had on its own and easier access to surplus supply. The Water Authority made its first delivery of

Colorado water to its member agencies on 24th November 1947. The imported water arrived just in time to spare communities throughout the county from severe water rationing. A booklet published to mark the significance of the occasion declared that:

> *"Few communities have faced the difficulties with which San Diego has had to contend in developing a water supply, and none has met them with more courage and determination… Of the successive steps, each greater than the one before, taken by the community to further its development, the arrival of Colorado River water…ranks as the crowning achievement."* (Citizen's Aqueduct Celebration Committee 1947, Forward)

Projections made in the late 1940s suggested that the supplementary water provided through the aqueduct would be sufficient to meet demand at least until the early 1960s. Again, these predictions drastically underestimated the rate of economic and population growth in San Diego. Coupled with this was the progressive annexation of more and more water districts and

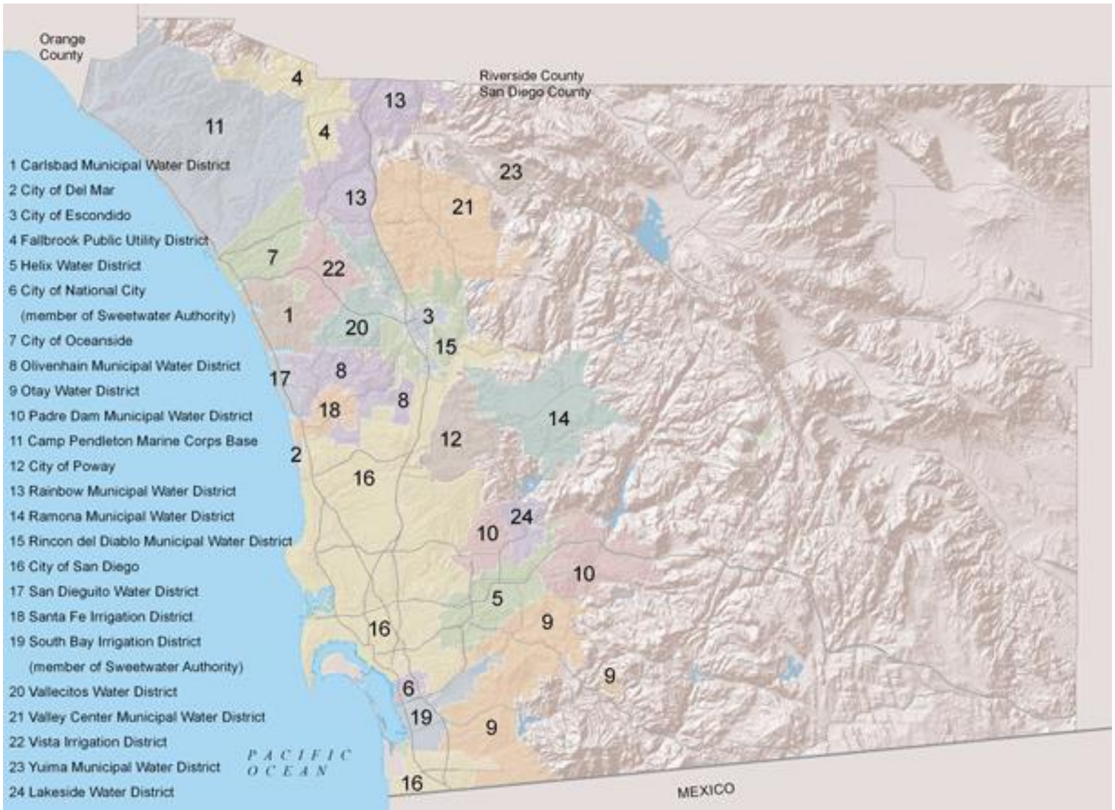


Figure 5.4: SDCWA member agencies. *Source*: SDCWA (2016e)

companies to the Water Authority. By the early 1950s the capacity of the single pipeline was deemed insufficient and in 1952 a second barrel was commissioned to augment imported supply. The addition of the second barrel, and later of a third, fourth and fifth pipeline connecting to Metropolitan supply, each of progressively larger diameter, cemented the transfer paradigm at the heart of water governance in San Diego. Imported water went from supplementary supply to indispensable baseload, creating the institutional and political conditions that, combined with the ecological realities of the 1987-1992 drought, led to the 50% cut to supply over which San Diego had virtually no control.

California State Water Project

The extensive development of California's water and hydroelectric resources through the State Water Project, construction of which began in 1960, marks a new chapter in San Diego's water story. The size and scope of this infrastructural water-energy regime is enormous. Today it delivers water to two thirds of California's population, and comprises: 34 storage facilities, with a combined capacity of 7.2 cubic kilometres; 20 pumping plants and 4 pumping-generating plants; and 5 hydroelectric power plants, producing an average of 6.5 billion KWh a year (Department of Water Resources 2016). The California Aqueduct conveys water from the Sacramento-San Joaquin Bay Delta more than 700 km, supplying Southern California with up to 3.1 million mega litres a year. The Edmonston Pumping Plant, which lifts water over the Tehachapi Mountains north of Los Angeles, is the single largest consumer of electrical energy in California. A comprehensive history of such a large project is clearly beyond the scope of this thesis. Instead, I highlight some important historical features, which are particularly pertinent to water and energy governance in San Diego.

Although visions of a unified state water programme had been circulating since the 1920s[2], the development of such a project was given urgency in the late 1950s and early 1960s by the implications of a protracted legal battle between California and Arizona over allocation on the Colorado River. This resulted in a decade of litigation at the Supreme Court between 1953 and 1963. The roots of this disagreement actually dated back to 1922, when Arizona had refused to ratify the Colorado River Compact. It had done so because, under the Compact, withdrawals from tributaries to the Colorado were included in the total allocation. For Arizona this meant that all of the water withdrawn from the Gila River for irrigation in the central part of the state was included in the overall allocation on the Colorado. This was the beginning of what Senator Thomas Kuchel (1964, 1) described in an address to Congress as “a long history of regrettable controversy over the Colorado River.” Indeed, this matter was not legally resolved until 1963, and its implications are still not fully resolved politically. Meanwhile, California had established rights to nearly 5.4 million acre-feet (6.6 million ML), and had financed the Palo Verde, Imperial Valley and Metropolitan systems on the assumption of receiving this amount annually. Arizona argued that its withdrawals from the Gila River, which amounted to around 2 million acre-feet (2.5 million ML), should not be included in its allocation of 2.8 million acre-feet under the Boulder Canyon Agreement. Arizona contended that the difference should be made available for its use in the Central Arizona Project. California, in turn, argued that such a move would make the likelihood of surplus supply in the Lower Basin, which it had relied upon, almost non-existent year to year. In 1963 the Supreme Court ruled on the tributary issue in Arizona’s favour, meaning that water withdrawn from tributaries of the Colorado became additional to the 1928 allocated rights, rather than ancillary. As a result, California was forced to reduce its use by 1 million acre-feet (1.2 million ML). The state needed to secure additional water, and the SWP was the solution.

[2] Initial efforts for a State Water Plan resulted in a report by the Department of Public Works Division of Water Resources in 1930. Although this did not lead to a state-wide project, it become instrumental in the development of the Central Valley Project.

Harvey Banks, the first Director of the California Department of Water Resources, which had been established in 1956 to deliver the project, summed up the problem:

> *"Although we have ample water for all foreseeable needs, in relation to the needs of people it occurs at the wrong times, in the wrong places and in the wrong amounts… The only solution to our water problem lies in the construction of major engineering works to transport surplus water in the northern part of the state….more than 700 miles to areas of deficiency in the central and southern areas of the state."* (Banks 1960, 2-4)

The State Water Resources Plan was therefore outlined in 1957 (figure 5.5), and later refined, as a "master plan for the full conservation, control, protection, and utilization of the State's water resources," intended to "meet the present and future water needs for all beneficial purposes and uses in all areas of the State" (DWR 1957, xxxiii). The vision embodied in this monumental task was to create a 'water bank' in the North, simultaneously fixing the problems of flooding and saltwater intrusion in the Bay area, and of contested and insufficient supply in the Central Valley and the South (Weber 1960). For Southern California this meant a potential lifeline after the devastating Supreme Court ruling of 1963. The SWP became an integral component of Federal Government plans for water transfers in the Pacific Southwest. The Udall Plan –named after the then Secretary of the Interior, Stewart Udall– proposed that the shortfall in supply to Southern California resulting from the California-Arizona dispute should made up by the transfer of water from Northern California (Department of the Interior 1963). This meta-plan, which drew together various projects in California, Arizona, Nevada, Utah and New Mexico, outlined proposals for 3.4 million acre-feet (4.2 million ML) of inter-basin transfers a year.

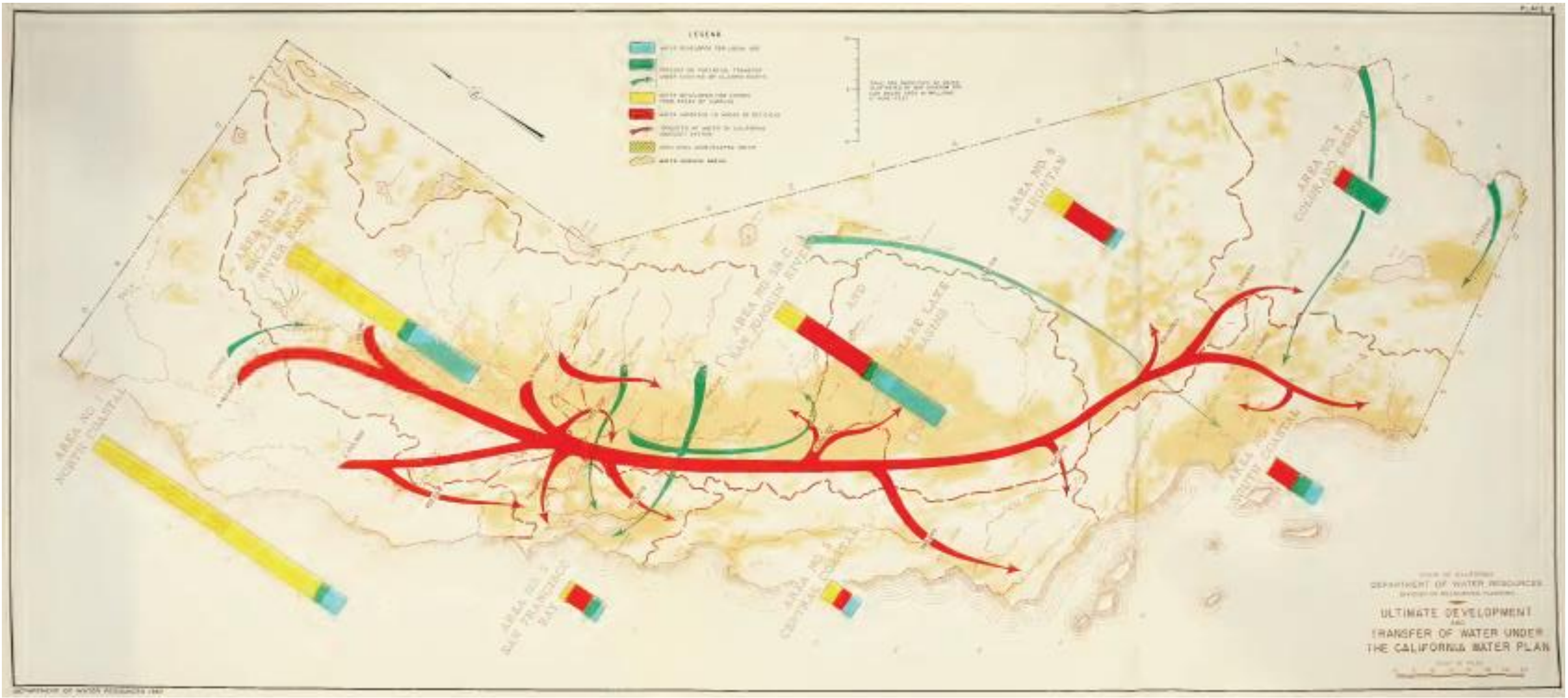


Figure 5.5: The California State Water project.
Source: California Water Plan (1957, plate 8)

Neither the Udall Plan nor the State Water Project received universal support in Southern California, however. In particular, there was disagreement between the Metropolitan Water District and the Los Angeles Department of Water and Power (LADWP). LADWP complained that it would be forced to bear a disproportionate burden of the $1.75 billion in bonds required to finance MWD's share of the project, and would therefore be effectively subsidising water for other cities, particularly San Diego. LADWP even proposed to substitute aspects of the development with an alternative plan, which would move surplus waters from the Columbia and Snake Rivers in Idaho, through Nevada to the Lower Colorado Basin –a project that LADWP calculated would, once operating, produce almost as much in hydroelectric revenue as it would cost in pumping (LADWP 1963). Without the support of Metropolitan, or the State and Federal government, this project never went past the design phase. The delays associated with the LADWP-MWD dispute caused some in Sacramento, including California Governor Pat Brown, to accuse MWD of deliberately stalling the State Water Project.

Nevertheless, the 1960s became the decade in which the long-distance transfer paradigm, characterised by large state-led water and hydroelectric infrastructures, became entrenched as *the* mode of water governance throughout the Southwest United States. By 1967, Metropolitan had begun work expanding its storage and delivery infrastructure to accommodate new water coming in from Northern California. Although San Diego, which sits at the end of all the transfer pipelines, did not receive any SWP supply until 1978, its growth between 1950-1990 was entirely predicated on an ever-expanding source of imported water. In 1954 work was completed on the second barrel of the San Diego Aqueduct; by the end of 1960 Pipeline Three began delivering water through the second San Diego Aqueduct; in 1971 Pipeline Four was added parallel to Three; and Pipeline 5 was completed in December 1982 (Figure 5.6). As one participant put it:

"If you look back in San Diego County's history, the last year the native water supply…was sufficient to support our population and economy was 1946. So the economic activity, the quality of life and the people you see in San Diego today, is made possible for the most part by imported water." (Assistant General Manager, interview 24/09/2014)

Sometime in the 1960s a crucial threshold was breached, although few at the time recognised its full significance: San Diego began to import more water than it had allocated rights to. By 1991, despite having preferential rights[3] to only 15% of Metropolitan's supply, the County Water Authority was taking delivery of up to 30% of MWD water every year (SDCWA annual reports).

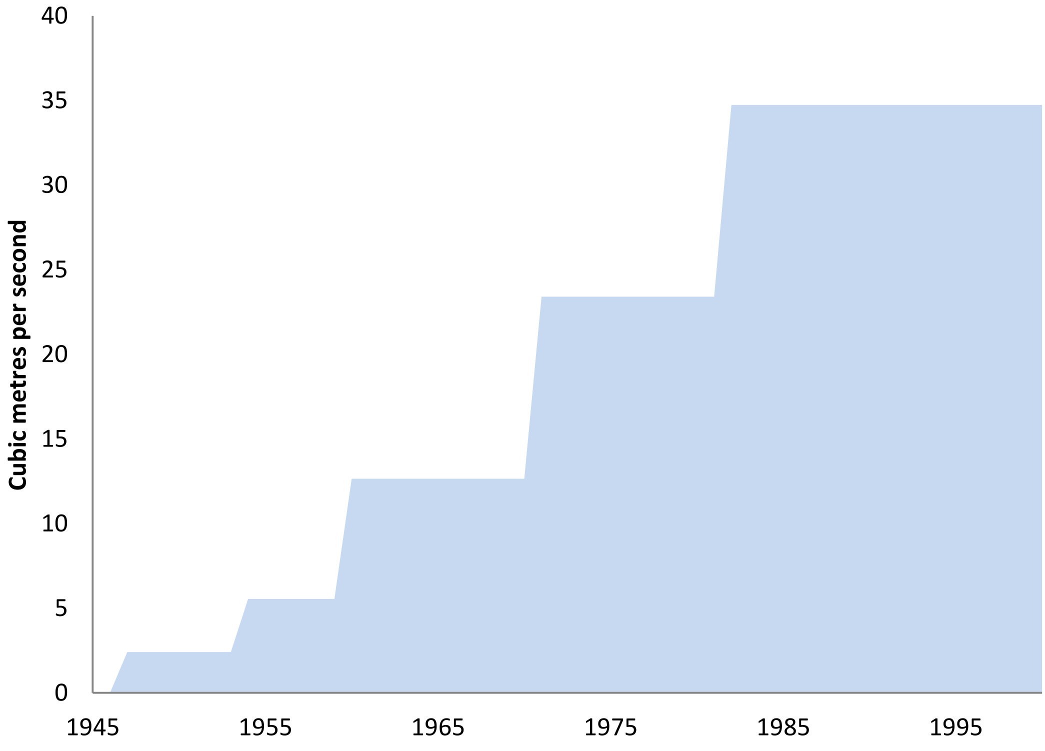


Figure 5.6: Pipeline capacity for imported water. *Source*: SDCWA annual reports

[3] Preferential rights are statutory percentage rights to MWD supply. Each member agency's preferential rights are re-calculated every year by MWD, based on property taxes, contribution to MWD fixed capital and some other charges. They are not, however, correlated to water purchases. When San Diego joined MWD it had preferential right to 10% of supply. This has now risen to around 18%, although this figure is currently being contested by SDCWA.

Desalination, the elusive catholicon

Of all the wild water solutions dreamt up in Southern California, the purification of ocean water, although the most tenacious, certainly sits amongst the most extraordinary. Those in the desert Southwest have always been pursuing the water panacea in its various guises. In the late-nineteenth and early-twentieth century, many believed in the strange power of the rainmakers. San Diego was not the first, nor was it the last municipality to commission the production of precipitation. In the mid-twentieth century rainmaking was back in vogue, encouraged by Federal research on cloud seeding. In the 1960s the San Diego County Water Authority considered weather modification to be as promising a solution as seawater desalting (SDCWA Annual Reports 1960-1970). In the 1950s, John Isaacs, a professor based in San Diego, developed a plan to float icebergs to Southern California from Antarctica. This proposal was developed more seriously in the 1970s by another scientist, John Hult, of Santa Monica. Hult calculated that iceberg water could be pumped into the southern end of the California Aqueduct for a total cost of less than $100 an acre-foot –a price comparable to MWD rates at the time. A *San Diego Union* headline from the time proclaimed that "an iceberg in the desert really isn't far-fetched" (Smith 1977). Curiously, this strange idea resurfaced briefly in the early 1990s as a possible drought-alleviation strategy (San Diego Union 1991).

While these examples all turned out to be somewhat faddish, the 'desalination solution' has been recurrent for a century. Dreams of tapping the Pacific Ocean –the 'largest reservoir on Earth,' as described by one participant (water company Senior Vice President, interview 24/10/2014)– have emerged periodically, each time associated with a particular technical, political or energy configuration. For the most part, however, visions for desalinating Southern California out of its water woes have gone the same way as the rainmakers, consigned to history, along with a multitude of other failed silver bullets.

The golden (but dry) age of desalination

Interest in desalination really began to pick up in the 1950s and 1960s, under direction from a well-funded Federal programme. This began in 1952 when Congress authorised funding through the Department of the Interior, under the Water and Power Development scheme. Research was coordinated by the newly established Office of Saline Water, which operated between 1955 and 1974. The era of state-funded R&D reached its height under the Kennedy Administration, when desalination was a high priority issue for the government. When the country's first ocean desalting test plant –a Multi-Effect Vertical Distillation facility in Freeport, Texas, with a 1 million gallon per day capacity– opened in 1961, President Kennedy said:

> *"I can think of no cause and no work which is more important, not only to the people of this country, but to people all around the globe… I am hopeful that the United States will continue to exert great leadership in this field, and I want to assure the people of the world that we will make all the information that we have available to all people. We want to join with them, with the scientists and engineers of other countries in their efforts to achieve one of the great scientific breakthroughs of history."* (Kennedy 1961a)

The desalination programme during this time was international in scope and ambition. The US government even signed an agreement with the USSR for the exchange of scientific information relating to saline water conversion. R&D funding was primarily contracted out to private research companies and engineering consultants. General Atomics, a subsidiary of General Dynamics headquartered in San Diego, emerged as a major player. Its desalination group, Reverse Osmosis General Atomics (or ROGA), was very successful in attracting government funds. Indeed, ROGA pioneered the RO method of desalination, which now dominates the industry, when at the time most efforts were directed towards distillation techniques. It was in San Diego where the spiral-wound RO element was first developed, which are now used in virtually all RO modules worldwide. According to one participant:

> *"The mark that the Federal government funded research left on the industry was tremendous. I don't think we would have ever developed the spiral wound membrane element, and we wouldn't have it today. It happened because of the research funding. It was a very competitive programme."* (Senior Development Consultant, interview 06/08/2015)

Although desalination never became the panacea that Kennedy had envisioned, the programme was in many respects highly successful. It really kick-started the desalination industry and facilitated the development of novel technologies, like RO, that many in the industry believe would not have been developed otherwise. San Diego became, and remains still, a hub for the desalting industry. Many splinter companies formed around the initial work of ROGA, specialising in everything from chemical treatment and membrane development to pumps, energy recovery and module housing.

During the 1960s desalination was the focus of interest at virtually every level of water management from Federal level to local water authority. The San Diego County Water Authority and Metropolitan Water District were both commissioning feasibility studies for large facilities and collaborated in a joint R&D programme. The development of coastal desalting capacity was also an important component of the aforementioned Udall Plan for the Pacific Southwest (1963). This involved, in addition to the comprehensive development water transfer potential, the construction of an initial 190 ML/day ocean desalter (the same size as the recently completed Carlsbad plant) as a way of compensating California for some of its supply lost to the Central Arizona Project. The huge efficiency gains borne out of the intensive R&D programmes during this time, combined with falling energy prices, led to optimistic (and entirely unrealistic) forecasts on the future cost of desalinated water. Indeed, one respected Berkeley professor confidently calculated that because the unit cost had fallen so rapidly in the decade following the commencement of Federal funding, by 1990 California would be able to produce desalted seawater at less than $30 a mega litre (Seckler 1965). Even taking inflation into account, he could hardly have been more wrong: water is now sold from the Carlsbad plant, which is touted as the most efficient of its kind in the world, at $1,900 a mega litre.

Unrealistic technological optimism aside, the plans for saltwater desalination during this period precipitated in many respects those of today. For instance, the Udall Plan and the SDCWA-MWD collaborative programme clearly position desalination as a viable technological solution to increase the overall allocation in the Colorado River's Lower Basin. The contemporary binational desalting plans for Rosarito Beach effectively reproduce this logic, albeit through different technological, political and economic assemblages. Even as early as the 1960s, then, ocean desalination was being proposed as a political 'solution' that addressed water supply issues without addressing those of a dysfunctional water rights system and a metabolic logic of capitalism based on agrarian accumulation in the context of an increasingly urbanising coastal economy.

Desalination, energy regimes and infrastructure

Energy is, of course, deeply implicated in the history of desalination. Through desalting technologies water and energy become co-constituted in two broad respects. Firstly, the energy required to remove salt from seawater, although now substantially lower than in the 1960s, is still great. Indeed, in the history of failed desalination projects in Southern California the dual issues of cost and energy intensity have been cited as the principal limiting factor in virtually every instance. Without the progressive efficiency gains in membrane technology, pre-treatment, membrane treatment, and notably the development of ultra-efficient energy recovery systems in the late 1990s, the current generation of desalting plants would certainly not have got past preliminary phases in San Diego. Secondly, the co-production and co-location of energy and desalting facilities adds an important, if often overlooked dimension to energy-water coupling. Co-location refers to the siting of desalination plants adjacent to existing coastal thermoelectric power facilities so as to take advantage of existing seawater intake and outfall infrastructures, reducing overall capital cost. This infrastructural ‘piggybacking’ is generally used for reverse osmosis desalination plants, and is the model on which the Carlsbad and Rosarito developments pertinent to this research are both based. Co-location is discussed in great detail in chapter seven.

Co-production, by contrast, is the model used in thermal desalting, where the cooling mechanisms for thermoelectric generation are combined with multi-stage or multi-effect distillation in the same unit. This technique is only used on a large scale today on the Arabian Peninsula, but for the first generation of large desalters, before membrane technologies became a viable option, this was the industry method of choice. Without co-production benefits, distillation desalination would not have been economically feasible on a large scale. In the 1960s and 1970s the grand plans for a desalinated future in Southern California revolved around this model. During this time various proposals for plants with capacities three times larger than the recently completed plant at Carlsbad (up to 570 ML/day) circulated, some of which got past the feasibility and design stage (Holtom and Galstaun 1965). The 190 ML/day plant initially proposed in the Udall Plan was developed in the 1970s for a site at Huntington Beach, just north of San Diego in Orange County –the same site and capacity, in fact, as Poseidon’s proposed second desalination plant, which is currently stuck in the permitting phase. The plan was to build a multi-effect flash distillation facility twinned with a nuclear power plant. In the United States in the 1970s, much as it was in Spain at the same time, the desalination ‘solution’ was premised on, and intimately linked with, the assumption of long-term cheap nuclear energy. This was, after all, the height of the atomic era, and it was generally agreed that large-scale desalination could take advantage of both low-cost energy and efficiencies through co-production with thermoelectric nuclear plants. Nuclear technology would, it was thought, solve the problems of energy and water supply simultaneously. But as the nuclear sector went into decline, and energy prices rose rather than fell, the desalination industry underwent corresponding changes, and many of the planned developments, including Huntington Beach, were abandoned. As one participant explains:

> *"Nuclear power had a reversal in the US, it lost its momentum…which encouraged the Department of Interior to look harder at membranes. They believed the thermal process had reached a plateau with respect to progress, and membranes seemed like they were just at the very beginning of development."* (Senior Development Consultant, interview 06/08/2015)

The trajectory of desalination, then, as a recurrent focus of water stress solutions, is closely related to particular energy regimes and the techno-political configurations that coalesce around them. Intriguingly, whereas in the 1970s the nuclear energy and desalination regimes were very much mutually reinforcing, current paradigmatic shifts in the energy sector –such as the growth of renewable energy, the imperatives of GHG emissions reductions, and the movement away from large centralised coastal thermoelectric baseload production– are now being discursively and materially enrolled in the contestation of desalination. These themes are discussed in more detail in the next chapter. Notwithstanding, the historical development of desalination illustrates how, through the (re)assembling of social and technical relations, water and energy become historically co-constituted and contingent. In turn, this points to the importance of adopting a dialectical understanding of the water-energy nexus as emerging through internal relations, rather than the simple logic of external relations typically espoused in nexus thinking so far.

The political fix

Rather than forming the centre of a new water paradigm, as was envisioned by some in the optimism of the 1960s, the few examples of successfully developed desalination plants in Southern California during this time were built as technological solutions to resolve specific political conflicts. Two examples stand out as particularly illuminating: the plant at Point Loma and the Yuma Desalter.

In 1962 a company called Burns and Roe, funded by Federal research grants, began operating a small seawater conversion plant at Point Loma, San Diego. This was a test facility, the second of five commissioned by the US government, designed to trial different techniques and produce the necessary data for the development of commercial facilities (Foster and Herlihy 1965). The plant used a multi-stage flash distillation process, was twinned with three thermoelectric steam turbine units, and could produce 4.5 ML/day. In the end, Burns and Roe ran this facility at Point Loma for less than two years, before the plant became embroiled in political struggles between the US and Cuba. At the end of 1963, as tension between Cuba and the United States escalated, Fidel Castro ordered the water supply to the US military base in Guantanamo Bay to be cut off (Gleick et al 2009). Faced with this unanticipated water crisis, the US Navy began shipping in potable water at great expense. When relations did not improve, Navy commanders cut the old pipeline, symbolically denying their reliance on Cuba for water. In February 1964 the desalting module at Point Loma was disassembled and shipped to Guantanamo Bay, where it was operated by Burns and Roe for many years.

The Yuma desalination plant also emerged from the intersection between water and international dispute. It was designed and built during the 1970s and 1980s as a political fix for ongoing disagreements between the United States and Mexico over deliveries of Colorado River water (Postel et al 1998). The roots of the crisis go back to 1929, at the beginning of the comprehensive development of the Lower Colorado Basin by the Bureau of Reclamation, when Mexico claimed 4.5 million acre-feet a year for irrigation, primarily in the Mexicali Valley. Mexico had been unable to develop its own large projects on the Colorado for two main reasons. Firstly, because by the time the river reaches Mexico it is already flowing in a flat estuary, so the geological and hydrological conditions are not suitable for large dams, diversions and reservoirs. Secondly, Mexico is bound by the Treaty of Guadalupe-Hidalgo, 1848, and the Gadsden Treaty of 1853 to ensure the river remains navigable. The Mexican government argued at the time that the extensive development of the river by the US violated treaty agreements, and that Mexico should be guaranteed a fair share of the annual yield. The US, in turn, insisted that because Mexico was not able to develop its own projects, it was therefore not entitled to any more water than the average base-flow in dry months. The US offered to guarantee delivery of only 750,000 acre-feet, the amount that Mexico had claimed for irrigation in 1928. The state of California was particularly hostile to the Mexican proposal because such a guarantee would inevitably cause a shortfall in its own access to Colorado Water. The dispute continued unresolved for the next 15 years, in which time Mexico expanded its use to 1.8 million acre-feet. Finally, in 1944 the two countries reached a compromise, and the US signed a binding agreement to guarantee delivery of 1.5 million acre-feet a year –an agreement that stands today.

Construction of the Yuma Desalting plant was agreed between President Nixon and President Echeverria in 1974 under the Colorado River Basin Salinity Control Act. For years the United States had been in breach of the quality component of its water delivery commitment to Mexico (Judkins and Larson 2010). Saline spent irrigation water from the various irrigation districts in the Colorado basin was being returned to the river untreated, meaning that at certain times, water reaching Mexico had too high a salt content for Mexican irrigators to use. The severity of this problem had become a point of significant political disagreement between the two countries. After lengthy negotiations the US government embarked on a campaign of point-source treatment. The plant at Yuma, located very close to the border, was built to desalt agricultural runoff from the Whelton Mohawk Irrigation and Drainage District, which was one of the main polluters in the basin (Taylor and Haugseth 1976). The design stage of the plant was very long –indeed, although agreed in 1974 the facility did not become operational until 1992. The Bureau of Reclamation used the plant as an opportunity to conduct research and develop desalination technology. Six different processes were extensively tested at Yuma, both membrane and distillation. After extensive research and development it was decided that spiral-wound reverse osmosis technology was the most promising (Lohman 1994). So while the facility was built to treat agricultural runoff, its design and operation is very similar to a modern seawater desalter. At the time, its development was cutting edge. Such was the success of the other point-source treatment deployed upstream, however, that since completion in 1992 the Yuma plant has only been operated twice (Bureau of Reclamation 2015). It stands as an idle monument, not only to the ecological carelessness that has characterised the Bureau of Reclamation's development of the Colorado, but to technological progress and the capacity of desalting technologies to fix insoluble political contestation.

Diversification and localisation: a new water paradigm?

In 1991 the situation in San Diego, now facing a 50% cut to its water supply, was this: the region's extraordinary urban growth since the Second World War had been achieved through, and was still dependent on, abundant supplies of imported water; and despite being home to the largest agglomeration of desalination industries in the world, and despite multiple attempts to develop projects, seawater desalination had not become the catholicon that had once been hoped. The severity and rapidity of the mandatory water cuts in 1991 became the catalyst for dramatic reforms to water governance in San Diego. Facing sharp criticism, particularly from the San Diego Chamber of Commerce and other business leaders, the County Water Authority embarked upon an aggressive supply diversification strategy. Over the past 25 years this has involved a $3.1 billion capital improvement plan aimed at enhancing local and alternative water supplies.

The SDCWA's 'foundational strategy' has been to "diversify the region's supply mix, thereby reducing dependence on Metropolitan, and also strengthening the reliability of existing supplies" (SDCWA 2011, 10-11). The County is aiming to reduce its use of MWD water from its peak in 1991 of 95% to below 20% by 2035 (figure 5.6). The overall aim is to improve reliability by diversifying the supply portfolio. On one level, this is of course a reaction to local contextual factors. On another, this strategy is clearly consistent with, and connected to, much broader trends in European and North American cities towards infrastructure decentralisation:

> *"The development of 'localized,' 'decentralized,' 'distributed' or 'alternative' technologies affects the inherently interconnected nature of the urban, on environmental, spatial, social and political levels."* (Coutard 2014, 92)

For the SDCWA the imperatives of this are twofold. Firstly, the SDCWA wants to dampen the effects of future cuts to its customers. Whereas a 50% cut to 95% of supply constitutes a 47.5% reduction in total supply, a 50% cut to 18% of supply works out as only a 9% cut overall. Secondly, the Water Authority decided that in order to secure reliable future supply, it needed to reduce imports back down to within its preferential rights to Metropolitan water. In the years leading up to 1991, SDCWA had been importing double the amount of water from MWD than it had preferential rights to. This added a further dimension to the precariousness of San Diego's supply in addition to the shortage allocations enforced by MWD. The County Water Authority's investments include securing additional supply though an unprecedented transfer deal with the Imperial Irrigation District (discussed below); developing the county's limited groundwater resources; promoting wastewater recycling; a reasonably successful (albeit still insufficient, some have argued) conservation programme that saves an average of 66,000 ML a year compared to 1991 levels; and of course, seawater desalination (SDCWA 2011).

The SDCWA has also encouraged its member agencies to pursue similar diversification strategies. Indeed, since 1991 all of the 24 cities and water districts annexed to the Water Authority have invested in some form of local water source development. Notably, the City of San Diego, the cities of Carlsbad and Encinitas in the north of the county, and the Otay Water District in the south, have significantly developed indirect potable reuse systems, treating wastewater for irrigation of parks, golf courses and playing fields, distributed through 'purple pipe' networks. There is also some limited development of brackish groundwater desalination, which uses the same basic RO process as seawater conversion –for instance, the San Elijo-San Dieguito Valley Groundwater Project in the Olivenhain Municipal Water District. In the same way that the SDCWA is reducing its reliance on MWD imports for political and institutional reasons, the County Water Authority's member agencies are looking for ways to reduce their reliance on transfers. This trend is likely to deepen, moreover, with a number of planned projects over the next 20 years. Two stand out as most significant and pertinent to this study. First, the Otay Water District's ambition to purchase 25,000 to 50,000 ML a year (roughly two thirds of the District's total water consumption) from the binational seawater desalination development at Rosarito Beach, Mexico. This project is discussed in more detail below. Second, the Pure Water wastewater IPR (Indirect Potable Reuse) project, under development by the City of San Diego. This will involve an extensive upgrade and development of the City's wastewater treatment that will incrementally contribute potable supply up to 315 ML/day by 2035 (approximately a third of the City's demand). This project is discussed more in the next chapter. The complex interplays between San Diego's desalination plans and the concurrent efforts to promote potable wastewater recycling as an alternative are discussed at length in subsequent chapters.

The efforts made towards supply diversification, so aggressively and effectively pursued in San Diego since 1991, are by no means isolated. Certainly, given the conditions experienced during the 1987-92 drought, San Diego stands as something of a bellwether for the rest of California, and has since been ahead of the curve in many respects. Notwithstanding, I argue that the valorisation of diverse and local water portfolios, and the important symbolic and practical role that the desalination assemblage plays in this, is indicative of a paradigmatic shift in modes of water (and by implication, energy) governance in California, and indeed throughout the West. Excerpts from interviews with two participants, who represent significantly different interests, illustrate this:

> *"It's my belief that the glory days of importing water out of one region and into another are behind us. To me the trend that we've seen in the last 20-30 years, particularly on the State Water Project, is inevitable… Because of the politics, because of the environmental issues, because of the opposition from those areas of origin to having water exported out of their region. I see a world where almost everything is local…where there's a lot more stormwater capture, a lot more recycling, and a lot less dependence on imported water. I'm not at all pessimistic for Southern California…To me it's not if we're going to get to where we need to go, it's how we're going to get there. Are we going to move proactively and do it in a planned and organised fashion, or are we just going to get ratcheted down every time there's a drought? …It could be easy or it could be painful, but we're going to have to get there… We're just getting started, but I wish we had started a hundred years ago."* (City water department General Manager, interview 18/06/2015)

> *"We need to do more to diversity our supplies, we need to do more to create local supplies, more conservation, recycling, desalination… it took us 60 years to go from totally self-sufficient to all of our water coming from somewhere else. I think you'll see 60 years from now that trend significantly reversed, where Southern California is recycling all the water it uses many times over and making up the difference from the ocean, and far less reliant on imported water than we are today."* (Senior Vice President, interview 24/10/2014)

It is within these paradigmatic shifts in the governance of water in Southern California that desalination emerges as a powerful rhetorical vehicle for aggressive diversification strategies. I say *rhetorical* only, not *material*, because desalination has yet to prove itself as an effective supply for San Diego.

The IID transfer

Curiously, the most significant success so far for San Diego, in its attempts to diversify its supply portfolio, has not been achieved through developing local supplies, like groundwater, or alternative supplies, such as desalination or recycling, but rather through a landmark contract with the Imperial Irrigation District for an alternative transfer. This deal, which was developed through the 1990s and signed in 2003, is a long term agreement for the transfer of nearly 350,000 mega litres a year of rights to Colorado water from the IID to San Diego. The Imperial Valley, which lies directly east of San Diego County between the Mexican border to the south and the Salton Sea to the north, holds ample and secure pre-1922 rights (as shown in table 5.1). This effectively means that the IID's access to water has, for the last century, been more stable than that maintained through the fourth and fifth tier rights held by the coastal urban regions. The agreement consists of two basic components:

1. **The IID transfer.** Surplus water made available through conservation in the Imperial Valley is transferred to the Water Authority. The volume of transfer will increase every year, up to 250,000 mega litres a year in 2021. This agreement lasts for 45 years, with an option to extend by 30 years.
2. **The All-American and Coachella Canal lining.** The Water Authority paid for the lining of the All-American Canal and the Coachella Canal, which transport water from the Colorado River to the Imperial and Coachella Valleys. The SDCWA then receives the water saved. This component of the agreement secures 95,000 mega litres a year for San Diego for 110 years.

The agreement is seen as a win-win scenario by both parties: San Diego secures a significant and reliable alternative long-term water supply that (in theory) circumvents the political struggles that have beleaguered MWD supplies; and the Imperial Valley improves efficiency whilst maintaining the 'beneficial use' status that guarantees its rights to the Colorado. To be clear, this is a transfer of water rights, not physical water. San Diego does not import water directly from the Imperial Valley. Instead, SDCWA invokes its constitutional rights to bring water through the MWD network. Although San Diego had hoped that this deal would relieve some of the disagreements between itself and Metropolitan, it actually led to new political battles. MWD, which had until that point, maintained a monopoly over water imports through the Colorado Aqueduct, was legally obliged to transfer the IID water to San Diego. It therefore devised separate charges for water, treatment and transportation, to replace the single rate it had used until then. San Diego argued that the new rates implemented by MWD were disproportionately weighted towards the transportation, or 'wheeling' charge, and that the Water Authority was therefore being overcharged for the IID water. This resulted in over a decade of litigation, not resolved until November 2015, when the San Francisco Superior Court ruled in San Diego's favour, ordering MWD to pay $235 million in damages and interest for overcharging on the transportation rate.

The water that arrives in San Diego is physically the same as ever, taken from the same point on the Colorado and transported through the same infrastructure networks. It is, rather, the political and institutional configurations through which this water is mobilised that secure greater overall reliability for San Diego. Although fundamentally this deal amounts to just another form of importation, an agriculture-to-urban transfer of this scale, unprecedented in the history of the American West, represents a fix to the inertia and political deadlocks that characterise water rights and allocations in the desert Southwest. It reflects a broader shift in Southern California from a metabolic water regime dominated by irrigated agriculture, to one in which the urban metabolism is increasingly the focus of capital accumulation, with its associated re-organisation of water circulation.

Desalination for San Diego

The success of the IID transfer agreement in reducing San Diego County's dependence on imports from Metropolitan initially drew attention away from desalination as the focus of efforts towards local and independent water source. In the early 1990s the SDCWA had begun developing plans for a 68 ML/day facility in Chula Vista, twinned with the existing SDG&E power plant, and a 189 ML/day plant in Carlsbad, twinned with the Encina Power Station. The Water

Authority even got to the point of submitting an Environmental Impact Assessment for the Carlsbad project. These projects were side-lined while the Water Authority concentrated on pushing forward with the IID deal. A consortium of cities in the north of the county, led by the City of Carlsbad, tried to move ahead with their own plans for a desalination plant independently from the Water Authority, but the group lacked the financial clout and expertise to advance such a large project. It was not until the late 1990s, when the project development company, Poseidon, arrived in California in search of suitable investment opportunities, that seawater desalination emerged as a significant element of the diversification process.

Nearly two decades on, seawater desalination is now at the centre of a powerful discursive and rhetorical framework for local and diverse water supply, which has intensified during the drought of the last five years. Prized for offering drought-proof, rainfall independent and local water, free from the politics and institutional disputes of traditional supplies, desalination has become emblematic of this new water paradigm. To the County Water Authority, desalination will "not only improve long-term water supply reliability for the San Diego region, but it also helps all of California by taking pressure off strained water resources" (SDCWA 2016b). Indeed, proponents have certainly not understated the significance of this additional supply. As one exponent interviewed for this research puts it:

> *"[T]he ocean is the only source of water that is not dependent on how much it snows and rains in any given year. And if we're going into an era of extreme uncertainty and extended droughts because of climate change, it's the only supply that's going to be there to protect the health, safety and welfare of the community during an extended drought. We've got almost a $200 billion economy in this county that's dependent on water –and you've seen the environment here, it's not a natural environment. So this entire place could dry up and blow away with one or two more dry years."* (Senior Vice President, interview 24/10/2014)

Even the most ardent advocates, however, do not see ocean water as the solution to all of San Diego's water problems, but rather as an important component of a diverse portfolio. Moreover, not only is the contribution from the Carlsbad plant relatively small –about 10% of the total demand in the SDCWA service region– and the plant only having been operational for a few months, but the success of other diversification strategies is already causing some to doubt the need for such a facility. Indeed, even at the end of a fourth year of severe drought, before the Carlsbad plant came online, San Diego County had already secured 100% of its supply for the coming year (water department General Manager, interview 05/06/2015). The success of other diversification strategies in reducing reliance on MWD imports, combined with state-wide mandatory cutback orders to reduce urban water use by 25%, issued by California Governor Jerry Brown in April 2015, meant that when the Carlsbad desalination plant began commercial operations in December of that year, the water produced was diverted directly to storage reservoirs.

Conclusion

The desert Southwest is a place of wild water dreams. The monumental efforts undertaken during the twentieth century to deliver water in abundance to an arid and isolated corner of the country were no less extraordinary than the countless schemes that failed. For much of the last hundred years the recurrent dreams of desalting the waters of the Pacific Ocean were firmly in the latter group; always just beyond the horizon of viability. The barriers were generally technical, rather than political, and almost always associated with the dual challenge of cost and energy intensity. Kennedy's dream of abundant water provided by high technology in the atomic age, of desalination as a panacea for scarcity, was never realised. Instead, seawater desalting has emerged as a contemporary technological fix to address the complex politics that beleaguer terrestrial water, which are insoluble without major political and social change.

The structural tensions that characterise water governance in the arid West stem from the particular historical development of the region. This history was inaugurated in 1926, when San Diego staked its claim to a portion of Colorado River water, a move that effectively aligned the strategic water interests of the County with the modernising agenda of state-led investment in mega infrastructures. The resulting infrastructural forms constitute vast and inert socio-technical assemblages of dams, canals, pipelines, treatment facilities, public institutions, private organisations, people, homes and lawns. The assembling of all of these elements, based on the logics of comprehensive riparian allocation and long-distance transfer of millions of mega litres a year, has sustained the metabolic circulation of water throughout vast areas of the desert southwest, and facilitated the rapid urbanisation of Southern California. Although the position of San Diego has been somewhat precarious –being peripheral in terms of the technical network, reliant on the operations of many other institutions and holding relatively insecure legal rights to water– the county and its cities have, since the mid-twentieth century, been successful in assembling an extraordinary infrastructural and institutional network to fuel economic growth and social development. Yet, this logic of water governance has locked San Diego into particular and peculiar development trajectories. The complex historical technological and social relations embedded in these vast assemblages, in a word, deeply influence contemporary governance debates.

Moreover, in aligning its water infrastructures so closely to the transfer model, San Diego bound its urban growth to a socio-technical assemblage that has historically been governed principally to serve agriculture. Put another way, the infrastructure systems that capture, store and transport water, the institutional arrangements, and the political and legal frameworks through which the waters of the West are governed together create conditions whereby water for large-scale irrigation in certain regions is prioritised. A Classical economist would say that problems of scarcity arise when water is not being directed towards its most efficient and profitable uses. This chapter, by contrast, argues that at the heart of this debate lies a disconnect between the inertia of modes of water circulation vis-á-vis capital circulation. The coastal urban growth of Southern California, which has become a core site of global capital accumulation, now outstrips the agricultural economies, which nevertheless maintain priority access to water under the transfer-oriented assemblage.

It is from these historical conditions that desalination emerges as a 'solution' that allows thirsty urban economies to secure vital supplies without having to engage with the broader political questions of allocation. In this sense, desalting technologies are being enrolled in broader processes of dis-assembling the centralised transfer paradigm. Ocean water desalting achieves a double movement in contemporary water governance. First, it essentially provides a way of increasing overall supply in the Colorado Basin and on the State Water Project, allowing urban regions to access secure supply, without entirely disassembling the socio-technical relations and systems that have historically been the catalyst for development in the West. Second, desalination has been enrolled as a powerful discursive (if not yet material) tool in the broad movement towards localised and diversified water supply portfolios. This shift towards localisation and diversification, although signalling a broad movement away from the transfer paradigm, does not represent total dis-assembling of its social and technical relations (upon which much of Southern California still rely), but rather a socio-technical reorientation and assembling of supplementary networks. Although most water districts in California are currently pursuing such strategies, the San Diego County Water Authority and its member agencies have certainly engaged the most aggressive tactics –tactics that appeared to be paying dividends even before the addition of desalted water. The extraordinary emergence of the desalination assemblage in Southern California is, therefore, symptomatic of the historical failures of water governance in the arid West.

~6~

At the nexus of scarcity and opportunity

Divergent water-energy politics and the crucible of desalination

> *"I have said that…if we could ever competitively, at a cheap rate, get fresh water from salt water, that it would be in the long-range interests of humanity which would really dwarf any other scientific accomplishments. I am hopeful that we will intensify our efforts in that area."*
>
> John F. Kennedy (1961b)

> *"How were we able to drink up the sea? Who gave us the sponge to wipe away the entire horizon? What did we do when we loosened the earth from its sun?"*
>
> Friedrich Nietzsche (1887)

Introduction

Through seawater desalination the problem of water availability becomes one of energy availability. At least in theory, through the application of desalting technologies a coastal society that has secure energy supplies can secure unlimited water. This is, of course, a reductionist formulation, but it illustrates a point: that in forming the desalination assemblage, water and energy are brought together in new and extraordinary ways, reconfiguring nexus interactions and interdependencies. Relative scarcities and abundances become muddied. The politics of energy become the politics of water, and water that of energy. This chapter provides a response to the de-political –or at least apolitical– character of discourses that have coalesced around both nexus thinking and desalination, identified in previous chapters (Allouche et al. 2015, Swyngedouw and Williams 2016, chapter three of this volume). It mobilises nexus concepts, and nexus language of tension, trade-off, maladaptation and synergy to structure a critical analysis of the contestations that have emerged around the deployment of desalting technologies in San Diego (Bazilian et al. 2011, Hussey and Pittock 2012, Scott et al. 2015). If water source options were a hand of cards, seawater desalination would be the ace of spades. The material politics of water are, because of the extraordinary characteristics of desalination, thrown into sharp relief. The energy intensity of the process, its cost and implications for water governance, and its effects on ecology, are balanced against the security of climate and drought-proof water supply, and the imperative to sustain growth. Different conceptualisations of water and energy futures are forced into counterpoint. Indeed, this is one of the principal reasons why desalination is such an illuminating topic of research. The desalination debate is, in a word, emblematic of divergent water politics.

Empirically, the chapter focusses on the various disputes surrounding the Carlsbad Desalination Plant. The chapter does not consider the planned binational development at Rosarito for two main reasons. Firstly, the developer, NSC Agua, has only just begun to embark on the permitting process, so the project's direction is not yet clear. Secondly, the project has not yet received any sustained or coordinated opposition –in part, because the groups that are most vocally opposed to desalination in California do not operate in Mexico. The story of the binational plant will be picked up again in the next chapter. The Claude 'Bud' Lewis Carlsbad Desalination Plant, named after a former mayor of the City of Carlsbad, began selling water to the San Diego County Water Authority in November 2015, more than 15 years after the project's conception. It is perhaps not surprising that the project took time to develop. This is, after all, the largest desalting facility in the Western Hemisphere (although still smaller than those in Israel and Australia) and the first large project on the West Coast. Although the technology is well understood and has been rolled out in other parts of the world, in California there was little precedent for a large desalting plant in terms of permitting process, deal structure or engagement by civil society. In many ways, this is a flagship facility for California. “Only the entire future of desal is riding on this project,” jokes Ron Davis, the former executive director of CalDesal, a desalination advocacy group based in Sacramento (quoted in Rogers 2014). Notwithstanding, the ‘long and winding road’ to the project’s completion –as put by one participant– was beleaguered by lawsuits and backlash from environmentalist groups, disputes between the project developer and permitting agencies, and struggles to secure municipal buyers to sign long term purchase contracts. In the decade leading up to construction no fewer than 14 separate legal challenges were brought against Poseidon and the San Diego County Water Authority as attempts to stop the project at various permitting hurdles (Garrett 2014). Indeed, the Carlsbad plant is possibly the most politically contested single desalination project in the history of the industry.

The chapter proceeds in two parts. The first considers the many disputes that have emerged around the desalination ‘solution’ in San Diego. These are structured into three core concerns: the implications of desalination for energy and greenhouse gas emissions; the socio-economic risks associated with the high cost of purifying ocean water; and the environmental politics of intake and outfall effects on marine ecology (Cooley and Ajami 2012, Cooley et al. 2013, Cooley and Heberger 2013). The second part interrogates the broader context in which these disputes over desalination have played out. It argues that desalination has become a crucible in which divergent visions of environmental and resource futures are forced into opposition. Through this two-part structure, the chapter develops a threefold argument. Firstly, at the heart of the contestations over the Carlsbad desalination plant, which are often crudely understood as binary tensions between ‘pro desal’ and ‘anti desal’ interests, lie profoundly different understandings of relative water and energy scarcities in Southern California. For supporters of the Carlsbad project, desalination is a necessary part of building a resilient water supply system in the face of climate change, drought and precarious imports, and the associated costs are an unavoidable price to pay for such supply reliability. By contrast, those who have criticised the Carlsbad plant (and other plans for seawater desalination), have argued that the ecological costs –including energy intensity and GHG emissions– as well as the financial and social costs of desalination are too great, given the potential for alternative water management strategies. Secondly, and related to the first argument, the divergent environmental politics that are brought into contestation in the desalination crucible represent divergent normative visions about how water and energy should be coupled. At stake, here, it is argued, is the future form of the water-energy nexus in Southern California. Finally, it is argued that while those who have contested desalination present a somewhat progressive vision of water-energy futures, these visions are neither radical nor emancipatory, in that they are broadly consistent with the techno-managerial, efficiency-oriented notions of the water-energy nexus discussed in chapter three. The unavoidable question is, then; does the desalination debate in Southern California matter politically, and if so, what is the political work –so to speak– that is being done?

Contesting desalination

The Carlsbad project, which is unprecedented in a number of respects, provides a particularly interesting study. Despite recurring interest in ocean water purification in California since the 1950s, Carlsbad is the first large desalination plant for municipal supply in the state. Although government agencies are beginning to set out a decision making framework, unlike thermoelectric power plant developments, for example, for which there is a single permitting process administered by the California Energy Commission, there is still no set regulatory pathway for desalination projects. To develop the Carlsbad plant, then, Poseidon (the developer) and the San Diego County Water Authority (the off-taker) had to run the 'regulatory gauntlet' (Garrett 2014). Poseidon produced over twenty major reports and plans for the five key state and regional agencies[4] that oversaw the permitting process (SDCWA 2016c).

The organised opposition to seawater desalination in California, and particularly of Poseidon's Carlsbad and Huntington Beach projects, began in the early 2000s with the establishment of a state-wide Desalination Task Force. At the time there were over twenty proposed facilities in the state, some public, some private (Cooley et al. 2006). The Californian government knew very little about desalination from a regulatory perspective, so the Department of Water Resources set up the 27-member task force, consisting of experts representing various interests, to assess its viability as an alternative water source. The group's findings and 29 key recommendations (Department of Water Resources 2003), although far from conclusive, really raised more questions than provided answers. The concerns highlighted in this short document, particularly around energy intensity, marine life impingement and entrainment, cost and financing, and public-private water governance, prefigured many of the debates that surfaced later in San Diego. Indeed, the task force became in incubator for anti-desalination advocacy raising the issue amongst environmentalist groups, who would perhaps have otherwise been slower to react, and establishing a network of informed and influential organisations.

Without much experience of large desalination developments, civil society organisations in the United States more generally were, until the Carlsbad project, fairly disengaged. For instance, the Tampa Bay plant in Florida, the country's erstwhile largest desalter, received little scrutiny, except concerning its particular financial and technical failings (of which there were many). The only organised opposition to the plant came from a single-issue local community group called *Save our Bays, Air and Canals*, who were narrowly

[4] The main regulatory agencies involved with Carlsbad were the City of Carlsbad, Carlsbad Redevelopment Agency, California Coastal Commission, California State Lands Commission, and the San Diego Regional Water Quality Control Board

Organisation	Details	Key issues Energy/ GHGs	Intake/ outfall	Cost	Water gov.	Env. justice
National						
Audubon Society	Conservationist group, focus on birds	X	X			
Food and Water Watch	National advocacy group for healthy food and clean water	X	X	X	X	X
Natural Resources Defence Council	National environmental group with 2 million members	X	X			
Sierra Club	USA's largest environmental and conservationist organisation with 2.4 million members	X	X	X		
Surfrider Foundation	Established in California –now a national network for coastal protection	X	X	X	X	
State						
California Coastkeeper Alliance	Represents 12 local Waterkeeper programmes in California	X	X	X	X	
Citizens For Responsible Desalination	Formed to oppose Poseidon's development in Huntington Beach, Orange County		X	X	X	
Desal Alternatives	Volunteer group that have successfully fought a planned project for the City of Santa Cruz	X	X	X		
Desalination Response Group	Formed from the California Desalination Task Force. Organises and advocates against desalination throughout the state	X	X	X	X	X
Environment Now	Southern California conservation		X			
Environmental Justice Coalition for Water	Sacramento-based coalition for water democracy	X			X	X
Heal the Bay	Los Angeles-based, coastal conservation focus	X	X	X		
Pacific Institute	Have not opposed desalination, but are critical	X	X	X	X	
San Diego Bay Council						
Audubon San Diego	San Diego chapter	X	X			
Coastal Environmental Rights Foundation	Environment focussed law group	X	X	X	X	
Coastkeeper San Diego	San Diego chapter –also in collaboration with Orange County chapter	X	X	X	X	
Environmental Health Coalition	Environmental and social justice organisation for San Diego/ Tijuana	X				X
Sierra Club San Diego	San Diego chapter	X	X	X	X	
Surfrider Foundation San Diego	San Diego chapter –also in collaboration with South OC and Long Beach	X	X	X	X	

Table 6.1: Civil society organisations actively involved in contesting the development of desalination in Southern California.

concerned with the effects of saline brine discharge (Stein 2005). By contrast, in California, where there is a large and vocal environmental movement, the desalination 'solution' has been disputed by a network of coordinated organisations, who have fought developments on multiple issues that go beyond NIMBYism (table 6.1). Both proponents and opponents of desalination have focussed their attentions on the Carlsbad plant because, in many respects, it sets a precedent for the rest of the state. In San Diego, opposition to the Carlsbad project has been coordinated by a group of environmental organisations called the Bay Council. The Bay Council –which includes the local chapters of some nationally and internationally known groups like Sierra Club, Surfrider and Coastkeeper– meet regularly and direct their individual resources and efforts in coordination with each other. Surfrider, Coastkeeper and the Coastal Environmental Rights Foundation led the efforts against Poseidon and the SDCWA, and were responsible for much of the litigation. These groups have been supported by their state and national counterparts, and by organisations like the Desalination Response Group (which was established by some of the original task force members) and Citizens for Responsible Desalination, that have formed specifically around the desalination issue.

The organisations detailed in Table 6.1 are by no means uniform in their views on water: they represent different groups with different political priorities, and they operate on a variety of geographical scales, with varied remits and influence. Nevertheless, a number of recurring concerns are consistently put forward as core issues by groups sceptical of, or opposed to desalination in its current guise. For instance, a joint policy brief published by eight of the above groups in response to increased interest in desalination as a drought coping strategy for California concisely summarises the environmentalist demur. The brief, entitled 'Proceed with Caution,' warns that seawater desalination is "typically the most energy-intensive water supply option" and is therefore associated with "significant greenhouse gas emissions;" that the technology is "very expensive" and could pose "financial risk for ratepayers and taxpayers;" and that the process can have "significant impacts on the marine environment" (NRDC et al. 2014, 2-3). This position was summarised well by one participant:

> "*We're not dead against desal, but we believe that it has a time and place, and that time and place is only after every other resource has been looked at significantly… We're wasteful of water, certainly, and you can go a long way before we start creating additional sources… You can put that in very simple terms: 'reduce, re-use, recycle.' Use less, capture when we have it, and recycle it. Then you work your way down the list, and probably last on that list would be desalination… We don't think the Carlsbad plant is necessary at all because we haven't even come close to reaching our conservation and recycling potential."* (Director of a local environmental group, interview 11/09/2014)

These interrelated concerns about the viability of seawater desalination as a drought-proof, reliable local water supply can be categorised under three headings: energy, cost and marine ecology. The first generation of large RO desalination plants (the developments in Florida and Australia are good examples) were primarily contested by environmental groups on the issue of saline brine discharge. In California, by contrast, the focus has been broader and more systemic. Indeed, the pollution issue has become somewhat peripheral to the debate, as one participant explains:

> *"For years everyone tried to push the environmentalists to focus on the brine discharge as our primary issue. Whereas we were looking at three, what we considered to be bigger issues for California: the energy consumption, the public ownership issue, and the impingement and entrainment issue."* (Co-founder of a local environmental group, interview 03/10/2014)

The disputes around these core concerns are examined respectively in detail in a three-part report series published by the environmental think tank, the Pacific Institute, called 'Key issues in seawater desalination in California' (Cooley and Ajami 2012, Cooley et al. 2013, Cooley and

Heberger 2013). The first part of this chapter teases apart how each became mobilised in the contested visions for San Diego's water-energy future as played out in the development in Carlsbad.

Desalination and the water-energy concatenation

In Southern California, water and energy are deeply bound together. In the previous chapter I argued that water and energy should not be conceptualised as separate material flows, but as co-produced in the historical development of the arid West and as co-producing new socio-material forms. A widely cited report by the California Energy Commission –indeed, one of the first pieces of research to highlight the importance of nexus thinking– found that the water sector accounts 19% of the state's electricity use, and that in Southern California, which relies on long distance transfers and alternative supplies like RO wastewater treatment, the energy intensity of water supply is approximately double that in Northern California (Klein 2005). For example, embedded energy in water delivered through the State Water Project is nearly ten times greater in the South than the North. In the San Francisco area, collection, treatment and distribution of SWP water embodies around 440 kWh/ML, compared to 520 kWh/ML in the Central Valley, and 4,000 kWh/ML in coastal Southern California (DWR 2016). For over a decade, civil society groups have been calling for government to investigate seriously the connections between water and energy in California, and to address the implications of the water-energy nexus for sustainability and development (NRDC 2004). These groups, broadly, argue that the relative abundance of cheap, state-subsidised water in the desert Southwest has encouraged wasteful use practices, and moreover, does not reflect the negative energy and GHG externalities of the water transfer system.

In terms of governing the nexus, the Californian government lacks a coherent policy framework to address the increasing tensions between water and energy sectors. Regulation is being introduced piecemeal by various agencies. At state-level, the California Public Utilities

Commission, which regulates privately owned utility companies and has a special nexus proceeding (CPUC 2016a); the California Energy Commission, which has a nexus technologies research programme (CEC 2016); the Department of Water Resources (DWR 2016); and the Climate Action Team (WET-CAT 2016) are making the most significant efforts in this area. From a regulatory perspective, certainly the greatest challenge is to foster cooperation and shared decision making between sectors that have historically communicated little, have very different institutional structures, and operate using very different indicators and data.

> *"Part of it is creating a method that quantifies the water-energy nexus, and to do so at a level that is both meaningful and administrable. There are very different government structures for water and energy, so getting the sectors to talk to each other is challenging, even within the CPUC… We don't seek to change the system of water or energy government, we're just trying to make sure we address the water-energy nexus."* (Commissioner, interview 30/07/2015)

Despite an overall lack of coordinated vision, the water-energy nexus is now a key policy area for a number of state-level government departments in Sacramento, as well as for regional government. One of the core strategies outlined in the 2016 update of the California Water Action Plan state 'roadmap' is to "increase water sector energy efficiency and greenhouse gas reduction capacity" (NRA 2016, 6).

In San Diego, where utilities have historically relied on long distance imports, the connections between water and energy are stark. The connected challenges posed for the region's development have, of course, long been recognised. For instance, a planning report from 1980 observed that "both water and energy are critical resources to the San Diego region, neither of which are locally abundant," and that "clear cut acceptable solutions to meet increasing demands are not at hand" (San Diego Water Utilities 1980, iii). With little local surface or groundwater supply, and sitting at the end of all the distribution pipelines, San Diego has the highest levels of embedded energy in its water supply in the state –around 2,500 kWh/ML for

Colorado River water and 4,000 kWh/ML for State Project water (Powers 2007). Nexus challenges are starting to rise in the priorities of local government and utilities. The San Diego County Water Authority and the San Diego Gas and Electric Company are, for instance, piloting collaborative approaches to fostering water-energy efficiencies (CPUC 2016a). And the SDCWA recently published its Climate Action Plan, a voluntary strategy to bring the Water Authority in line with the state's emissions targets by 2020 (SDCWA 2015).

Given the increasing traction of nexus thinking in environment and resource management at both state and local levels, the assembling of seawater desalination as a 'solution' to San Diego's water challenges is certainly contradictory. The significant trend in nexus thinking, identified in chapter three, where alternative sources of energy (biofuels, unconventional gas, low grade oil) and alternative sources of water (desalination, recycling, long distance transfer), which are developed to mitigate inadequate or unreliable supply, actually intensify nexus interactions and increase tensions between sectors, posing new governance challenges (King et al. 2008, Williams et al. 2014). These trade-offs, where the production of new water requires more energy and the production of new energy requires more water, I argue, fuel a concatenation of growth between water and energy. One participant called this relationship the 'water-energy cycle' (Director of a local environmental group, interview 11/09/2014).

Desalination is emblematic of the tension between the inconsistent imperatives of, on the one hand, securing reliable water supply, and on the other, of mitigating trade-offs between water and energy. The production of freshwater from seawater by reverse osmosis is highly energy intense. The energy required for seawater desalination is around double that for brackish water desalting and potable wastewater recycling, depending site-specific conditions, using the same basic RO process (Al-Karaghouli and Kazmerski 2013). Technological changes, particularly in the development of highly efficient energy recovery devices (image 6.1) and improvements in membrane performance, have reduced the energy requirements of the RO process dramatically.

Since 1990, when RO was beginning to emerge as the industry standard process, energy consumption by plants has reduced by about half (Elimelech and Phillip 2011). These efficiency improvements are, however, unlikely to continue at the same rate.

> *"The first RO system installed was in Jeddah, Saudi Arabia –it was about 10 kWhrs per cubic meter. Carlsbad will probably be something like 3.5 kWhrs. That's worst to best case. You can almost see the step change on the graphs at about 2000. There has been a little improvement since… Frankly, there'll be some incremental improvements, but it'll be incremental."* (Industry expert, interview 08/07/2015)

The major attainable improvements to RO desalination have, in a word, already been achieved. It would require, therefore, a technological step-change to bring seawater desalination down to levels of energy intensity comparable to other alternative sources of water. Even in San Diego, which has very little local supply and where imported water embodies very high levels of energy,

Image 6.1: Energy recovery devices reduce energy consumption at the Carlsbad Desalination Plant by 45%. *Source*: Joe Williams (2015)

seawater desalination still carries the largest footprint by a significant margin. Transporting water 500 km from the Colorado River via Los Angeles uses less than 45%, and 800 km from the Bay Area through the State Water Project less than 70% of the energy required to desalt the Pacific Ocean (see figure 6.1). This led a major report by the California Energy Commission to conclude that of all options currently available to California, seawater desalination is "the most environmentally burdensome water supply alternative" (Horvath and Stokes 2011, iii). In addition to the environmental implications explored below, the energy requirements of reverse osmosis have also raised concerns about the increasing vulnerability to energy disruptions and price fluctuations linked to the deployment of desalination (Cooley and Heberger 2013). Through technologies like desalination, that deepen nexus interactions, water and energy scarcities become inextricably connected.

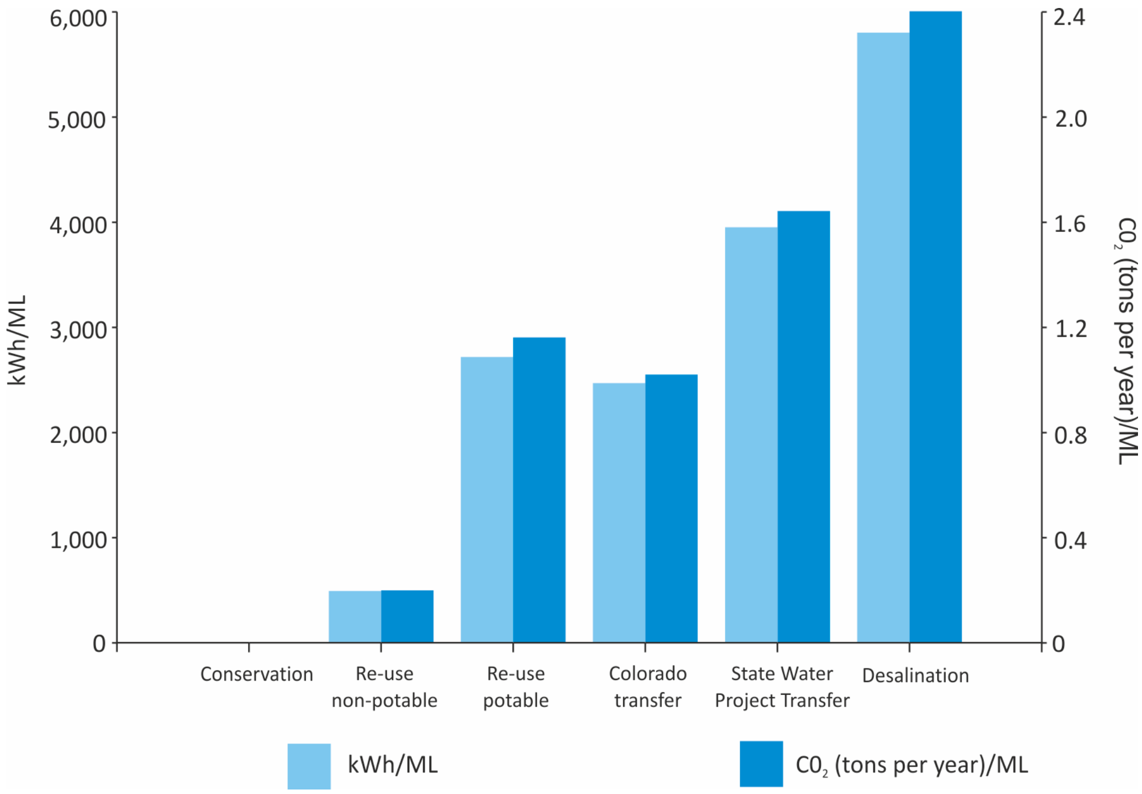


Figure 6.1: Embedded energy and CO_2 emissions associated with San Diego's water source options. *Source*: data adapted from Powers (2007)

Water for growth? The water-energy-climate nexus

The divergent visions for Southern California's water-energy future and contradictory notions of relative scarcities revealed in the desalination debate, are further complicated by a context of regulatory confusion. There are currently no laws in California requiring water companies or utilities to fulfil particular energy efficiency, source or use criteria. In other words, a desalination plant may be built without the developer having to meet any requirements in terms of energy performance. The water sector is, moreover, exempt from the state's greenhouse gas emissions reduction targets. The 2006 Global Warming Solutions Act, which set emissions reductions targets to 1990s levels by 2020, focusses on the energy and transport sectors, and has no specific requirements for embedded energy (California State Assembly 2006). New targets may, however, affect the water sector directly:

> *"In California, under the targets set, water utilities were not required to reduce their GHG intensity. But looking toward 2050 targets, there's interest in including the water sector in those requirements. Some of that will be made by the energy sectors themselves, in cleaner sources. In general, desal moves towards greater GHG intensity."*
> (Water Research Director, interview 29/12/2014)

As such, the lack of a clear regulatory pathway for desalination projects has contributed to a fuzzy and complicated permitting process. Without a state-wide framework, the energy issue is currently regulated by the California Coastal Commission, which oversees the use of land and water in the coastal zone, using the proxy of greenhouse gas emissions. Under the Coastal Commission's mandate it may stipulate certain energy requirements for desalination plant developments by asserting the link between GHG emissions, global climate change and sea level rise, which carries implications for its regulatory zone. The Commission therefore requires developers to submit an Energy Minimization and Greenhouse Gas Reduction Plan as part of the permitting process. Notwithstanding the obvious oversights of such a framework for comprehensively addressing the water-energy nexus, for instance concerning exposure to energy price fluctuations and other cost related vulnerabilities, the greenhouse gas issue became a key point of contestation of the Carlsbad project.

The debate so far has really condensed around the issue of growth. “The overall energy implications of a seawater desalination project,” argue Cooley and Heberger (2013, 1) “will depend on whether the water produced replaces an existing water supply or provides a new source of water for growth and development.” The project developer, Poseidon, have placed a lot of emphasis on the plant’s green credentials. Calrsbad is, they stress, the most energy efficient desalting plant ever built because of the Pelton Wheel energy recovery devices and the patented pump configuration developed by the plant’s designers and operators, IDE. Poseidon claim, moreover, that the plant is carbon neutral. At face value, this is an extraordinary claim to make, given the energy intensity of seawater desalination compared to other water source options. Indeed, the project’s website asserts that it is the “first water infrastructure project in California to have a net carbon of zero” (Carlsbad Desalination Project 2016).

The claim, outlined in the Energy Minimization and Greenhouse Gas Reduction Plan (Poseidon 2008, revised from the 2007 plan), which was approved by the Coastal Commission in August 2008, rests on the assumption that the water produced by the desalting plant will displace water that would otherwise have been imported through the State Water Project. The plan measures the overall indirect GHG emissions of the plant as the difference between emissions associated with the total electricity consumption of the plant and emissions associated with imported supply (see table 6.2). The 6,000 kWh required to desalt a mega litre of ocean water at Carlsbad is effectively mitigated by removing the need to import water from Northern California at 4,200 kWh/ML. Poseidon therefore calculates that the total energy footprint of water manufactured in Carlsbad is only 1,800 kWh/ML. This one-for-one replacement of supply accounts for around two thirds of the CO_2 emissions mitigation for the plant. The remaining emissions are then off-set by a variety of mitigation strategies, including on-site solar energy production, reforestation programmes, and sequestration through wetlands conservation and restoration projects near the desalination plant site on the Agua Hedionda Lagoon. Any outstanding emissions identified in the annual emissions report submitted to the Coastal Commission will then be off-set through carbon credits. This, according to Poseidon, "represents an unprecedented voluntary commitment to account for and bring to zero indirect GHG emissions" (MacLaggan 2008, cited in California Coastal Commission 2008, 2).

Identification of GHG amount emitted		
Source	**Total annual power use (MWh/year)**	**Total annual emissions (metric tons CO_2/year)**
Project baseline design	274,400	97,165
On-site and project-related reduction of GHG emissions		
Reduction due to high-efficiency design	28,244	10,001
Green building design	300 to 500	106 to 177
On-site solar power generation	0 to 777	0 to 275
Recovery of CO_2	NA	2,100
Reducing energy needs for water recycling	1,950	690
Reduced water importation	190,641	67,506
Sequestration in coastal wetlands	NA	18 to 188
Sub-total	NA	**80,421 to 80,937**
	Net GHG emissions	**16,422 to 16,288**
Additional off-site reductions of GHG emissions		
Sequestration through reforestation	NA	245
Potential renewable energy partnerships	0 to 2,260	0 to 800
Sub-total	NA	245 to 1,045
Off-set and REC purchases	**16,499 to 15,067**	
Net GHG emissions	**0**	

Table 6.2: GHG emissions reduction and mitigation strategy for the Carlsbad Desalination Plant.
Source: Poseidon (2008, 20-21)

The projected climate impact and energy footprint of the desalination plant is premised on two assumptions. First, that the plant is producing replacement water for San Diego, rather than additional water. Second, that it replaces water imported through the State Water Project, rather than the less energy intense Colorado River transfer, both of which are delivered to San Diego by the same wholesaler, the Metropolitan Water District of Southern California. The additional-versus-replacement water issue became a key point of contention between Poseidon and the Bay Council. Opponents of the project contended that there could be no clear link drawn between the addition of desalted water and removal of imported water from San Diego's supply. It is more likely, the Bay Council argue, that desalination will increase overall supply, that the supply security it guarantees will foster further development of the region, and that its viability as an alternative supply should therefore be assessed on the grounds of its true energy intensity. To critics, Poseidon's tactics in promoting the project's climate credentials, and their involvement with the Agua Hedionda Lagoon Foundation, amount to dishonest political manoeuvring aimed at gathering support.

> *"As we got educated and started seeing all these problems, they [Poseidon] saw things going south with the environmental community. So what did they do? They went to the Agua Hedionda Lagoon Foundation, they became the biggest supporter of that group, they put their people in positions of power. And before you knew it they'd green-washed the shit out of their project."* (Co-Founder of a local environmental group, interview 03/10/2014)

To the project's supporters such strategies are part and parcel of large infrastructural developments.

> *"I think that any large infrastructure project requires political support to get it done. Poseidon is very adept at garnering political support, and that was very helpful in moving this project through, particularly the regulatory requirements and the hearings and approvals. I wouldn't call it a negative, I give them a lot of credit to be able to show the regulators that there was strong support for this project."* (Water Resources Director, interview 24/06/2015)

In December of 2009 the Bay Council environmental groups, led by Surfrider, Coastkeeper and the Coastal Environmental Rights Foundation, appealed against the Coastal Development Permit issued by the Coastal Commission. The permit revocation request, the Coastal Commission staff recommendation, and communications are all now in the public sphere (California Coastal

Commission 2010). The contention of the environmental groups was that Poseidon intentionally misled the Coastal Commission in its commitment to developing a carbon neutral facility. Three elements needed to be satisfied for the Coastal Commission to revoke the permit: 1) that Poseidon provided false or misleading information in the original application; 2) that this was done intentionally to mislead; and 3) that this would have affected the Commission's decision to approve the project. The dispute centred on an agreement made in 2005 with the Metropolitan Water District, who were offering a subsidy of $250 per acre-foot purchased from Poseidon under its Seawater Desalination Program –a subsidy on which Poseidon had been relying before the Water Purchase Agreement with the SDCWA in 2012. The agreement had a clause protecting MWD's imports, stipulating that the addition of desalted water would not affect receipt of its full State Water Project entitlement. In other words, MWD was intending to continue importing its full entitlement, regardless of the development at Carlsbad. Poseidon did not disclose this agreement in the permit application. The Coastal Commission, upon investigating the accusation by the environmental consortium identified two of the three criteria. It found that Poseidon had deliberately withheld information and intentionally misled the Commission in order to claim that the Carlsbad facility would be net carbon neutral. It concluded, however, that due to overwhelming political support for the project at both the state level and from local municipalities "the Commission's decision would not have changed based on Poseidon providing complete or accurate information about the project's effects on SWP-related emissions" (California Coastal Commission 2010, 121). As one participant put it, "the political fix was already in." Despite retaining the permit, however, the GHG dispute has not been fully resolved. Now that the plant is operational, Poseidon is under pressure from the Coastal Commission to demonstrate rigorous carbon accounting (Rivard 2016).

In charting this dispute over water and carbon accounting, my aim is not simply to outline the choreographies of contestation over the development of one desalting plant, but to point to a deeper dispute. The extraordinary material and political factors that are brought into play in the desalination assemblage are such that the Carlsbad project became the focus of broader debates on environmental governance and water-energy futures. Indeed, the desalination debate has raised the water-energy nexus in the priorities of California's environmental groups, as well as government and industry. NGOs and civil society organisations like the California Coastkeeper, the Natural Resource Defence Council and the Pacific Institute are beginning to put pressure on governments to address the tensions and trade-offs between water and energy. In 2014 the San Diego Coastkeeper sued the County Water Authority over the contents and strategy of the SDCWA Climate Action Plan (SDCWA 2015). One of Coastkeeper's main contentions was that the Water Authority's inclusion of a planned large desalination plant in Camp Pendleton in its long term supply plan, which sets out a water strategy until 2035 (SDCWA 2013), was contrary to the goal of reducing GHG emissions associated with water supply (San Diego Coastkeeper 2015). Given that the SDCWA is currently under no legal obligation to consider energy intensity or GHG emissions in its water strategies, the Superior Court ruled against Coastkeeper's claim in 2015. Nevertheless, the conflicts that have surrounded the development of desalination in San Diego –particularly in the contradictory imperatives towards increased water supply reliability through alternative sources and climate change mitigation– may well be a bellwether of things to come.

Cost and 'demand risk'

Deeply related to the energy issue is that of the cost of desalting seawater. The unit cost of producing water from a desalination facility is, of course, highly variable, and depends on local context, site-specific factors, source of energy, and size of plant (Cooley and Ajami 2012). The cost of energy typically accounts for 25% to 50% of the total price of desalted water. This may vary due to the technology used, possible benefits gained from co-location with power facilities, and price of energy. For instance, if the Los Angeles Department of Water and Power (LADWP) were to build a desalination plant, the department –because it supplies both water and power–

could sell itself electricity for 20% to 30% cheaper than the electricity wholesale rate (Director of Water Resources, interview 16/07/2015). For the Carlsbad plant, which purchases its electricity off the grid from the San Diego Gas and Electric Company but is nevertheless highly efficient, the energy component of the water price is 25% (Water Purchase Agreement 2012). Moreover, under the Water Purchase Agreement between Poseidon and the SDCWA, Poseidon must fulfil maximum energy use criteria or bear the financial burden. The SDCWA (the purchaser), however, takes on all the risk associated with electricity price rises. This means that as energy prices increase, so does the price of desalted water for rate payers. The water produced at Carlsbad is the most expensive source available to San Diego by a significant margin. The Water Authority pays Poseidon between $1,728 and $1,919 per mega litre, depending on how much water it orders (Water Resources Director, personal communication 24/06/2015), compared to $590 for untreated water imported from Metropolitan (SDCWA 2015, annual report). In part, the high price of water from Carlsbad can be attributed to the drawn-out permitting process and the financial deal structure between Poseidon, its financiers and the SDCWA. The public ownership and financial issues are explored in detail, however, in the next chapter. This chapter is concerned more with two additional aspects of the desalination cost debate: those of demand risk and price burden.

For municipal-level facilities (i.e. plants built as a component of water supply for urban populations, rather than to fulfil specific functions), there is a tendency in the desalting industry towards building single large projects instead of multiple smaller plants. In part, this allows developers to take advantage of economies of scale in plant design (Kim et al. 2009). Reducing the unit cost of water by increasing capacity, however, may represent an economic trade-off when it comes to utilising the additional supply generated. Given the cost of producing desalted water compared to other sources there is a danger with such flagship projects that, even after construction, the economics of desalination don't pencil out. This is known as demand risk:

> *"That's the idea that the demand for the desalinated water is not there –there are still cheaper alternatives, whether it be conservation and efficiency or cheaper supplies. That even after these plants have been built, even after we invested the capital cost to build them, that operating them still doesn't make economic sense, and then the plants are shut down. Then they become a fairly expensive insurance policy –and we have to be thoughtful and determine if that was a wise investment or if there were other ways we could have got that same reliability."* (Water Research Director, interview 29/12/2014)

Cases of demand risk are manifest in the short history of large scale seawater desalination. Such examples are particularly evident where desalination has been integrated into urban water supply as a quick fix for drought and contested traditional water sources. Australia, for instance, is often cited as exemplifying the cost risks of desalination. During the Millennium Drought, which lasted for over a decade (1997 to 2010) and affected much of the continent –particularly the populous East Coast and the Murray-Darling Basin, the country's breadbasket– Australia's major cities (Sydney, Brisbane, Melbourne, Adelaide and Perth) all invested in large seawater desalting plants as an emergency response to falling reservoir levels (Heberger 2012). The plant constructed for Melbourne, at the time the largest RO facility in the world, which can supply 40% of the city's demand, was completed in 2011, shortly after the drought broke (Porter et al. 2014). Since the end of the drought, four of the six major plants have been idle, or operated at minimum capacity. Servicing the debt on these plants and fulfilling the contract conditions with private developers now costs Sydney's water rate payers $535 million (Australian dollars) a year (Barlass 2015), and Melbourne's, $600 a year (Ferguson 2014). In other words, even accounting for the huge costs of these facilities, it is more cost effective to keep them idle as a drought insurance policy than expend the energy and other associated costs to operate them as a component of urban water supply.

The difficulties of managing demand risk are not limited to the Australian case. The Tampa Bay Plant in Florida, which was mired for many years with construction and financial difficulties, is now operated significantly below capacity for similar reasons (Cooley and Gleick 2013). In California, the city of Santa Barbara (150km northwest of Los Angeles) built a medium sized desalter (25,000 m^3/day) during the 1987-1992 drought. Again, the facility has never been operated because the drought ended, reservoir storage levels recovered and the city went back to relying on MWD imports shortly before its construction was complete. Despite never having distributed desalted seawater to its rate payers, in 2015 the city commissioned IDE (the Israeli company that designed and operates the Carlsbad plant) to renovate the facility at a cost of $55 million (City of Santa Barbara 2016). The structure of the financial arrangement between the SDCWA and Poseidon is, however, such that the Carlsbad plant is unlikely to be mothballed. The Water Authority is obliged to pay for 60,000 ML/year, regardless of whether the water is actually needed, and may purchase a further 10,000 ML/year at a reduced rate. In this sense, desalted water will become part of San Diego's baseload, rather than variable supply. Nevertheless, the concern lies in whether it was necessary for the Water Authority to raise water rates for the duration of the 30-year contract before fully exploring less costly alternatives.

Related to the problem of demand risk, some opponents of desalination in California, albeit not many, have raised issues of environmental justice. Who pays for desalination? Do any groups bear a disproportionate burden? Whose interests are best served by increasing water supply at great cost? These are questions that remain on the fringes of the debate in California, but are nevertheless present. The environmental justice position was well summarised by one participant.

> *"We've found this issue is not just about water. It's clearly about politics. For communities that have the least capacity and pay both in pollution and price for water, what's the benefit going to be of this very expensive water? It looks like the benefit is going to be for new development along the coast, including in places where they don't have access to imported water, and that desal has a very clear link between growth and development, and is not affordable to people who actually need water. We're essentially subsidising the rich, putting an improper burden on the poor, and creating*

profit for a private company. The public agencies that serve, including SDCWA should be paying attention to those issues. When you think of California you think of the land of abundance, but there's also the other side, where there's Third World conditions for drinking water." (Executive Director of an environmental group, interview 05/11/2014)

This argument has been expounded most notably by the Desalination Response Group, a small organisation that was formed to consolidate opposition to desalination in California, and to support, coordinate and educate local civil and environmental groups. Their website argues that desalination in its current configuration creates the condition whereby "water is sold to the highest bidder rather than allocated to the areas where it is most needed" (Desal Response Group 2016). In general, however, the politics of desalination in California are not radical or emancipatory. The groups that have been most vocal in opposing developments along the coast have focussed on the cost impacts on the average ratepayer, rather than challenging the role of water pricing in reinforcing socio-ecological inequalities and marginalisation. Whereas the energy and GHG argument against desalination has primarily been expressed as one of resource efficiency (i.e. that less energy intense sources of water should be utilised before desalination), the cost argument is similarly one of economic efficiency (i.e. that less costly supplies should be given priority). Notwithstanding the marginal presence of more radical perspectives (like those expressed in the interview excerpt above), the arguments against the development of desalination in terms of energy and cost have largely not sought to challenge the underlying logics of water governance in Southern California, but rather to integrate the ecological and financial trade-offs of the water system more fully into the decision-making process.

Fishy politics

The final issue raised by critics of desalination concerns the impingement and entrainment of fish, larvae and other marine life in seawater intakes. The potential detrimental effects of saline brine discharge, which was for example, one of the major political issues surrounding the

Australian desalination developments, have been peripheral to the debate in California. From a regulatory perspective, a major report commissioned by the State Water Resources Control Board concluded that, if properly managed, "concentrate can be disposed of with minimal environmental effects" (Jenkins et al. 2012, ii). And environmental groups have not highlighted discharge as a significant concern. Instead, disputes over intakes have taken precedence. These disagreements have been discombobulated by a changing regulatory process and disagreement about technological feasibility.

Central to this debate has been the curious political enrolment of aquatic life by both proponents and opponents of desalination. Proponents have argued, on the one hand, that developing Southern California's desalting capacity offers a viable strategy to reduce reliance on imports from Northern California, and concomitantly to protect the habitat of the Delta Smelt and Chinook Salmon in the Sacramento–San Joaquin Delta. The fate of the Delta Smelt –a protected species– has long been the Achilles Heel of the State Water Project. The habitat alterations caused by the construction of mega-infrastructures for water capture, storage and conveyance, and the removal of vast volumes of water from the Delta every year have driven down smelt populations (Bennett 2005). In response to fierce environmental campaigning and litigation, the state government instituted a programme in 2001 called the Environmental Water Account to resolve conflict between protecting delta habitat and securing water supply (Brown et al. 2009). This and other programmes have created a complex governance structure comprising a growing number of disparate actors that is ultimately squeezing allocation on the State Water Project (Norgaard et al. 2009). Desalination is thus presented as a fix to the problems that beleaguer State Water Project supply:

> *"Everybody said we're going to draw more on Northern California. Well along came the Delta Smelt and salmon, and court decisions were made that said 'you're not going to get as much as you thought.' Couple that in with dry conditions and concerns about climate change, and the writing's on the wall: we need to do more. We need to do more*

to diversity our supplies. We need to do more to create local supplies." (Vice President of a water company, interview 24/10/2014)

Through this strategic enrolment of non-human actants, the Delta Smelt is effectively used to bolster the case for desalination: Southern California should shun the stagnant politics of the North and look for opportunities in the West.

On the other hand, those groups concerned about the ecological impacts of drawing in seawater through open intakes have effectively mobilised the material agency of fish larvae and other small marine life to contest the permitting of desalination plants. The impingement and entrainment issue was one of the key points of dispute over the Carlsbad plant. The Bay Council groups again attempted to have the permit revoked on the grounds that Poseidon had not provided accurate or complete information on the marine life mortality effects of the facility (California Coastal Commission 2009). Furthermore, these disputes were played out in the context of significant uncertainty over the permitting process. The intricacies of the Carlsbad case are explored in more detail in the next chapter. Here, I highlight two pertinent points.

First, the model of co-locating large desalting facilities with existing coastal thermoelectric power plants in order to utilise existing intake and outfall infrastructure was propounded by Poseidon in California just as the law on open ocean water intakes was changed. Environmentalist groups had, for over a decade, campaigned against the use of once-through cooling technologies because of their harmful effect on marine life. In May 2010 the State Water Board adopted a policy to phase out once-through cooling for coastal power stations by 2017. Poseidon was able to secure permits for the Carlsbad plant before this law was introduced, although it is not currently clear how the plant will transition when the Encina power station is closed in 2017. Again, this is explored in detail in the next chapter.

Second, until 2015 there were no state-level permitting procedures or frameworks. Instead, each proposed project was assessed on a case-by-case basis. In May 2015 the State

Water Resources Control Board (SWRCB) implemented an extensive amendment to its Ocean Plan (SWRCB 2012, 2015). A response to regulatory confusing between various agencies involved in permitting, the desalination amendment is an attempt to "provide guidance and direction to regional boards" for plant intake and outfall standards (SWRCB Staff, interview 20/07/2015). Crucially, the amendment requires that projects must, wherever feasible, use subsurface intakes rather than open water intakes. In general, environmental groups have supported subsurface intakes because they eliminate marine mortality, but industry experts argue that these technologies raise the price of desalted water and are not feasible for large-scale plants. While the subsurface rule does not apply to facilities that were 80% complete when the amendment was adopted, which exemplifies the Carlsbad plant, this has become a major battle ground for Poseidon's other project in Huntington Beach, Orange County (ISTAD 2014). Again, these very specific and technocratic disputes are indicative of growing calls for a fuller and more integrated recognition of the ecological trade-offs of water supply systems.

On alternative visions

These contestations around the embedded energy, cost and ecological impacts of ocean water desalination in San Diego are playing out in the context of broad transitions in environmental and resource governance. Desalination, because it illustrates the extraordinary lengths societies will go to in order to secure the material flows through which they are constituted and sustained, cuts to the heart of debates about the form and relations of possible futures. The deeper questions at stake are, however, not immediately clear:

> *"The nature of the non-profit NGO community is that we are always running around putting out fires, so we're always reactive. We actually do an amazingly good job at engaging at that pace, but it's not the most effective… One of my frustrations is that*

we don't present our vision of the world very well; something that should be compelling to folks." (Former Director of a local environmental group, interview 19/09/2014)

The discussions on desalination have formed around a set of discursive antitheses that represent divergent notions of resource governance. Desalination, and the disputes that have emerged around the development of the Carlsbad, Camp Pendleton, Huntington Beach and Santa Barbara projects, sit at the apex of a deeper debate about the future of water supply reliability in Southern California, and the ways in which the trade-offs and shared goals between water and energy should be managed.

Water-energy concept sharing

The first of these antitheses has, broadly speaking, engendered a discursive convocation into two opposing visions on water security, sustainability and relative water and energy scarcities: as diversified supply portfolio on the one hand; and as loading order, or priority list on the other. Proponents of the first position argue that water security should be achieved by spreading the risk of shocks or supply reduction over many water sources. In other words, having a diverse portfolio means that the effects of reductions to one supply are cushioned by the reliability of others. This is exemplified by the San Diego County Water Authority's aggressive supply diversification strategy following the shock of the 1991/92 cuts by the Metropolitan Water District (SDCWA 2016d). By contrast, other groups (led by the Bay Council) have argued that the diversification paradigm encourages utilities, firstly, to focus on supply solutions rather than demand management and behaviour change, and secondly, to invest in expensive and ecologically unsound supplies before fully exhausting more viable options (California Coastkeeper 2016). Instead, these groups advocate the institution of a water 'loading order.'

The concept of a loading order was developed in energy sector in the early 2000s. Its implementation was a response to the dual pressures of: firstly, structural mismanagement of electricity that led to severe price increases and widespread power outages in 2001 –now known as the Californian energy crisis; and secondly, climate change and the imperative for increased renewable generation (CEC 2003). Adopted in the California Energy Action Plant (CEC et al. 2003, CEC and CPUC 2005, 2008) the loading order became the foundation of a significant restructuring of the state's energy sector. The premise is quite simple. All potential energy sources available to Californian companies and utilities are placed on a priority list, based on their comparative merits and drawbacks. Solar power is, for example, higher on the list than large-scale coal generation because it is consistent with the state's aim to enhance its renewable energy capacity. These various energy sources are then invested in and brought onto the grid in accordance with this 'loading order.' Particular priorities are: first, energy efficiency through the implementation of building and appliance standards; second, demand response, which includes new rate structures that encourage consumers to lower high peak demand; third, renewable energy, in particular from wind, solar and hydroelectric pump storage; and fourth, distributed generation by consumers, for example through home installed solar panels (CEC 2005). This paradigm shift in electricity production, combined with the aforementioned phasing out of coastal once-through cooling for thermoelectric generation, signals a movement away from the previously dominant energy regime of large base-loaded fossil fuel generation from coastal power plants. The political and material repercussions for the assembling of desalination as a new water source are explored in greater detail in the next chapter.

In an intriguing development of nexus thinking, California's environmental community, including the Bay Council, are almost unanimous in their call for a loading order in the water sector. The concept was originally put forward by the Coastkeeper Alliance, as a framework for the "prioritization of sustainable water supplies to ensure water infrastructure planning provides the most social and environmental benefits, while minimizing negative impacts to California's waterways" (California Coastkeeper 2016). This would involve, more or less, a direct transfer of policy from the energy sector to the water sector. Water source options would be ranked based on their ecological and socio-economic credentials, with investment being directed with priority to the most cost effective and environmentally sound. Southern Californians should, according to this vision, fully exhaust conservation potential before moving to more expensive and energy intense options. Seawater desalination, because of the social and ecological trade-offs it embodies, would be a last resort option in the loading order. By contrast, the utilisation of seawater desalination has been justified by the San Diego County Water Authority as representing one element of a diverse portfolio. (The motivations and drivers of supply diversification were explored in the previous chapter.) So, for proponents of a loading order, seawater desalination represents the most drastic and lowest priority water source option available to Southern California, whereas for those who argue for portfolio diversification, the capacity of desalting technologies to produce climate and rainfall-independent and local water makes it an invaluable part of prudent water governance.

These two concepts, which have been brought into direct conflict in the development of desalination, represent divergent visions of water governance, and contradictory notions of relative water and energy scarcities. Proponents of each have been equally adamant in their criticism of the other. The diversification argument has been challenged from a range of perspectives:

> *"They sort of make an analogy to financial markets –they say there's lots of alternatives, and we're doing all of it because it's diversifying our portfolio. I'm not convinced that a financial portfolio is a really good analogy for a water portfolio, but even if it was, that isn't exactly how diversification in a financial portfolio really works. You don't buy junk because it's different."* (Environmental Activist, interview 05/11/2014)

> *"Certainly, we want a diverse portfolio and to balance all of these reliability issues…but the notion that we're going to do everything now does not lend itself to addressing that demand risk issue. We need to be looking at the notion the energy sector has used, the notion of least-cost-planning, and building new supplies and reducing demand as needed."* (Water Research Director, interview 29/12/2014)

The large water utilities have, in return, been highly critical of the loading order concept, arguing that the material characteristics of water would make such a policy transfer inappropriate. The Metropolitan Water District of Southern California, for instance, retort that the "water industry, unlike the energy industry, is wholly dependent upon the availability of its water sources and cannot 'generate' water supplies upon demand," and that therefore "resource 'loading orders' will not work" (MWD 2014, 1-2). The SDCWA responds along similar lines.

> *"[The loading order] can work in a sector where you have the luxury of figuring out where you want to place a plant and make electricity. We can't make water in the water sector; we have to go to where the source is. Our response to that has been that it's the exact opposite of a strategy of diversifying your portfolio. It's more of a balance between these two concepts: adaptation to climate change, we have to reduce our GHG emissions; and we have a mandate to provide reliable water, it's an essential service. You've got these two policies coming to a head. We've been trying to explain that first and foremost comes water reliability. Is energy a consideration in supply development? It is, but it is not the primary factor."* (Water-energy Resources Specialist, interview 24/06/2015)

At its heart this dispute, which has crystallised around seawater desalination as being emblematic of divergent water politics, lie very different understandings of scarcity, and contradictory visions for future resource governance. It is important to note, however, that both approaches are, in essence, technocratic, managerial and solutions-oriented. The categorisation of savings through conservation as 'new supply,' and the focus of conservation programmes on demand-side technologies like water meters and smart appliances illustrate this. The call from environmental groups for a loading order in the water sector does not, of course, represent a radical re-imagining of California's water-energy future. The driving imperatives that underpin the concept of a loading order for the water sector –just as in the energy sector– are towards greater use efficiencies, minimisation of resource trade-offs, and maximisation of synergies and multi-benefit management strategies. Indeed, the loading order suggests –as does the very concept of the water-energy nexus– a shift towards integrated environmental governance whereby externalities are increasingly internalised to the processes of accumulation.

It's all in the name

Embedded within this polarised construct between the diversification and loading order models is a further antithesis, between two applications of reverse osmosis technology: seawater desalination and wastewater recycling. While the large water wholesalers in Southern California –the Metropolitan Water District and the San Diego County Water Authority– cannot directly develop recycling capacity because they provide only water services, not sewerage or drainage services, they are nevertheless supportive of re-use as an alternative supply that contributes to a diversified portfolio (MWD 2016, SDCWA 2016). Over the last decade, through multiple small and medium sized projects its member agencies have increased the recycled supply in the SDCWA service area to 37,000 ML a year, roughly 6% of total supply (SDCWA 2016). This is a little over half the amount produced at the Carlsbad Desalination Plant. The SDCWA say that "in our regional planning, we've identified our next incremental water supply to be the recycled and potable reuse… Our policy decision is that we want our member agencies to develop this local supply" (SDCWA Leadership and Executive Team member, interview 24/09/2014). To the SDCWA, recycled wastewater and seawater desalination are compatible alternative supplies, and suggest that both should be developed in tandem.

Critics of desalination argue, however, that not only should utilities and companies be expanding wastewater recycling, but that investment in desalination directly draws funds away from the less energy intensive and more ecologically sensitive process of re-use. This position was well summed up by one participant:

> *"So you're right at ground zero, the push between greater recycling and greater desal. And the County Water Authority say, oh those things aren't in opposition, they work great to diversify. But in reality, they are opposing because there's only limited funding,*

and there's only so much water we actually need once we start conserving. One is much more environmentally friendly. They're not necessarily mutually exclusive, but they are in opposition." Director of a local environmental group, interview 11/09/2014)

There are two principle types of wastewater re-use: potable and non-potable. Recycling for non-potable purposes (i.e. not drinking) involves treating wastewater to a standard suitable for uses such as irrigation of parks, playing fields, gardens and golf courses, industrial applications, or power plant cooling (Judd and Judd 2010)(Image 6.2). Wastewater for non-potable re-use (NPR), which is treated using micro and nano filtration techniques, and sometimes RO membranes, is distributed through networked systems, or 'purple pipes,' entirely separate from potable supply networks. Potable re-use has formed a small portion of supply in San Diego County since the 1960s (Otay Water District 2015). Many of the SDCWA's member agencies have invested in expanding this supply as part of their own localisation and diversification strategies since the early 1990s, led by the City of Carlsbad and the Otay Water District, where NPR accounts for 25% and 10% of total portfolio respectively (interviews with utilities managers, 24/10/2014 and 09/09/2014). Nevertheless, with most of the large golf courses, parks and playing fields now connected to purple pipe networks, and given the high cost of expanding a dual distribution system, focus is now shifting to recycling for potable use.

Recycling for potable use is, again, categorised into two types: Direct Potable Re-use (DPR) and Indirect Potable Re-use (IPR). DPR involves purifying wastewater to drinking standard using the same basic RO process as desalination, albeit with some differences in pre-treatment and membrane composition, and delivering the output directly back into a water distribution system. Although there are very few examples of DPR worldwide (Leverenz et al. 2011), interest is growing –the Californian government, for example, is currently developing a DPR/IPR regulatory framework. IPR, which is becoming an increasingly popular alternative water supply strategy globally, uses the same treatment process as DPR, but the freshwater produced is deposited in a reservoir, river or aquifer to mix with other water before being re-used (Rodriguez et al. 2009).

Orange County, which borders San Diego County to the north, has led the water treatment industry in IPR since the 1970s. The OC Water District's Groundwater Replenishment System (GWRS), which began in 1975 as a 20 ML/day facility called Water Factory 21 (OCWD 1976), is now the largest potable recycling operation in the world, producing 380 ML/day – double the output of the Carlsbad Desalination Plant (OCWD 2016). After being treated with an RO membrane process, water is pumped into the ground via wells and percolation basins to recharge the underground aquifer. The GWRS has been hugely successful, and has been used as a model for IPR projects in a number of other cities, notably Perth and Singapore, in large part because it solves two problems. Firstly, water pumped underground acts as a seawater barrier, preventing saltwater intrusion into groundwater. Secondly, recharging the aquifer provides Orange County with a reliable alternative water source (Anderson 2003, Dillon 2005).

Image 6.2: Non-potable wastewater used for landscape irrigation at a science and business park, San Diego. *Source*: Joe Williams 2015

Similarly, a major new recycling development by the City of San Diego will tackle two of the City's key water challenges: meeting standards for wastewater discharge into the ocean, and diversifying water supply. The project, called Pure Water San Diego, is being delivered independently from the County Water Authority to service the City's 1.3 million water customers and 2.5 million wastewater customers. The $2.85 billion development, which will incrementally upgrade three existing wastewater facilities, will treat to potable standard using RO membranes. The purified wastewater will then be put back into the City's reservoir system to mix with imported supply –an environmental 'buffer'– before re-entering the distribution system. On the waste management side, the City has been discharging more than it is allowed from its sewerage treatment plant at Point Loma into the ocean, and has been in breach of its outfall permit for the last 20 years. Currently, the Public Utilities Office has to re-apply to the Environmental Protection Agency and Regional Water Quality Control Board every five years for an exception to the permit, and has been under pressure from the Bay Council groups to reduce discharge flows. To upgrade the Point Loma plant simply to bring it in line with permitting standards would cost an estimated $1.8 billion, without producing any additional water. The full implementation of the Pure Water programme, by contrast, will reduce ocean discharge by half and create a potable water source.

On the supply side, Pure Water will, when complete, provide 315 ML/day of rainfall-independent and import-independent water –around a third of the City's current demand. Given that the City currently relies on the SDCWA for 85% of its water, this strategy is, again, consistent with trends towards supply diversification and localisation. The water produced will be around 40% less energy intense than desalted seawater from Carlsbad and will cost an estimated $2,350 a mega litre (around $600/ML less than Carlsbad). The project is still in the development and testing stages (see image 6.3), and is scheduled for completion in 2035. The Pure Water project will be delivered entirely by the public utility through bond financing. The 2035 timeline is based on projected optimum financing to cushion the effects of infrastructure spending on customer rates, but could feasibly be accelerated (City of San Diego 2015, 2016, interviews with Assistant Director and Programme Manager 30/10/2014, 11/06/2015).

Purifying wastewater through reverse osmosis may be considerably less energy intense than using the same technology to remove salt from seawater, but compared to other water source options IPR still carries considerable embedded energy –around 3,000 kWh/ML (figure 6.1). As an alternative source of energy intense and GHG intense water, then, recycling for potable re-use could be subject to precisely the same scrutiny as seawater desalination. Yet, IPR has received overwhelming support from California's major environmentalist groups. The Bay Council organisations have, for instance, signed a memorandum of understanding with the City of San Diego in support of the Pure Water programme. They have also agreed to assist the City with the environmental permitting process (interview, Program Manager 11/06/2015). There are, moreover, signs that prominent voices in the desalting industry may be starting to shift focus onto wastewater and other applications of RO technology. IDE (the Israeli company that

Image 6.3: Recycled wastewater at the North city Pure Water test facility. *Source*: Joe Williams (2015)

designed and operate Carlsbad, and are a world leader in desalination) are, for example, broadening their business horizon away from seawater:

> *"As a global company, we started off in seawater desalination, but it's fairly clear that the markets for seawater are somewhat limited… But the technologies deployed are useful in other forms of treatment… We have a push right now to get into the wastewater business. We could use our RO know-how in recycling and re-use."* (CEO of a water company, interview 29/07/2015)

Certainly in the context of the United States, the development of seawater desalination as a reliable alternative source has faced many barriers, both technical and social. In the early 2000s there were more than 20 proposed ocean water desalting developments along the California coast, with a combined capacity of 630 ML/day (Cooley et al. 2006). To date, the only projects of size significant for municipal supply to have been completed are those in Santa Barbara and Carlsbad, the first of which has been idle since 1992. In terms of supplying reliable water supply, recycled wastewater has been a far more effective strategy in California –a trend set to continue with renewed interest in potable re-use. Moreover, given that technological improvements to desalting processes have plateaued, there is far more scope for innovation in the re-use sector. As one participant explains;

> *"There's a lot of room for wastewater economics being improved. We can work with industry to treat point sources and reduce the cost of recovering that water. If we're going to recover it, it makes sense to be careful about what we're going to put into it... There aren't things we can do to make the seawater task more attractive. There's a lot we can do with respect to wastewater… We've been operating wastewater and chemical treatment facilities for so many decades, it is entrenched technology… This is a paradigm shift in how we treat wastewater, if we're going to recover it. Every point source, everything entering the sewer has to be re-evaluated. Then the treatment process has to be re-evaluated. And even the way we collect sewerage. For me, that's*

a huge contrast with the ocean. We can't change the environment of the ocean." (Senior Engineering Advisor of a water treatment company, interview 06/08/2015)

Despite using the same technology, despite representing the two most energy and GHG intensive sources of water available, and despite being the only significant options for local supply available to San Diego, recycling and desalination nevertheless represent divergent paths for water governance.

Breaking the 'cycle of insanity'

An explanation for this divergence, I argue, may be found in nexus thinking. By this I mean that the discursive polarisation between desalination and recycling is driven not by deep political difference, but by techno-managerial disputation. As outlined in chapter three, nexus thinking conceptualises the relationships between water and energy in four broad categories. First, as *tensions*, which arise when competition between uses squeeze supply. Second, *trade-offs* occur when changes in one sector carry negative implications for another sector. Third, an adaptation to a particular problem is said to be *maladaptive* when it inadvertently increases vulnerability to that problem. Fourth, *synergies* may occur when adaptations benefit more than one sector. The main managerial aim of nexus thinking, is therefore, to find ways of reducing tensions, trade-offs and maladaptations between energy and water, and to identify and develop synergies between them (Williams et al. 2014).

Wastewater recycling, although its energy intensity may well carry tensions and trade-offs between water and energy, nevertheless embodies multiple benefits that go beyond purely water supply. In Orange County, wastewater provides both a source of potable water *and* mitigates the problem of saltwater intrusion into the aquifer. In San Diego, the Pure Water will provide a local source of potable water *and* solve the City's longstanding wastewater discharge issue. Re-use projects can serve multiple purposes, then, on both the supply and treatment side. In Southern California, it is becoming clear that potable re-use not only pencils out for utilities and businesses, but fulfils the criteria of efficiency and stewardship of the vocal environmentalist lobby. As one participant put it "we're importing this water from a long way away –once it gets here, let's reuse it" (Director of a local environmental group, interview 11/09/2014). Seawater desalination, by contrast, fulfils only one function: water supply. Certainly, it provides a reliable source of water, but generally at the expense of other resource and environmental governance imperatives. For critics, desalination epitomises the failures of urban water management, and completes a term coined by one participant, the 'cycle of insanity':

> *"You look around at these urban environments and everything is flat and sloped to make sure that whenever there's a drop of water, we capture it and get it in a storm drain and force it off the land. And everything that goes down your toilet goes to one centralised plant and cleaned up and dumped in the ocean. Then we turn around and say 'oh my god, we don't have any fresh water, how could that happen?' Because we force it back to the ocean. And to complete the cycle of insanity, rather than not doing that anymore, we pump it right back out of the ocean and take the salt out of it, then dump it back in the system that forces it back into the ocean again… Our governance of water is fragmented. We've got these pollution prevention agencies, and flood control agencies and water supply agencies: they were all developed with the notion of specialising in their mandate. Now we're realising it's a really broken system… Really the only water proposal out there that doesn't fit into a multi-benefit future management plan is seawater desal. It's a supply development for sure, but it doesn't do anything else; it's just really expensive supply."* (Environmental activist, interview 05/11/2014)

In this sense, although using the same basic technology and requiring more energy than traditional water supplies, wastewater recycling is still consistent with urban resource integration. Desalination, by contrast, which provides a 'solution' to just one issue, and represents a trade-off between water management and other resource governance sectors, is inconsistent with emerging paradigms like nexus thinking and Integrated Water Resource Management (IWRM) towards multi-benefit governance. By recycling water, instead of making new water from the oceans, environmental externalities like wastewater discharge and wasteful water use practices are internalised by the sphere of resource management.

Conclusion

To some proponents of the desalting solution the Pacific Ocean is the largest reservoir on the planet, and desalination the key to unlocking unlimited supply. “Just stick a straw in it,” as one participant exclaims. Reality is different. Nature and economics tend to get in the way of the desalination utopia. President Kennedy’s vision in the 1960s, of a prosperous world built on an abundant supply of uncontested and limitless freshwater from the oceans, has certainly not been realised. ‘Desalination, the panacea’ has turned into ‘desalination, the more or less prudent component of a diversified portfolio.’ Still, for agencies like the SDCWA, whose priority is to guarantee that water will flow to its customers, and Poseidon, who represent the profit motive in water, the ecological and socio-economic costs of desalination are simply a price worth paying for reliability. To those who have opposed, or been critical of the development of desalination for Southern California, the Carlsbad plant is a white elephant, producing expensive and ecologically harmful water that would not be needed if the SDCWA and its member agencies pursued more responsible water management strategies.

This chapter has presented an ostensibly contradictory argument. On the one hand, it charts the fierce disagreements that have unfolded over more than a decade about the development of the Carlsbad desalting plant and the viability of seawater desalination in Southern California more generally. These disputes, which have largely been litigious – California’s courts being the battleground favoured by the Bay Council and the convoluted permitting process the subject– go beyond those of a reactionary, project-specific fracas. Indeed, the crucible of desalination has brought divergent notions of sustainability, relative scarcity and resource governance into direct confrontation. The various groups and interests that have marshalled themselves on either side of the desalination debate (for the debate has become somewhat reductionist and polarised), represent very different visions of Southern California's water and energy futures. Desalination has emerged at the centre of these debates. Indeed, desalination, because it is so contentious, illustrates well the broader paradigmatic shifts around the water-energy nexus in California.

Although –as I argued in the previous chapter– desalination is being enrolled in a process of re-assembling the technical and social relations of water in San Diego through diversification, aimed at reducing reliance on contested transfer networks, the arguments for integrating desalination as a component of a diversified portfolio are exclusively water supply-oriented. In other words, that which is gained in terms of water supply represents a direct trade-off for energy and other areas of resource governance. Desalination, because it addresses only water challenges regardless of interconnected implications for other sectors, is consistent with compartmentalised modes of resource governance. Indeed, led by the Bay Council and California's vocal environmental groups, those who oppose desalination developments are arguing for water governance practices and technologies that reflect the resource nexus. Put another way, desalination represents a solution under a very particular resource rubric, but is inconsistent with growing calls for integrated environmental governance. The disputes over the intricacies of carbon accounting, or the measurement of fish larvae mortality that have structured the desalination debate, this chapter argues, stand as proxies for deeper divisions between concepts of nature and the future of resource governance.

Yet on the other hand, I have suggested that these disputes don't really matter politically. Certainly, the debate in California has hardly been radical or genuinely progressive. Rather, the alternative formulations of Southern California's water challenges and their solutions –for instance, in the loading order concept and the promotion of wastewater recycling– are largely consistent with a productivist logic of resource management, geared towards efficiency and multi-benefit planning. This chapter has mobilised nexus thinking, understood in a broader context of the re-organisation of nature under capital (Harvey 1996, Smith 1984), to critically interpret the desalination phenomenon. Where previously, the extension of capitalist socio-material relations into water, energy and food sectors developed through the assumed separation between them, with externalities banished to the realm of 'nature', emerging notions like the WEF nexus presuppose a logic of accumulation where externalities, like energy intensity and GHG emissions, are increasingly internalised. Under the nexus framework, then, certain forms of relationality (or interconnection) become the new frontier of capital accumulation. In contrast to this new paradigm of integrated environmental governance, notions of separation and resource compartmentalisation are implicit in the desalination logic. One could almost say, then, that by arguing so emphatically for greater integration of resource management without challenging the underlying contradictions of resource use, California's 'progressive' environmental community are emerging as important new players in the changing logics of capital accumulation.

~7~

The water factory

Desalination, material vitality and the techno-politics of water privatisation

"In the West, it is said, water flows uphill toward money."

Marc Reisner (1986, 13)

"The use of the sea and air is common to all. Neither can a title to the ocean belong to any people or private persons: forasmuch as neither nature nor public use and custom permit any possession therof."

Queen Elizabeth I (cited in Barrow 1844, 76)

Commodifying the Pacific Ocean

This chapter considers the peculiar particularities of the dual trends towards water commodification and privatisation. Through an analysis of the extraordinary technical, discursive and political work of assembling desalination as a viable decentralised and local water supply for San Diego, I argue for an understanding of these meta-political and economic trajectories as complex, diffuse, contingent, and as socially and materially heterogeneous. The principle aim of this chapter is to demonstrate how processes like privatisation, which are often considered to be directed, logical and coherent, always unfold through the re-forging of highly complex and contradictory, social and material relationships. Furthermore, I attempt to uncover how the ‘generative principles’ of the real subsumption of nature by capital (Smith 1984), intersect with existing assembled actors and factors, including geophysical processes, alternative forms of accumulation, techno-legal configurations and governing institutions. This explicit engagement with heterogeneity –or the unpacking of the material embeddedness of political economy– is intended to build on and extend Karen Bakker’s (2003) seminal work on water as an ‘uncooperative’ commodity. In particular, the key intervention here is to demonstrate how the enrolment of particular technologies and materialities by various interests, and the resultant techno-political configurations drawn together in the desalination assemblage in California, are efficacious in the market disciplining of water in the arid West.

To make this argument, the chapter places two literatures, which so often lie as incongruous bedfellows within geographical analysis, into dialogue. The first –the political ecology approach– understands the privatisation and neoliberalisation of nature as part of broad political economic movements emerging from the dialectical contradictions of capital. The second –the assemblage approach– elucidates contradiction and contestation by extrapolating focused analysis of particular socio-materialities –say, of a specific technology. The central divergence between these two approaches, as I argue in chapter two, is their handling of relationality. Where the former begins with a whole (capitalism) and teases apart the relationships through which the whole is constituted, the latter attempts to assume no whole, but builds up a picture of heterogeneous relations from principle materialities, be they people, animals or things. With some notable exceptions (e.g. Kirsch and Mitchell 2004, Loftus 2006, Swyngedouw 2006), attempts to integrate these two approaches in geographical research, particularly through empirical analysis, have often struggled theoretically. Through an analysis of the particular technological and material configurations of desalination, and their efficacy in reconfiguring the social and political relationships of water, this chapter represents an attempt to bridge this gap. In a word, I aim to demonstrate how mundane materialities really matter in political economy and political ecology research.

The concept of the 'desalination assemblage' is used throughout. This is intended to connote two key notions of the assemblage literature. First, that of emergence, or the 'hard work' of drawing together heterogeneous elements into a form of (greater or lesser) coherence (McFarlane 2011). Second, the concept of distributed agency attempts to capture how effect emerges through the interaction of various elements rather than through the intentions of a singular actor (Bennett 2010). The desalination assemblage does not, however, simply describe a set of enumerated technology-focussed relationships –as is often the case in applications of assemblage thinking in Geography. Rather, it attempts to grasp the multiple, trans-scalar elements and processes that coalesce around a particular technology in its construction as a particular response to particular pressures. These include the curious infrastructural linkages and contingencies between desalting projects and energy systems. The chapter, therefore, also engages nexus thinking, in that it uses a specific technological focus to unpack the multiple connectivities between water and energy. Indeed, despite burgeoning interest in the water-energy nexus, very little attention has been paid to the socio-spatial connectivities between water and energy infrastructures (Moss et al. 2016). In this sense, the argument engages one of the key research imperatives for politicised nexus thinking called for in chapter three, in that it develops an understanding of desalination as co-producing water and energy through contested and contradictory processes.

The chapter proceeds in three phases. The first engages Bakker's notion of the 'uncooperative' commodity in the context of the arid West. I argue that the biophysical characteristics of water that, because of its density, fluidity and primacy, cause it to "deviate from the standard behaviour of commodities" (Bakker 2003, 22), are magnified by the ecological conditions and economic history of Southern California. Indeed, despite a steady trend in declining government investment in development projects in the West, private capital has failed to profitably invest in water (Smith 1988). These material, social, political, economic and infrastructural conditions have combined to create a situation particularly unfavourable for the comprehensive insertion of capitalist relations into the Californian waterscape. These barriers have largely prevented capital from transforming water from a *general precondition* of production, to vehicle of accumulation and bearer of surplus value.

The substantive part of the chapter is then devoted to an analysis of two principle seawater desalting ‘factories’. These are the recently completed Claude ‘Bud’ Lewis Carlsbad Desalination Plant in northern San Diego County, and the binational project in Rosarito Beach, Baja California, south of Tijuana, which is still under development. Both projects, although differing in many ways, have entailed significant reconfigurations between public and private governance of water. The particular materialities of the desalination assemblage are paramount in these changing configurations. For instance, both projects were conceived as public ventures –the Carlsbad plant by the San Diego County Water Authority and several water districts, and the Rosarito plant by a number of US and Mexican government agencies. In both cases, however, the projects were appropriated by private sector companies that were able to insert themselves as developers by purchasing or leasing the prime land adjacent to coastal thermoelectric power stations, which guaranteed the economic and permitting benefits of co-location. In this sense, the formulation of neoliberalisation as a conjunct, albeit piecemeal, process between the state and private capital towards market governance (Heynen and Robbins 2005, McCarthy and Prudham 2004) is challenged, and instead presented as more diffuse and contested. The manner in which desalination has been assembled in these two cases, it is argued, has been efficacious in the privatisation and commodification of water, both by opening up new opportunities for the insertion of private capital, and, because of the high price of desalted water, contributing towards pricing conditions necessary for the development of market institutions. Finally, the presentation of desalination as a market-disciplining technology is cautioned. Desalination is, of course, a highly contested and contradictory process. Indeed, the assembling of this new and extraordinary technology, while presenting many opportunities for new actors, also erects new barriers. The contradictions of desalination, therefore, render this an imperfect form of commodification.

Barriers to accumulation

Water is big money in California. The San Diego County Water Authority, for instance, takes annual revenues of nearly $600 million (SDCWA 2015), and the Metropolitan Water District of Southern California over $1.5 billion (MWD 2015). Many of the public water districts in California –particularly the smaller utilities– operate like monopoly-holding companies, in that they purchase a product, treat and sell that product, and receive all revenues through customer payments. Notwithstanding, California's water sector is dominated by public sector provision. Only 16% of the state's residents are supplied by investor-owned water utilities (CPUC 2016), and those small areas that are serviced by monopoly-holding private companies generally receive less reliable supply at higher costs (General Manger, interview 18/06/2015). The continued failure of private capital to insert itself into Southern California's water supply, I argue, stems from the combined and related barriers of, on the one hand, the particular materiality of water as an uncooperative commodity, and on the other, the historical socio-material development of water infrastructures, rights and institutions in the desert Southwest that was discussed in chapter five.

The first of these barriers –that of the biophysical characteristics of water– has been well explored in the literature (Bakker 2003, Bear and Bull 2011, Castro 2013, Page 2005, Swyngedouw 2005). These characteristics, which are manifest the density, volume and fluidity of water compared to other commodities, make this substance in many ways difficult to tame to the logics of the market, and unsuitable to be the bearer of surplus value for private accumulation. The implications of this for political economy and the (broadly understood) neoliberalisation of nature, as well as an analysis of Karen Bakker's notion of the uncooperative commodity, were discussed in chapter two. In this chapter, I argue that in Southern California these material characteristics of water are combined with a geographical, political and economic history that has created conditions particularly unfavourable for capital accumulation in the water sector.

These historical-geographical trajectories were discussed in some detail in previous chapters, but it is worth highlighting several key points. Notably, there has been an historic trend in the West, albeit currently undergoing something of a reversal, towards centralised distribution. This trend has been driven by factors both physical and political. First, the aridity of the southwest, and the seasonal and annual variability of supply –particularly on the Colorado River– require enormous storage and conveyance engineering projects, huge fixed capital investment and the development of mega infrastructures to fully utilise available water. The comprehensive development of water in the West from the 1930s to the 1970s required the efforts of both federal and state governments with vision and resources beyond the capacity of private capital (Sneddon 2015, Worster 1985). This argument echoes Karl Wittfogel's (1957) notion of the 'hydraulic society,' whereby social power concentrates in the hands of those with the technological and financial capacity to control water in arid conditions. Second, the peculiar system of water rights, allocations and priorities created a strong imperative for water users to combine their rights to increase security and reliability. This is true for both urban and agricultural water, and led to the rapid annexation of small urban districts and companies to agencies like the SDCWA and MWD, as well as the formation of large irrigation cooperatives like the Imperial Irrigation District. Moreover, the complex and obscure forms of ownership that have formed as a result now impede the development of water markets. For example, referring to the challenges that beset the Imperial Valley to San Diego transfer deal (discussed in chapter five), one participant argued:

> *"There's no way you can think of a market transaction when you have fights over the rules of the road. You've got a junk yard of 50 years of issues. People are trying to trade things, and they ended up managing to, but they did it in the context of ambiguity, if not outright conflict over the rules of the road."* (President of water trading company and consultant, interview 09/07/2015)

Finally, water has been historically subsidised by the State of California and Bureau of Reclamation developments, and through low interest bond financing. This has kept water price artificially low, particularly for agricultural users. It is in these general conditions of entrenched centralised institutions of water governance and subsidised supply that the desalination assemblage emerges.

Plugging in

The premise of this chapter's argument is twofold. Firstly, that the material and technical configurations that are drawn together in the desalination assemblage are particular and distinct from other water and water-energy configurations. Secondly and moreover, that these particular materialities are highly efficacious in re-shaping the social, political and economic relationships with and between water and energy, creating new opportunities for capital to remake the hydro-social sphere in its own image. Traditional water supply configurations are deeply embedded within the physical, technical and social landscape. Surface water and groundwater, and their capture and use by humans are of course influenced by climate, precipitation and geology. Terrestrial water, from the moment of precipitation to its eventual depositing in the sea, flows and morphs, moving through manifold and heterogeneous compositions of legal and political rights and cultural associations, and combining with other material forms like agricultural fertiliser, industrial chemicals and human waste, which in turn coalesce with new political and cultural forms.

Even recycled water, the only other ‘alternative’ water source, is embedded within technological configurations and forms of ownership. For instance, in San Diego County, the vast majority of wastewater flows through municipal infrastructures to centralised, publically owned and operated treatment facilities. The City of San Diego’s Pure Water recycling project, which will supply over 300 ML/day by 2035 (significantly more than the Carlsbad desalination plant), is designed to enhance existing wastewater treatment on sites already owned by the municipality (City of San Diego 2016). Although using an almost identical RO membrane process to seawater desalination, therefore, wastewater recycling is in general structurally unfavourable for full private sector appropriation. Desalted seawater, by comparison, is new water at the point of manufacture, H_2O, devoid of other chemical and social associations. Desalting factories –for this is what they are– are modular. They may be plugged into existing water and power networks, bolted on to other infrastructures where opportunity and profit permit. In this sense, the desalination facility is more analogous to a coastal thermoelectric power plant, which is built for a given capacity, depending on market and demand, and may connect straight to the grid to sell its output.

Infrastructural piggy-backing

The particular techno-political configurations of large seawater desalting factories, because they are plugged into existing infrastructural systems, present many opportunities and pitfalls for new actors and relationships to coalesce around the desalination assemblage. In particular, the issue of plant siting becomes paramount. Along the heavily urbanised Southern Californian and Baja Californian coast, where real estate is at a premium, there are limited locations suitable for such facilities. Furthermore, the specific physical, infrastructural and legal characteristics of a potential site are critical in determining the viability of projects and relative cost of water produced. As one participant explains:

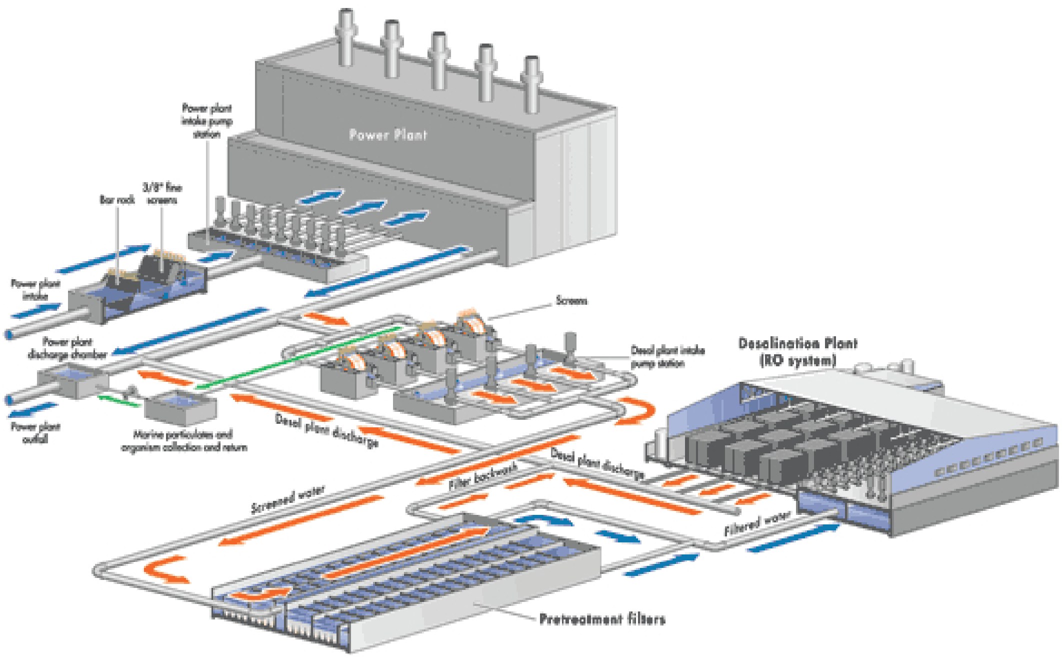


Figure 7.1: The co-location of desalting factories with coastal thermoelectric power facilities. *Source*: Voutchkov (2007)

> *"We look for several things when we site desal plants: appropriate zoning; the ability to take advantage of existing infrastructure, which reduces the capital investment and allows you to produce water at a lower cost; the third one is proximity to demand. So the site at Carlsbad has all of those things: an existing intake and outfall; public utility zoned property on the power plant; and we're within 10 miles of the water delivery point."* (Senior Vice President of a desalination company, interview 24/10/2014)

In the late 1990s and early 2000s when large-scale RO began to take off in North America, co-locating desalination facilities with existing coastal power plants became the preferred model for developers, advocated by some of the industry's most respected experts (Kamal 2005, Pankratz 2004)(figure 7.1). By piggybacking on existing technologies, it was generally agreed, projects could take advantage of multiple benefits and efficiencies. Firstly, using rejected water from the thermoelectric cooling process significantly reduces capital costs by sharing seawater intake and outfall infrastructures. Operating costs are also reduced slightly from lower pumping costs and because the raised water temperature improves the efficiency of the RO process

(Shannon et al. 2008). Secondly, co-location offers benefits in terms of localised environmental impact. The usual problem of fish and larvae impingement and entrainment associated with open water intakes is effectively avoided because the desalination intake water has already been through the power plant. And brine discharge is mixed with additional power plant discharge, which lowers the salinity of outfall back into the ocean. Thirdly, although co-located desalination plants take electricity from the grid and not directly from the power plant, there are benefits associated with being located close to transmission points. And finally, land adjacent to power plants is often zoned for industrial uses, making the permitting process easier in some instances. Together, these benefits help to mitigate two of the key barriers to desalination: cost of production and environmental impact (Voutchkov 2004). Thus;

> *"The reason it has been popular in the US, like around the world, was that the power sector relied on large, base-load power plants that used once-through cooling, so they had a large cooling water intake permitted, and they also had a large cooling water outfall permitted. So in the US, the thought was we can piggy-back on that existing infrastructure, we can take a bit of the flow and then dilute the concentrate or brine with cooling water and discharge it –and that made absolute sense."* (Industry expert, interview 16/10/2014)

The co-location model formed the basis of the Tampa Bay plant in Florida, which until 2015 was North America's largest desalination facility. This was also the favoured model for the wave of proposed sites in Southern California following the 1987-92 drought (Yamada et al. 1995). The Carlsbad and Rosarito projects are both twinned with large coastal thermoelectric power plants (image 7.1 and 7.2). In the Carlsbad case, the benefits of co-location have been undermined by changes to power plant once-through cooling laws in California. These contradictions are teased out in more detail later in the chapter. Notwithstanding, this model effectively placed the state's coastal power plants at the centre of a renewed interest in the desalination 'solution,' with projects vying for the most favourable location and technological advantage.

Image 7.1: The Carlsbad desalination plant (left) is twinned with the Encina power plant (centre). *Source:* Joe Williams 2014

Image 7.2: Presidente Juarez CFE power plant cooling water outfall. *Source*: SDCWA 2010 (2-9)

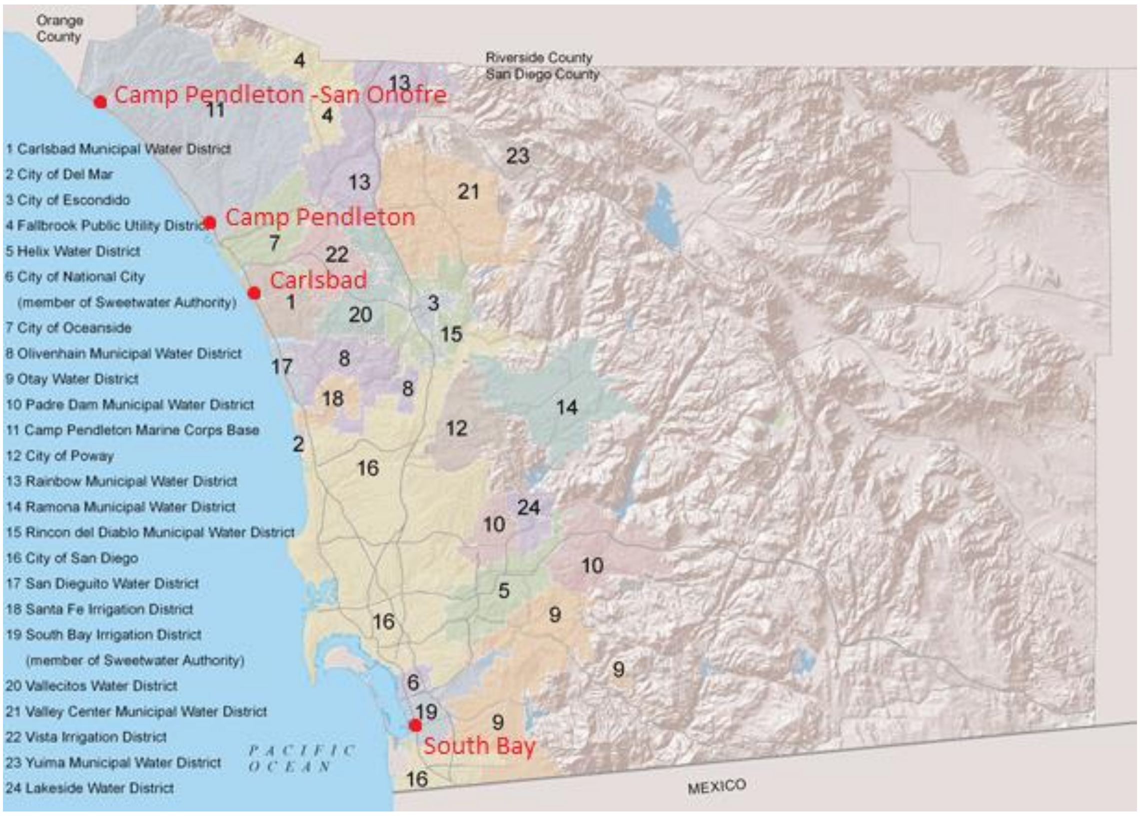


Figure 7.2: Sites considered by the SDCWA for large desalters in San Diego County. *Source*: (Adapted from) SDCWA 2016e

The model described above created a particular and peculiar set of material conditions for the deployment of desalting technologies. It also presented a unique opportunity for private capital to insert itself into a sector dominated by public utilities. Curiously, both the Carlsbad and Rosarito plants began as public projects. They were conceived by public utilities, and the initial plans in both cases were for delivery through public finance and within public ownership. In both cases, however, the projects were appropriated by private companies, who took control of development by securing the prime land adjacent to power plants.

Co-location as speculative strategy in Carlsbad

The San Diego County Water Authority had been considering developing its desalination capacity since the early 1990s as part of its diversification and localisation strategy following the shock of the 1991 mandatory water cutbacks (SDCWA 2016d). A number of potential sites were examined (Figure 7.2). Initially, efforts were focussed on developing a 100 ML/day plant twinned with SDG&E's South Bay power plant in Chula Vista in the south of the county. This plan was abandoned, however, in 1994 when the Water Authority concluded that "environmental, regulatory and institutional issues combined to make desalted water from this proposed facility more expensive than other water supply options available to the Authority" (SDCWA 1994 annual report, 77). The SDCWA also began studies with the US Marine Corp Base for a desalination plant at Camp Pendleton in the north of the county. The original proposal was to co-locate a facility with the San Onofre Nuclear Generating Station. This plan was dropped for several reasons, including unwillingness from the plant's owner, Southern California Edison; public concern about the co-location of a municipal water supply with a nuclear power station; and the unexpected closure of the plant in 2013. The SDCWA continues to conduct studies for a desalination plant at Camp Pendleton. Currently, the plans for a 570 ML/day facility at another location in Camp Pendleton are on hold, but Water Authority officials maintain that the project is crucial to the region's long term water strategy (SDCWA 2009).

Similarly, the history of the *Claude 'Bud' Lewis Carlsbad Desalination Plant* goes back to the early 1990s. Mayor Claude 'Bud' Lewis, who held office at the City of Carlsbad for 24 years until 2010, had been an instrumental proponent of a desalination plant twinned with the gas and oil-powered Encina Power Station. Carlsbad is heavily reliant on the County Water Authority's imported supply, and along with a number of neighbouring cities and water districts was searching for opportunities to secure local alternative supplies (Carlsbad Municipal Water District 2016). Various attempts were made within the City to move forward with a project, but the financial and technical challenges associated with large desalination developments proved to be insurmountable for a small municipal district. The SDCWA were also developing plans for a 189 ML/day plant in Carlsbad co-located with Encina. The proposal reached the permitting stage when the Water Authority submitted an Environmental Impact Report (EIR) for the project. This, combined with the EIR submitted by Poseidon makes the Carlsbad plant one of the most studied sites for desalination in the world. The initial plan was for the SDCWA, in collaboration with the City of Carlsbad, to develop, finance and own the facility –a similar model to its on-going project with the Marine Corp in Camp Pendleton. Development, however, progressed slowly through the 1990s. The SDCWA never abandoned it, but instead focussed its attention on securing the alternative transfer deal with the Imperial Irrigation District, discussed in the previous chapter (SDCWA 2011).

Poseidon came to California in 1999. A Connecticut-based venture capital firm specialising in delivering RO water treatment projects, the company's first large desalination project was the ill-fated Tampa Bay plant in Florida, twinned with the TECO Big Bend power station. Poseidon's involvement in the troubled history of the Tampa Bay project, which led to the bankruptcy of three of the companies involved, beleaguered by poor financing, incompetent contractors and inappropriate technical design, came to an end in 2002 when they were bought out by the Tampa Bay Water district (Williams 2012). During this time, Poseidon had begun looking for investment opportunities on the West Coast. Their business plan was simple: secure prime real estate adjacent to coastal power plants (Poseidon Water 2016). At one point, Poseidon was attempting to lock up land at approximately ten sites along the Californian coast. In the end, they managed to secure leases to two sites: one in Carlsbad, San Diego, and the other in Huntington Beach, Orange County. As two participants explain:

> *"Poseidon came to town and proceeded to conduct a feasibility study. What they also did, which was very smart from a business perspective, was to lock up the land, and got the owner to give them…exclusive right to use the land for a desal plant."* (Water Resources Director, interview 24/06/2015)

> *"Poseidon has certainly taken the lead –I have a lot of respect and admiration for their ability to see what needs to be done and going out and doing it speculatively. They went out and identified the best sites, and entered into agreements with the power*

companies long before anybody else was thinking about it." (Industry expert, interview 16/10/2014)

Poseidon even holds a 2005 patent[5] on the co-location design of RO seawater desalination with once-through cooling systems. By securing a long term lease on the land adjacent to the Encina Power Station, Poseidon ensured that, because of the benefits of co-location, it could produce desalted water at a lower cost than any other potential project in the region. This effectively removed the desalination 'solution' from public hands. Critics argue that this business strategy represents an attempt by Poseidon to establish monopoly control over California's present and future seawater desalination capacity (see chapter six). Although this ambition, if indeed conceived, was never realised, the cases of Carlsbad and in a different manner, Huntington Beach (which has not yet progressed beyond the permitting stage) constitute an extraordinary appropriation of water services by the private sector, in some respects against the will, and certainly outside the control of the public utilities. In Carlsbad particularly, a private company was able to manipulate a particular techno-material-political configuration in order to forcefully insert itself into the future water supply of an entire county, which otherwise governs its water resources entirely in the public domain, and then to sell its output to the very agency that had planned to deliver the project itself.

Co-location as speculative strategy in Rosarito

Having been effectively shut out of the Carlsbad project by Poseidon, the County Water Authority increased its efforts for alternative desalting schemes. These efforts centred around two proposed projects. The first, which has already been discussed briefly, was at Camp Pendleton in northern San Diego County. Interestingly, because all the land around Camp Pendleton is owned by the US Military and cannot easily be leased or sold to private actors, this

[5] US Patent and Trademark Office, #6,946,081. September 2005

project is unlikely to undergo the same privatisation process as Carlsbad. Second, the SDCWA engaged more seriously with the potential for a binational agreement between the United States and Mexico for a shared desalination facility. In 2005 the Water Authority published a feasibility study for such a project. The report considered a number of potential sites, recommending two to be particularly promising: the first on the US side, adjacent to the SDG&E South Bay power plant in Chula Vista (a location that had been studied by SDCWA in the 1990s); the second on the Mexican side, next to the Presidente Juarez gas-powered thermoelectric plant operated by Comisión Federal de Elecricidad (CFE –the Federal Electricity Commission) in Rosarito Beach (SDCWA 2005). The Rosarito site, where there had been a small RO desalination plant owned by CFE in the 1980s and where various subsurface and surface seawater intake technologies had been tested at the time, was also well studied (Industry expert, interview 08/07/2015).

Binational desalination	
United States	**Mexico**
San Diego County Water Authority	Comision Nacional del Aqua (CONAGUA)
Central Arizona Water Conservation District	Comision Estatal de Servicios Publicos de Tijuana (CESPT)
Metropolitan Water District of Southern California	Comision Estatal del Agua (CEA)
Southern Nevada Water Authority	Comision Internacional de Limites y Agua Seccion Mexicana (CILA)

Table 7.1: Agencies participating in the Rosarito binational desalination project.

Interest in the Rosarito project increased rapidly and, led by the SDCWA, a total of eight water agencies from both sides of the border embarked on an extensive feasibility and development study (table 7.1). The first phase of the study concluded that a binational desalination plant of 189 ML/day capacity (107 ML/day for Mexico and 82 ML/day for the USA) would be both feasible and desirable (SDCWA 2010). This is double the size of the Carlsbad plant. Two mechanisms for water delivery to the Unites States were considered: the ‘wet water’ option and the ‘paper water' option. A pipe connecting the desalination plant with San Diego's storage and distribution system could deliver 'wet water' across the border. Alternatively, the entire output of the plant could supply Tijuana and surrounding region, allowing US agencies to withdraw a portion of the output from Mexico's Colorado River allocation. This 'paper transfer' would mean that the desalination plant output would effectively augment the supply available in the Lower Colorado River Basin, allowing the various right-holding agencies to re-allocate water accordingly. For US agencies, the Rosarito project represented a viable way to ease contested Colorado supply. Indeed, the Las Vegas Valley and Southern Nevada had been considering the possibility of financing coastal desalination in return for increased Colorado allocation for some time (Shrestha et al. 2011). On the Mexican side, the Baja State Government had attempted a number of times to develop desalination capacity to increase supply reliability. In Tijuana particularly, which relies almost entirely on limited Colorado supply imported from the Mexicali Valley, per capita water consumption is 30% lower than the Mexican national average and there is widespread belief that inadequate and insecure water supply is retarding the city's growth (Fullerton et al 2007, Meehan 2013).

The governments of the United States and Mexico, coordinated by the International Boundary and Water Commission, took a further step towards a binational desalination project in 2012 with the signing of a landmark five year agreement at the International Boundary and Water Commission. *Minute 319* to the 1944 Treaty, which was intended to increase cooperation between the two countries on the Colorado River, had a number of components (IBWC 2012). Two are of particular interest. The first allocated storage rights to Mexico in Lake Mead, allowing the government to defer delivery of Colorado water. This component, cemented in 2012, was initially introduced in 2010 under *Minute 318* as a response to a severe earthquake in the Mexicali Valley in 2010, which destroyed parts of the water conveyance system and interrupted deliveries (IBWC 2010). Now, Mexico's storage right, which is due to be extended on a long-term basis, opens new opportunities for water trading between the two countries and their various

Image 7.3: Mexican Commissioner Roberto Salmon (left) and US Commissioner Edward Drusina (right) agree on Mexican storage allocation in Lake Mead. *Source*: IBWC 2010

agencies –this will be discussed later (image 7.3). Secondly, Minute 319 allowed for investment in Mexican water infrastructure by US government agencies, and highlighted desalination as a promising area for collaboration.

As interest from the Colorado River agencies peaked, a small company was formed by two businessmen: Gough Thomson, a desalination industry expert based in San Diego, and Alejandro de la Vega, of Baja California (Dibble 2016). Headquartered in Tijuana's business district, the company's name was Norte-Sur Agua (North-South Water). Its ambitious mission was to deliver the world's first binational seawater desalination facility. Having studied the 2005 and 2010 reports, NS Agua recognised that the most favourable site on the entire coastline for a large facility was next to the CFE power plant in Rosarito. The new company also recognised that the institutional and political complexity of the original proposal would slow development. Therein lay opportunity. NS Agua began to conduct low-profile work; completing feasibility studies, establishing contacts, developing a viable project. Their main limiting factor was lack of capital. Being a small company with no track record of successful projects and no large investors, NS Agua lacked the financial clout and the technical expertise to get a project of this size off the ground (Director of a desalination company, interview 25/09/2014).

NS Agua therefore began searching for partners and opened negotiations with a publically traded (Nasdaq-listed) company based in the Cayman Islands called Consolidated Water. Established in 1973 to supply desalted seawater to a large hotel complex in Gran Cayman, Consolidated Water grew steadily to become one of the largest desalination companies in the Caribbean, with operations in the Cayman Islands, the Bahamas, the British Virgin Islands and Belize (Consolidated Water 2015). Although Consolidated Water has until now only delivered small and medium-sized projects (its entire portfolio currently amounts to only a quarter of the capacity of the proposed Rosarito plant) the company has been, in some respects ahead of its time. It began making the transition from thermal distillation to reverse osmosis in 1989; earlier than much of the rest of the industry. And in its Caribbean facilities it has pioneered subsurface intake wells and subsurface discharge, which are only now coming to be seen as the best available technologies (Consolidated Water annual reports 2000-2015). Wishing to expand investment and facing a fairly saturated market in the Caribbean, Consolidated Water identified Bali, Indonesia (where it has already installed some small facilities) and the Tijuana–San Diego metropolitan region as promising areas for growth. As one participant explains:

> *"We were looking for growth and there wasn't much happening in the Caribbean. So through some intermediaries we became aware of the company, NS Agua. They were looking to develop this project, which wasn't really their idea; the idea was from this binational study. It looked like a good idea; it was well studied by people on both sides of the border. NS Agua said 'This is a good plan. All these public sector dudes are just talking and talking and talking.'"* (Executive Vice President of a desalination company, interview 18/09/2014)

In May 2010 Consolidated Water acquired a 50% share in NS Agua, which then became *NSC Agua* (Norte-Sur-Consolidated). This share has now risen to 99.9% of the company. With the injection of capital and technical expertise, NSC Agua was able to progress more rapidly. They installed a pilot plant to test the characteristics of the intake water, and developed a plan for a 378 ML/day facility –twice the size of the plant in Carlsbad– which would supply both Tijuana and San Diego. In 2013 NSC Agua purchased the 20 hectares of land adjacent to the CFE thermoelectric plant –the same parcel of land that had been identified by the 2005 and 2010 binational studies as the best location for a large desalination plant on the entire San Diego–Baja California coastline (Consolidated Water annual reports 2000-2015). NSC Agua was also eager to secure purchasers, and entered into negotiations with two agencies. The Mexican off-taker, the Comisión Estatal de Servicios Públicos de Tijuana or CESPT (State Public Service Commission of Tijuana), is a state-run agency controlled by the State of Baja, rather than an independent municipality. On the US side, the Otay Water District, which had been interested in a binational facility since 2005, saw an opportunity to secure long-term supply independently from the County Water Authority (Otay Water District 2014). The Otay WD (No.9 in figure 7.2), in the south of San Diego County bordering Mexico, is the SDCWA's largest customer by land area, its second largest by water sales, and has the second highest growth projections after the City of San Diego. In 2012 Otay signed a Letter of Intent to purchase 25,000 mega litres a year from NSC Agua –about two thirds of their total requirement.

Interest from the original participating government agencies dropped off somewhat. The SDCWA, which had been instrumental in initial efforts, has decided to focus attention on Carlsbad and Camp Pendleton. The original binational proposal has not been abandoned, but if it were to be pursued again, it is unlikely that a plant at a different location would be cost competitive with the development at Rosarito. Here again, just as had happened a decade earlier in Carlsbad, a private company was able to appropriate a major government project (in this case, a project involving agencies of two national governments) simply by securing the land rights that guaranteed technological (and therefore cost) advantage. In this way, the very particular technical and legal configurations of the desalination assemblage are serving to circumvent the material and historical barriers to water commodification in the West, and now offer private capital opportunities to insert itself into the water production business. Although there is nothing about the reverse osmosis desalination process that makes it suitable for water commodification *a priori*, the unique infrastructural, institutional and political relationships that have formed around it are certainly efficacious in the market disciplining of the uncooperative commodity.

The desalting factory

With the possible exception of bottled water, which intersects the cultural and economic relations of water in the most curious ways (Jaffee and Newman 2013, Wilk 2006), the desalination of seawater in many respects represents the purest form of water commodification. Terrestrial water supplies exist in an almost constant state of flux: both physical flux, in that they flow and combine with other material and technical forms, are dependent on unpredictable climate and rainfall patterns, and are challenging to capture, store and transport; and socio-political flux, in that they pass through multiple overlapping and complex forms of ownership and use, and are increasingly contested. In North America's desert southwest, where water has traditionally been governed through large and inert government institutions, potable water has generally formed, in Marx's words, the *preconditions of production*, rather than commodity or object of accumulation. In the desalting factory, this relationship is turned on its head: water becomes the focus of accumulation and the bearer of surplus value. In other words, desalination has become a technology of water commodification.

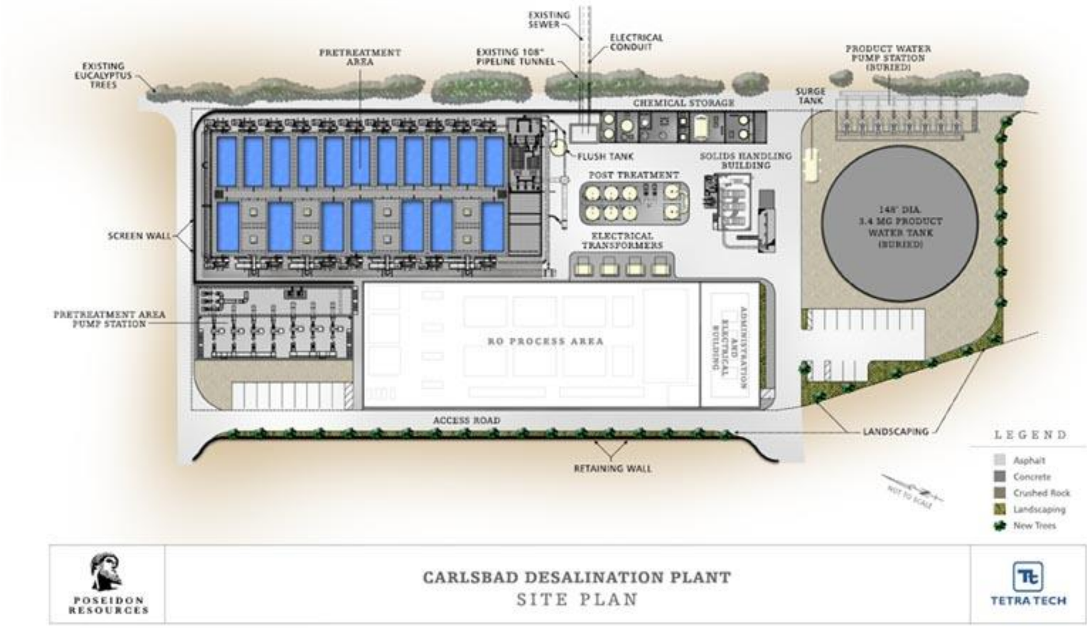


Figure 7.3: Carlsbad desalination plant site map. *Source*: SDCWA 2016b

Image 7. 4: Reverse osmosis trains, Carlsbad Desalination Plant. *Source*: Joe Williams 2015

The seawater desalination plant is a factory in every sense of the word, albeit with some technological peculiarities. Ocean water, which has previously been filtered through a production process in the thermoelectric power station as an accessory to the production of electricity, enters the desalination factory as raw material. This water is effectively purchased from the power station, although under different circumstances in the Carlsbad and Rosarito cases. In Carlsbad the price of seawater is bundled into the property lease. In Rosarito, the details are still unclear, but it is possible that the developer will pay a unit price to CFE for intake water, or that the purchase of seawater will be bundled up in the details of the new public-private partnership (outlined below). The ocean water is then combined with the means of production, which are the fixed capital associated with various purification processes and electrical energy from the grid, and labour to produce a commodity. This commodity embodies surplus value produced by the labour of operating the desalting process and the dead labour ossified in the fixed capital of the factory. In a high-technology process such as reverse osmosis, the fixed capital component is significant, representing 45% of the cost of water produced at Carlsbad, compared to 28% for electricity and 27% for operations and maintenance (including labour). Desalting factories are modular. They can be built to manufacture any given quantity of water, regardless of environmental factors like rainfall or stream flow. Indeed, the only capacity-limiting factors are energy supply and price, and intake and outfall permitting.

Designer water

There are several stages to the production of H_2O by reverse osmosis desalination (see figure 7.3 and image 7.4). Before reaching the RO stage, intake water goes through two pre-treatment processes to remove suspended solids (Vedevyasan 2007). Intake water is first pumped into filter tanks, filled with layers of anthracite, sand and gravel to remove algae, biological material and other large particulates. The filtered water is then passed through a microfiltration membrane process that removes all other suspended particles. After pre-treatment, the water enters the RO building. Here, feedwater is forced at high pressure (around 800psi) into tubular pressure vessels housing spiral-wound thin film composite membranes (Greenlee et al. 2009). These membranes remove salt and virtually all other dissolved elements. For every 2 litres of seawater, the RO process separates 1 litre of potable water and 1 litre of highly saline brine reject. The RO method is therefore, as one participant put it, more a process of 'de-watering' than 'de-salting' because it extracts freshwater from saltwater, rather than removing salt (as some less popular desalting processes do, such as electro dialysis). Before the brine stream is returned to the ocean, it is passed through highly efficient energy recovery devices, which capture the hydraulic pressure of the rejected flow and feed the recovered energy back to the RO pumps (Stover 2007). The development of these devices effectively halved the energy requirements of modern desalination plants and was instrumental in making RO a commercially viable process.

The resulting product is pure H_2O, lacking in virtually any other chemical constituent. Water in this state, if distributed, would leach minerals from any metal it came into contact with. Post-treatment is therefore required to avoid pipe corrosion (Lahav and Birnhack 2007). Product water is, therefore, put through a process of re-mineralisation, pH adjustment, disinfection and fluoridation. This final stage can be tailored to accommodate the specifications of the water purchaser, for instance, if the off-taker requires particular chemical characteristics, or would like the RO water to mimic the taste of the other water supplies in the region. For example, one participant describes the process of buying RO water:

> *"Desal is a world commodity. It's not exotic, it's been tested. The people who'll build this plant are going to be one of three or four world-class companies…and they've done this in Australia, the Middle East, Israel… Desal is really a designer water, and it's a factory product. I can tell NSC Agua I need water that looks like this, these constituents, and they manufacture it. There are some areas in the Caribbean and parts of the Middle East, they're not as sensitive to boron... We are sensitive to that, so we're going to ask*

NSC Agua to dial the boron down." (General Manager of a water district, interview 09/09/2014)

The specific example used here of the chemical boron is slightly exaggeration. Boron, which occurs in relatively high concentrations in seawater and can impair plant growth, is actually quite difficult to remove in the RO process, requiring a second pass through separate RO membranes configured specifically to remove boron, and has recently become a political issue in California (Taniguchi et al. 2004)(image 7.5). Notwithstanding, the point is well made: seawater desalination is the only water supply that can be produced in a pre-agreed quantity and with specified physical characteristics. It is the manufactured product of an industrial process, object of private ownership like any other commodity, rather than a flow resource subject to multiple forms of ownership and cultural association. It is ocean water metabolised, socialised, re-made in the image of capital, and sold as a commodity, H_2O –or, 'designer water'.

Image 7.5: Second-pass bank of RO modules configured to reject boron and other chemicals. Carlsbad Desalination Plant. *Source*: Joe Williams (2015)

‘Pay or pay’: price expectations and the marketization of water

The desalting factory is a factory where the total commodity output has a guaranteed purchaser for many years, even before its construction has begun. No company seeking to create surplus value in water would invest speculatively in something as large and capital-intense as a desalination plant without a long-term secure market to guarantee a return (Wolfs and Woodroffe 2002). The material characteristics of water, combined with the embeddedness of desalting plants in existing distribution networks, and the difficulties of trading water outlined above, would make it very difficult for a desalination factory owner to find new customers after construction. This has led to the development of ‘take or pay’ contracts, or what one participant calls ‘pay or pay’ contracts. This has become the standard model for desalination Public-Private Partnerships, where a municipality or water agency commits to paying for a given amount of water a year (Ghaffour et al. 2013). This commitment stands regardless of whether the water is actually required –consider for example the large desalters built in Australia around 2008-11, which have barely been used, but for which the cities of Brisbane, Sydney, Melbourne and Perth are still paying (Keremane et al 2013).

For the Carlsbad desalting factory the terms of purchase were agreed between the County Water Authority and Poseidon in 2012. This agreement –the Water Purchase Agreement, or WPA (SDCWA and Poseidon Resources 2012)– remains effective for 30 years, after which the SDCWA may choose to purchase the plant for one dollar. The contract is structured such that, after 30 years Poseidon will have recouped its investment plus 12% return. To the Water Authority, the WPA “assigns appropriate risks to the private sector while keeping costs for water rate payers as low as possible” (SDCWA 2016). Critics of the project disagree with both of these claims. Taking the latter first, the cost of water from Carlsbad, and its effects on ratepayers, has long been an issue of contention. In the early 2000s, Poseidon, when they were attempting to canvas local cities and water districts to become direct off-takers (rather than selling to the SDCWA), claimed that they would sell water at the same price as the cost of imported supply from Northern California (Voutchkov 2005). Their calculations were based on the assumption that the price of imported supply would continue to increase, compared to the relative stability of desalinated water price. In other words, they were betting on a projected price cross-over point.

By the time the County Water Authority came on board as the main off-taker, however, it had become clear that Poseidon's price estimations for the Carlsbad output had been dramatically optimistic. Their pledge to match imported supply was, therefore, not included in the WPA. Under the 2012 agreement, the SDCWA committed to purchasing a minimum of 48,000 acre-feet and a maximum of 56,000 acre-feet a year (59,000 and 69,000 mega litres respectively) for the entire 30 years contract, regardless of other supplies. Any purchases above the 48,000 acre-feet will be substantially cheaper, giving the Water Authority an incentive to order the full amount. Water from Carlsbad, therefore, has become part of the county's base-load, rather than variable supply. The SDCWA pays Poseidon between $1,728 and $1,919 per mega litre, depending on volume ordered (Water Resources Director, personal communication 24/06/2015). This is significantly higher than the cost of untreated imported water, for which the Water Authority pays the Metropolitan Water District of Southern California $590 a mega litre (SDCWA 2015). With the price of imported supply rising at 6% to 7% a year (MWD 2016), and desalted supply projected to rise at 2.5%, it is unlikely that the cross-over point will occur during the contract lifetime. The resulting rate increases for customers, which it calculates will raise the water bill for average households by $5 a month, the Water Authority argues, reflects the cost of increased supply reliability.

On the question of risk. One of the major contentions of Poseidon in justifying their involvement as a private sector actor (and of the SDCWA in purchasing from them), is that the public rate payer is protected from risk (Poseidon Resources 2016). In other words, the rate payer does not pay a penny towards the project until water of a pre-agreed quantity and quality is delivered. This claim does not, however, fully stand up to scrutiny. Under the Water Purchase

Agreement the County Water Authority bears many of the unforeseeable risks, such as changes to law, intake changes (discussed later), uninsurable force majeure (Poseidon is only responsible for insurable circumstances), changes to raw seawater, electricity rate increases, bond interest changes and other uncontrollable circumstances. Certainly, Poseidon does take on other risks like permitting, construction and operation cost overruns, delays, contract disputes, plant efficiency and electrical consumption. Many of these risks are, however, transferred on to Poseidon's contractors, IDE, who designed, built (with construction company, Kiewit Shea) and operate the plant on behalf of Poseidon. IDE, for example, have a separate contract with Poseidon, under which they become responsible for efficiency and electrical consumption (CEO of a desalination company, interview 29/07/2015).

Similarly, the Rosarito desalting factory, when it is complete, will deliver water through a take-or-pay contract. NSC Agua's plan is to finance, develop and operate the plant, and to sell output to municipal agencies. The current cost estimates are significantly lower than at Carlsbad, however. NSC Agua calculated that they could sell the Comisión Estatal de Servicios Públicos de Tijuana desalted water for $850 per mega litre (15,000 Pesos per ML). This is $400 (7,000 Pesos) less than the current domestic rate in Tijuana for imported Colorado River water (Director of a desalination company 25/09/2014). The US off-taker, too, is hoping for competitive rates. NSC Agua's initial calculations suggested that they could sell water to Otay, taking the cost of the pipeline to the border into account, for around $1,380 a mega litre. This would make internationally traded desalted ocean water reasonably cost competitive with imported supply for Otay, which buys from the SDCWA at $859/ML for untreated and $1,080/ML for treated water (SDCWA 2016). One of the reasons attributed to the expected lower price from the Rosarito factory, according to the Otay Water District (2013), concerns the more favourable 'litigious environment' south of the border, where infrastructure developments tend to face less organised opposition and fewer legal challenges. Whether these prices are achievable remains to be seen. There is, however, room for scepticism, given some more recent changes to the project, which are outlined in the next section.

Perhaps more importantly, the significance of this insertion of private sector actors into water governance through desalting factories and take-or-pay contracts may extend beyond the desalination debate itself. As discussed earlier, water in the desert Southwest has been historically subsidised at the Federal and State level. Relatively low prices, combined with the physical characteristics of water and institutional structures through which it is governed, have been prohibitive to the formation of water markets and private sector water trading (Smith 1988). Desalted seawater, by contrast, delivered by the private sector and purchased by municipalities (as it is in Carlsbad and will be in Rosarito), reflects both the economic cost of creating new water and the surplus value produced in its making. The higher cost of water from these factories, and the commitment by municipalities to pay this premium on a long term basis is justified by water agencies as reflecting the cost of water reliability, independence and security. This may well, however, have the effect of altering price expectations, thereby creating room for the development of market institutions. This point was made particularly well by one participant:

> *"I think the significance of desalination is in demonstrating the value of reliable water supply. It's like a really interesting price point. I don't think we can desalinate our way out of the Southwest's challenges –I don't see it as the total silver bullet here. It's going to have its role, but really it's changing the debate on price expectations… So what we're seeing is a steady progression of the realisation of the economic value of water… Once things get to sufficient value there almost comes a tipping point, where you get institutional change. Many of us are thinking we're getting there, at least in the Southwest."* (President of water trading company and consultant, interview 09/07/2015)

Certainly, the movement towards decentralised alternative water supplies with prices that reflect the economic cost of production, away from centralised monopoly control of single-source subsidised water will have significant implications for the economics of water in the Southwest. Indeed, there are signals that market institutions are beginning to emerge –the San Diego–Imperial Valley transfer, although convoluted, represents another significant development. It is still too early to know how the development of large desalting factories will affect these trajectories. What is certain, however, is that the financing structure of desalination means that the water from these plants not only raises the overall cost of water, but also reflects the full financial costs of its production.

New water, new rules

Both the Carlsbad and Rosarito desalting projects set new precedents in terms of size and scope for the USA and Mexico. In the USA the next largest desalination facility is Florida's 95 ML/day Tampa Bay plant, which is half the size of the Carlsbad desalter. Before the completion of the Carlsbad plant in 2015 California's largest facility was in Santa Barbara (Pacific Institute 2015). This facility, which is currently under renovation, can produce 25 mega litres a day –less than 15% of Carlsbad's capacity– and has been on standby since completion in 1992 (although it is now under renovation). In Baja California, the next largest facilities, both current and planned (in La Paz, Cabo San Lucas, Ensenada and San Quintín), have capacities of around 20 ML/day (D&WR 2015, McEvoy 2014). At 380 ML/day, the Rosarito plant will be double the size of Carlsbad, replacing it as the largest in the Western Hemisphere. Before these projects, neither California nor Baja California had clear or prescribed permitting processes for desalination infrastructures. This legislative muddiness has since been somewhat addressed in California by the State Water Resources Control Board's 2012 Ocean Plan and 2015 Desalination Amendment (SWRCB 2012, 2015)(discussed in the previous chapter), and in Baja California by a new Public-

Private Partnership law passed in 2014 (discussed below). Nevertheless, both projects are treading new ground in terms of political, institutional and legal process. This, I argue, combined with the techno-political particularities of the desalination assemblage described above, has created a unique set of conditions for the reconfiguration of public-private relationships in the sphere of water governance.

From private to public–private: financing Carlsbad

When, in the late 1990s and early 2000s, Poseidon were speculatively securing prime real estate for co-located desalting factories along the Californian coast, their vision in Carlsbad was for a fully privatised facility, from which they could sell water to local cities and water districts. In 2008, before the County Water Authority joined the project, Poseidon had a total of nine water agencies and districts willing to purchase water. The City of Carlsbad itself had hoped to take 40% of the plant's output (Voutchkov 2005). Poseidon managed to raise $167 million in private equity through the New York–based investment firm, Stonepeak Infrastructure Partners. This amount was, however, insufficient to cover the full cost of the plant, which, despite initial lower estimates, has cost nearly a billion dollars to deliver. Even with anticipated assistance from the Metropolitan Water District of Southern California, which had a programme (discussed in the previous chapter) to refund $250 per acre-foot of desalinated water that offset imported water[6], the project still required substantial additional financing. The City of Carlsbad, combined with the eight other agencies, lacked the financial clout to attract public money for the development. Poseidon then entered into negotiations with the SDCWA to become the sole off-taker. This led to an agreed Term Sheet in 2010 and the final Water Purchase Agreement in 2012.

Put simply, the Carlsbad project could not have been successful without collaboration between Poseidon and the SDCWA. On the one hand, Poseidon had control over the land

[6] Although the SDCWA was not eligible to receive this incentive because it was involved in a legal dispute with MWD over rates, the nine participating agencies did qualify.

adjacent to the Encina Power Station, had secured some private equity, and had already begun the permitting process and lobbying for political support. On the other hand, the SDCWA, as one of the largest urban water agencies in the country, had the capacity to secure finance and the ability to guarantee long-term purchase of water through a public-private partnership (figure 7.4). In 2012, Poseidon and SDCWA submitted a joint application to the California Pollution Control Financing Authority (CPCFA), which issues tax exempt bond financing for waste, recycling or water projects that in some way contribute to pollution control. The purpose of the bond programme is to "stimulate environmental clean-up, economic development and job growth throughout the state of California" (CPCFA 2013, 1). Less than a month after Poseidon and SDCWA signed the Water Purchase Agreement, the CPCFA issued $734 million in low interest tax exempt bonds for the project. The bond issue, which allocates $530,345,000 for the plant and $203,215,000 for the pipeline and associated works, was the second largest in the

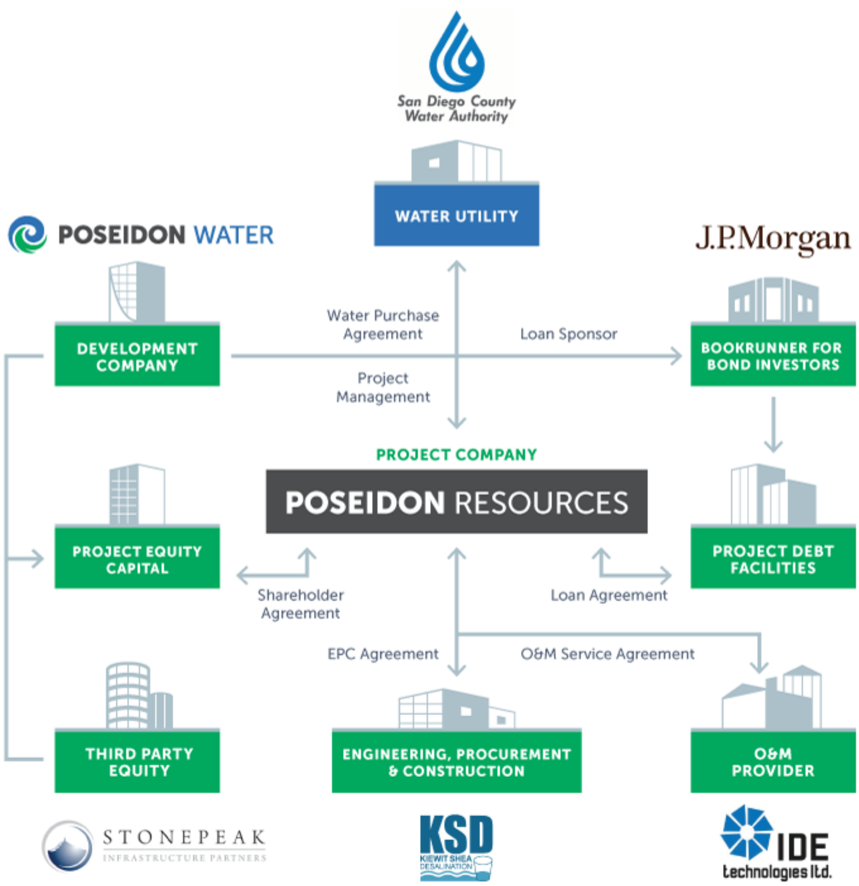


Figure 7.4: Carlsbad PPP structure. *Source*: Poseidon 2016

CPCFA's 40 year history (CPCFA 2012). Critics of the project, particularly the Californian and San Diegan environmental communities, have argued that not only does the Carlsbad desalination plant not fulfil the CPCFA's criteria for addressing pollution, but that publically subsidised finance should not be directed to venture capitalist firms such as Poseidon. This was central to the disputes discussed in the previous chapter.

Re-insertion of the state: Public-Private Partnerships in Baja

Currently, the binational desalination project in Rosarito Beach is very much in a state of flux. With the completion of due diligence, purchase of the power plant–adjacent land, and submission of the environmental impact documents to SEMARNAT,[7] NSC Agua and their parent company, Consolidated Water, had envisioned an entirely private project. NSC Agua had assumed, because they controlled the prime land that guaranteed a cost advantage over any other desalting facility in the region, that they would be able to privately develop, finance and operate the plant, from which they could then sell water to two public agencies; the Comisión Estatal de Servicios Públicos de Tijuana and the Otay Water District (Director of a desalination company, interview 25/09/2014). A peculiarity of Mexican law was to be used to assert NSC Agua's ownership of off-take water from the CFE power plant. Under Mexican federal law all waters, including seawater, are held as national assets. This means that all seawater within Mexican sovereign territory is publically owned and cannot be claimed by an individual or company. If a water body is polluted, however, it becomes the responsibility, and therefore the *property*, of the polluter. This means, say, that a factory holding a permit to withdraw water for washing, owns the polluted water and therefore has a responsibility to clean it before returning to the larger water body. Under the same law, heated water is classified as polluted. The CFE, which has a permit to withdraw seawater to cool the power plant generators in Rosarito,

[7] SEMARNAT, or Secretaria del Medio Ambiente y Recursos Naturales (Secretariat of Environment and Natural Resources), is Mexico's Federal environment ministry, equivalent to the US Environmental Protection Agency.

therefore owns that water until it is returned to the ocean. In a word, the industrial process of raising the temperature of the seawater transfers it from state ownership to private ownership by the power plant. NSC Agua had planned to purchase a portion of that heated water from CFE, therefore enabling it to claim ownership and therefore to sell purified seawater as a private commodity.[8]

This unusual techno-legal transformation of property rights has, however, recently become extraneous to the development in Rosarito. In 2014 the State of Baja enacted a law requiring that all private infrastructure projects must be delivered through new Public-Private Contract of Association schemes, or APPs (Congreso del Estado de Baja California 2014). This law effectively re-wrote the rules about private sector infrastructure investment in Baja California. Under the APP model, every new project idea must be submitted to the state government for review, and is then released by the state to the private sector for bids. Multiple companies may put forward bids to deliver a project, from which the State of Baja chooses the most suitable developer. Crucially, under this law the government may forcefully acquire land for the project on behalf of the developer. A medium-sized desalination plant (22 ML/day) in San Quintín, Baja California, has already reached financial close under the APP competitive bidding system (GWI 2015). It is hoped that, for a flagship project like Rosarito, unprecedented in Mexico's history, this new law will streamline and clarify the permitting process, which could otherwise have been convoluted and drawn out. Nevertheless, for NSC Agua not only did this change mean that they had to bid competitively to develop the project, but that if they had not been successful in the bid, the land the company owns next to the CFE power station may have been acquired by the State of Baja. NSC Agua, who submitted a bid for the project in March 2016 along with several competing companies, had something of a head start on the project, having already begun the permitting process and completed a number of preliminary studies at the site, are still hoping

[8] The plans to utilise this invoke this unusual element of Mexican environmental law are not widely known, and have certainly not been published. This information comes, therefore, entirely from interview data.

to deliver the plant. In June 2016 NSC Agua successfully won the bid, and maintained their position as project developer.

Marketing Mexican water

During the same period, the project underwent a further phase of re-structuring. These changes were prompted because the Rosarito plant is actually being designed to produce more water than the original two off-takers were willing to buy. From a total annual production capacity of 125,000 mega litres, NSC Agua had at first planned to sell 25,000 to the Otay Water District through a cross-border pipeline, and 100,000 to the CESPT (Tijuana's public service department) through the State of Baja. The CESPT, however, decided that it required only 62,500 ML to supplement Tijuana's water supply, leaving 37,500 ML a year without a guaranteed purchaser. The State of Baja therefore engaged another company, a Los Angeles-based firm called Baja Norte Water Resources LLC (hereafter BNWR), to work with NSC Agua to find US buyers for the remaining water. Established in 2009 for the specific purpose of furthering binational water trading agreements between the United States and Mexico, BNWR, although headquartered in the US, claims to represent Mexican interests. BNWR has advised the State of Baja on a number of binational water issues on the Colorado River. After struggling for several years to negotiate a transfer agreement between San Diego and the Mexicali Valley wheeling water via the Tijuana Aqueduct, BNWR was eager to engage in the desalination deal.[9] Given the high stakes involved, however, the company was unwilling to enter into a contract solely with NSC Agua and Consolidated Water:

> *"I think I'd rather be in partnership with the State of Baja. And this is why: for anything binational, you need governmental approvals, governmental buy-in, governmental support, which then gets into the politics. We're not political operatives. All we do is say 'how do you create incentives for people to have an interest in doing something?'… Our*

[9] Again, these negotiations were not made public, so this information is based on interview data alone.

analysis was: to be in partnership with a Cayman-based developer or the State of Baja? If that's a hard choice, I shouldn't be in the business." (President of water trading company and consultant, interview 25/06/2015)

Instead, BNWR proposed an alternative deal structure, to which the State of Baja agreed in 2015 (see figure 7.5). The new agreement is outlined as follows. The State of Baja purchases the entire 125,000 ML/year output from the desalination consortium –which will be NSC Agua, because it won the competitive bid to be project developer. It then directs 62,500 ML to CESPT for Tijuana's supply. The remaining 62,500 ML is sold to the Mexican-based affiliated entity of BNWR called Baja Infrastructure Resources (BIR). Water then flows across the border from BIR to BNWR, who establish purchase contracts with various US water end-users. The Otay Water District will almost certainly become an end-user, probably taking delivery of 'wet water' through a cross-border pipeline. In addition, the Metropolitan Water District of Southern California has already

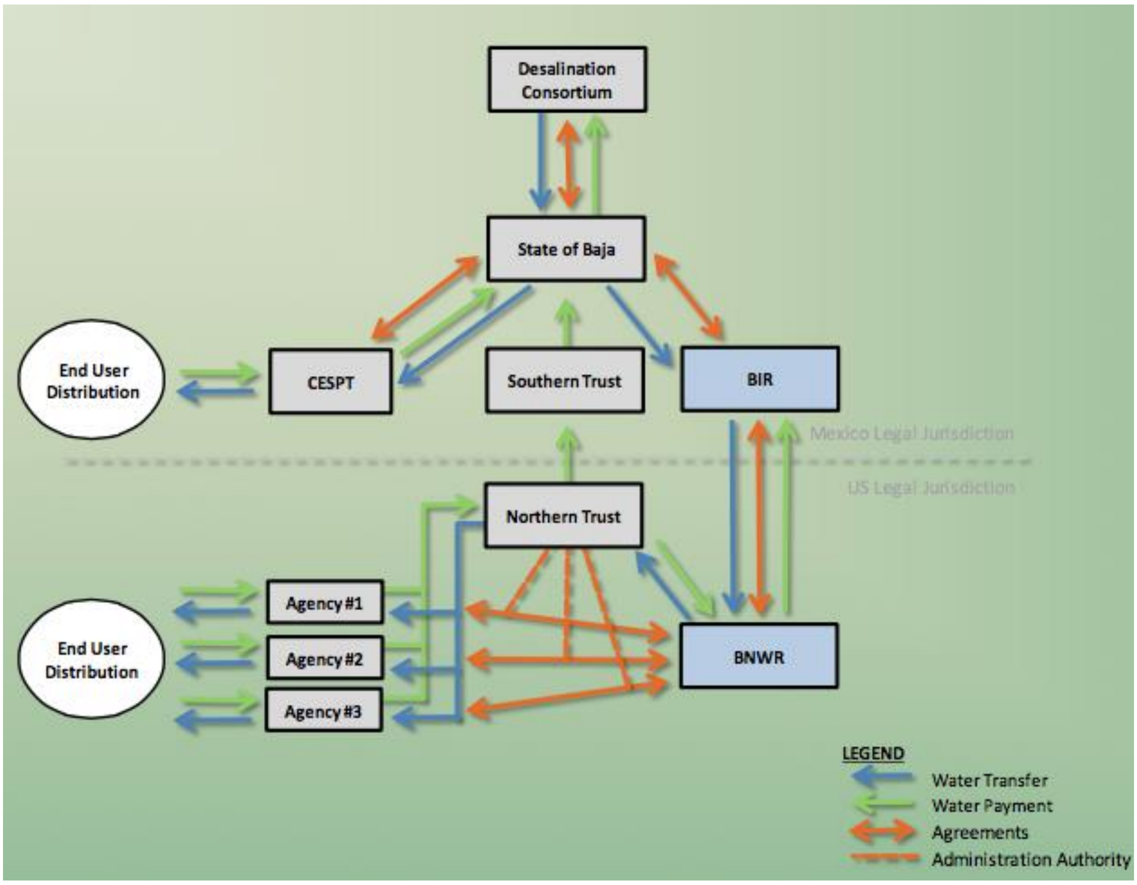


Figure 7.5: Deal structure for binational trading of desalinated seawater, Baja Norte Water Resources. *Source*: Smith 2016 (7)

expressed an interest in establishing a 'paper transfer' of desalinated water with BNWR, along with water wholesalers in Nevada and Arizona. Such contracts may possibly utilise Mexico's storage right in Lake Mead, established in Minutes 318 and 319, provided the storage agreement can be extended. Payment for water then flows back across the border to the State of Baja and the desalination consortium through a North-South Trust structure, which will be administered by a respected public institution –possibly the International Boundary and Water Commission.

The significance of this agreement, which remains effective for a period of 50 years, despite the APP contract for the desalination plant lasting only 25 years, is greater than simply the sale of desalted seawater from Rosarito. Certainly, in negotiating this deal BNWR has ensured that all of the water from Rosarito sold in the United States flows through an institutional and economic structure with itself at the centre. But moreover, the company's broader intention here is for this model to become the blueprint for future binational water trade agreements in the West. In effect, BNWR has used the Rosarito desalination development, the particular material and political assemblages of its deployment, and the uncertainty associated with a project without precedent, to insert itself into the very structure of water trading between two countries. Here again, the peculiar particularities of the desalination assemblage, and the material and political relationships that are drawn together, have been directed towards the creation of new opportunities for private capital to insert itself into the waterscape of the arid West, this time, across an international border.

Desalination as imperfect commodification

So far, this chapter has presented desalination as uncontested. The aim of the argument has been to demonstrate how the assembling of a particular techno-political configuration can have a market disciplining effect on an element that has historically been ill-suited for private investment and accumulation. Certainly, the emergence of seawater desalination technologies as a viable water source option represents an important shift in the governance of water, and presents many opportunities for the formation of new relationships. But the process of commodification through desalination is far from smooth and uncontested. The formation of new relationships and assemblages is always concomitant with the solidification of new contradictions and contestations. The six contradictions of desalination identified by Swyngedouw and Williams (2016) and outlined in the introduction to this thesis –those of energy and climate, marine ecology, governance, growth, cost and ownership– were explored in some detail in the previous chapter, particularly relating to energy and climate. The final section of this chapter, however, refocuses attention on the particular techno-politics of co-located desalting facilities. It investigates how the unique technological configurations of these plants, which have proved so efficacious in the market disciplining of water, might also be disruptive to these same processes. In particular, I highlight how certain technologies, designed for one function, can be discursively enrolled to subvert by dissenting groups or people. This is intended to be something of a theoretical intervention, given that the political strategy Cupples (2011, 942) has called the "tactical enrolments of nonhumans," is a theme usually applied to micro-technologies like water meters, not large infrastructures like billion-dollar desalting plants.

Decoupling

In 2010, while the Carlsbad project was still mired in litigation with environmental groups and a drawn out permitting process, the California State Water Board adopted a policy on the use of coastal and estuarine once-through cooling technologies for thermoelectric power generation (SWB 2010). The policy was the culmination of nearly two decades of environmental activism over the harmful impacts of impingement and entrainment of fish, larvae and other marine life during seawater intake. The 2010 law requires that all coastal power plants in the state (there were nineteen operational at the time, with a combined capacity to withdraw nearly 60 billion litres per day) must phase out once-through cooling processes by 2017. The retraction of seawater intake permits by the State Water Board accompanies (and is linked to) a broader shift in California's energy regime. This shift will see a movement away from large base-loaded nuclear and fossil coastal power plants, to a model based more on imports (for instance, through the new Sunrise Powerlink) and renewables, with peak supply met by smaller gas-powered peaker plants and pump-storage (CEC 2014). Indeed, by passing the Global Warming Solutions Act of 2006, California committed to reduce state-wide greenhouse gas emissions to 1990 levels by 2020 (California State Assembly 2006). And in 2015 California Governor, Jerry Brown, signed legislation requiring the state to receive 50% of its electricity supply from renewable sources by 2030. To exacerbate these changes for Poseidon's Carlsbad project, in 2014 an agreement was reached between the City of Carlsbad, San Diego Gas and Electric Company and NRG Energy to decommission the 60 year old Encina Power Station by 2017 (image 7.6). Encina will be replaced by a much smaller, gas-powered peaker plant on the same site, which will use cooling towers rather than a one pass system (City of Carlsbad 2015).

In California, at least, the model of co-located desalting plants began to gain in popularity just as the model of large base-loaded coastal power plants was waning. These two factors –the 2010 once-through cooling law and the decommissioning of Encina– together effectively removed almost all of the benefits of co-location to the desalination plant. The technological and political configurations that Poseidon had used so effectively to secure near-monopoly control over large-scale desalination project development in San Diego County, by taking advantage of the multiple benefits of co-location, began to fall apart just as the project was picking up momentum. From 2017 (less than two years after opening) the desalination plant will no longer be able to off-take cooling water nor dilute the saline brine outfall. Poseidon will instead be required to develop alternative intake and outfall technologies. This has now become a matter of fierce disagreement. For instance, some argue that the new law undermines the very basis of Poseidon's model and the designs upon which the project was approved:

Image 7.6: The Encina Power Station, Carlsbad. *Source*: Joe Williams 2015

> *"The big problem I have now, looking back, is that all the permits they got from the regulatory agencies were premised on a business model that was made out of hole-cloth –it doesn't exist today."* (Co-Founder of an environmental law group, interview 03/10/2014)

Between 2010 and the signing of the Water Purchase Agreement between Poseidon and the SDCWA in 2012, uncertainty and ambiguity around the specific implementation of the intake law allowed the project to complete the permitting and financing stage without too much interruption. Moreover, under the Water Purchase Agreement, the intake regulations (despite being adopted before the contract was signed) are classified as a 'change in law event,' meaning that the risk is borne by the SDCWA not Poseidon. In the finance agreements more than $20 million is set aside for the development of new intake/outfall technologies, and the increased cost of operation is passed on to the rate payer. In addition, the Carlsbad project is exempt from complying with state-wide desalination intake and outfall regulations passed by the State Water Resources Control Board in 2015 –this is discussed more in the next chapter.

Nevertheless, as discussed in the previous chapter, opposition groups have been highly effective in mobilising around the intake law to undermine the viability of large desalting plants. One participant described it as “the biggest lightning rod for people to oppose that project” (Industry expert, interview 16/10/2014). Indeed, this has become one of the key issues for Poseidon’s similar project in Huntington Beach, Orange County, which is currently struggling to fulfil the permitting requirements. Technologies of market-disciplining are becoming, in a word, potential barriers to accumulation. Interestingly, this law, which only applies to California, does not affect the Rosarito development, and there are currently no signals that Mexico will impose similar restrictions.

Conclusion

The extension of the social relations of capital –specifically in neoliberal form– into areas, places and socio-materialities that have previously been characterised by incomplete or non-capitalist relations is receiving keen attention in Geography and related disciplines. Ethical concerns raised by issues including the imposition of intellectual property rights to genetic code, the appropriation of land and resources by global capital, and the marketization of ecosystem services, have placed Nature at the centre of debates over social and environmental justice. These trends, it was argued in chapter two, all emerge from capital’s constant imperative to internalise that which is external, to render commensurable those elements that, because of their heterogeneity, are radically incommensurable. The privatisation of water and water services, because water has so far has not easily been brought in line with market logics, has received considerable critical attention, particularly from geographers. In Europe and North America particularly, the state hydraulic paradigm, where water is supplied in large quantities at low cost by the state as the general preconditions of production and reproduction, has been remarkably successful in fostering economic growth –notwithstanding, of course, its failures in other respects. Indeed, attempts to privatise water have been geographically piecemeal, largely limited to profitable urban areas, and of questionable success.

This is certainly true in Southern California, where water has historically been governed by large public institutions, circulated through centralised capital-intense mega infrastructures, and subject to complex forms of ownership. Emerging paradigms throughout the desert West towards diversified and localised water management, then, present certain opportunities for the insertion of private capital into the waterscape and for the re-formulation of water as an accumulation strategy and vehicle of surplus value. Despite the barriers to accumulation in the water sector, the dual trends towards water privatisation and commodification have continued over the last 20-30 years. Yet, insufficient attention has been paid to the technological and political tactics through which this is being achieved. How are particular socio-material relationalities brought together in such a way as to discipline water to the logics of the market? It is with this question that the chapter has grappled.

The central theoretical argument running throughout this chapter has been that processes like commodification and privatisation always unfold through the assembling and re-assembling of heterogeneous elements and relations. In the case of water commodification, multiple technologies, material elements, and socio-political relations are enrolled in complex, and often contradictory, forms. Structural trends in political economy and ecology must be understood, therefore, in relation to the complex assemblages out of which they unfold. Seawater desalination, because it is at the centre of a dramatic re-assembling of water governance relations, illustrates this well. Desalting plants are modular and may be plugged into existing systems, designed at given capacities to meet particular markets. Desalted water is new water, designer water, made to order and free from the politics of terrestrial supplies. Unlike other sources of water, purified seawater may be manufactured and traded in a manner more similar to other commodities –the only limiting factors being energy, intake and outfall permitting, and proximity to demand. Moreover, the infrastructural peculiarities of co-located desalting facilities have been central to the privatisation of desalination capacity in California and Baja California. The emergence of the desalination assemblage, therefore, has entailed a significant reconfiguration of public–private relationships in the governance of water. In a word, even considering its multiple contradictions, desalination has become a market-disciplining technology, efficacious in the commercialisation of an 'uncooperative' commodity.

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Conclusions

Lessons from the desalination assemblage

A final note on relationality

This thesis has developed around the notion of the politics of relationality. By this I mean that one of the core aims of this project has been to demonstrate both theoretically and empirically that the ways in which humans and nonhumans, society and environment are seen to be connected matters politically. Put simply, how the nature and form of relationality is understood by various theories and concepts carries very particular implications. To say only that things are inherently interconnected, then, is not enough –indeed, this is only where politics begin. To say how they are connected, and more importantly how things *should* be connected, is a deeply political project. Given the recent profusion of concepts calling for greater integration in environmental governance, this is, furthermore, an argument that needs continuous re-statement.

The critical materialist social sciences, from Marx to Deleuze, Foucault and Latour, have always been based on a profoundly relational understanding of the social and natural world. As discussed in chapter two, these meta-theories are not antithetically opposed or fundamentally incompatible, as strong proponents of each are quick to argue. Certainly, the broadly understood structuralist and post-structuralist theories represent very different perspectives –

sometimes wildly so. But these divergences, I argue, arise from the different ontological ways in which the question of relationality is handled. After all, Marx and Foucault set out to answer very different questions about the world. The somewhat hybrid theoretical approach taken for this research, utilising insights and concepts from Marxian political ecology and assemblage thinking, is certainly not an attempt to overlook or understate these differences. Indeed, the intention was to fruitfully mobilise them to more richly address the novelty of the desalination question.

The key difference can be articulated as that between internal relationality and universal relationality. In the dialectical view, espoused in much of the UPE scholarship, elements are understood to internalise particular social relations. Thus, in the production of H_2O as a commodity derived from seawater in the desalting factory, that water is mobilised and socialised according to particular logics of resource use and accumulation, and therefore internalises those relationships and contradictions, for instance in becoming the bearer of surplus value. Moreover, through the dual notions of circulation and metabolism, such relationalities are understood to be both historically produced and historically producing. Assemblage thinking, by contrast, tends to adopt a notion of universal relationality, where given elements, as the foci of analysis, are understood to be infinitely connected. Although the invocation of materiality as being efficacious in producing effect, assemblage thinking lacks, often consciously so, the conceptual tools to prioritise one form of relationality over another, or to identify trajectory or direction. Notwithstanding McFarlane's (2011b) notion of the history-potential relation or Robbins and Marks' (2010) distinction of metabolic assemblages, in general, assemblage analysis provides a snapshot of relationality. Nevertheless, a unifying feature of these theories of relationality is a common call to dismantle reductionist, violent or exclusionary ideologies of society and nature, and to build more progressive or emancipatory notions of relationality.

Thus, we arrive at a central dilemma that has been grappled with throughout the thesis. The recent burgeoning interest in nexus thinking, on the one hand, represents a popularisation, and broader recognition of the importance of relational thought. In many respects it reinforces what political ecology and other theories of relationality have been saying for years: that everything –humans and nonhumans, nature and society– are inherently interconnected, and that our governance practices and institutions should reflect these deep contingencies. At face value, then, the fact that calls for more socio-material relational perspectives are being echoed throughout academia, from engineering to economics, and policy, from the United Nations to (increasingly) national and regional governments, should be cause for optimism.

On the other hand, under closer interrogation the particular ways in which nexus thinking is being operationalized reveals an entirely different notion of relationality, and consequently an entirely different handling of the politics of relationality. This is unsurprising, given that nexus thinking emerged from managerial environmental governance circles, not from social theory. In contrast to the above mentioned theories of internal and universal relationality, nexus thinking, as a discourse of environmental governance, has developed a concept of external relations. Put another way, under the nexus rubric as developed so far, resource flows that have historically been governed as separate institutions are understood to be interrelated, but not necessarily as co-produced or co-constituted. The call for greater integration between these sectors, as argued in chapter three, is essentially a call for the optimisation of efficiencies, institutional restructuring and information sharing. Although nexus thinking is still a poorly defined field and is currently not widely understood, this approach is both evident in the most influential literature on the subject, and is abundantly clear in the growing number of nexus governance programmes administered by the State of California. Water and energy are, therefore, still understood to be conceptually and materially distinct entities –they are *externally related*– with the primary governance imperative being the better management of the connections between them.

From this very particular and situated concept of relationality flows a particular politic. The nexus terminology of tensions, trade-offs, maladaptations and synergies delineate a somewhat reductionist, exclusionary, and above all techno-managerial concept of connectivity. Nexus thinking only accommodates specific types of connections between resource sectors, and moreover, propounds very particular models for how they *should* be connected. This notion of external relationality, I argue, has caused the nexus discourse to become profoundly de-politicising. By framing the *problems* of social and environmental sustainability in terms of *quantifiable* tensions, trade-offs and maladaptations, and therefore the solution to these problems simply as a matter of pursuing synergetic relationships through integration and multi-benefit planning, the deeper contradictions of resource use are pushed to the margins. In effect, nexus thinking reduces heterogeneity and contingency –notions that in political ecology provide the imperative for radical change– to a set of delineated and manageable relationships. In this way, relationality is 'rendered technical,' to used Murray Li's (2011) phrase. One of the principal interventions of this thesis, then, is to insist that saying how society and environment *should* be put together –which is the basic premise of nexus thinking– is always a fundamentally political project.

Nevertheless, the current fervour around nexus thinking could potentially be harnessed in the pursuit of a politicised and progressive concept of resource integration. Just as notions of socio-material relationality are mobilised to call for more progressive dialogue on, for instance, genetic modification or animal welfare, so too might a politicised concept of the water-energy-food nexus be mobilised towards a more just and equitable distribution of resources. Urban infrastructures, which structure and mediate the flows of essential resources to more than half the world's population, are of course an essential part of this debate. In principle, increasing awareness of the importance of integrated governance should be the basis for greater appreciation of the social implications of interdependency and contingency. Rather than simply considering the tensions and trade-offs between resources in binary terms, a politicised notion of the resource nexus would, for instance, highlight the intersecting vulnerabilities borne out of intersecting resource flows, and identify the combined imperatives for more progressive uses of and access to water, energy and food.

Lessons from the desalination assemblage

The seawater desalination phenomenon, and the contestations that entangle it, sit at the apex of contemporary debates in environmental governance. The novelty of large-scale desalination, and particularly in the extraordinary case of a binational desalting project between the United States and Mexico, elucidates relationships and processes that would perhaps otherwise remain unseen or un-problematised. An important aspect of this analysis has been to point to the trans-scalar nature of the desalination phenomenon, in the way that it intersects politics at multiple levels. This is why the notion of the desalination assemblage has been employed as an analytical tool. Desalination, in effect, becomes enrolled in the local environmental politics of fish larvae, through to divergent visions of public/private water governance, the geopolitics of multi-state river basin management, and even the climate change politics of embedded energy and associated greenhouse gas emissions. All of these themes are drawn together in the material assembling of a desalination plant. Analysing the political ecology of urban infrastructure, therefore, necessarily requires consideration of the multiple geographies of technology.

The different notions of relationality represented in political ecology and assemblage thinking, which offer different explanatory potential, have therefore been mobilised throughout the thesis to engage with slightly different questions arising from the desalination phenomenon. After all, different concepts of relationality are needed to interrogate, for instance, the technological interfacing of water and energy, and the historical conflicts over access to Colorado River water. But both perspectives are central to understanding the politics of water and energy in California, and the development of desalination in San Diego. In an attempt to grasp this scalar complexity, the case study analysis was structured in three phases, each of which considered the lessons from desalination at a different level. Broadly, the three phases of analysis each addressed one of the core research questions of the thesis:

1) How have historical urbanisation and the co-production of water-energy shaped the desalination 'solution' in Southern California?
2) How does seawater desalination intersect nexus thinking and associated contemporary trends towards more integrated models of environmental governance?
3) How are heterogeneous actors and factors re-aligned and enrolled, and what new forms of relationality are created in the emergence of the 'desalination assemblage'?

A bit of a fix

The first phase considered the historical significance of the emergence of desalination in the economic development of urban Southern California. By placing desalination in historical context, this remarkable technological phenomenon is understood conceptually as fulfilling two important functions. Firstly, as a political and scalar fix for the inter-state contestations over allocation on the Colorado River and for the intra-state conflicts between water importers on the California State Water Project. Desalination, because it is rainfall and climate independent and locally produced, has become a powerful discursive tool in San Diego's desire to reduce its reliance on water imported from the Metropolitan Water District of Southern California. Although San Diego has been taking delivery of desalted Pacific water for less than a year, and most of that water has been superfluous to the County's needs and put directly into storage, for two decades desalination has been an important rhetorical part of the San Diego County Water Authority's aggressive diversification strategy. The wake-up call for San Diego, so to speak, came in 1991 with the threat of a 50% cut to total supply from MWD. But the roots of this imperative were founded a century ago with the entrenchment of the expansionist and federally subsidised mass allocation and long-distance transfer of the waters of all of the major rivers in the West. At its core, I have argued, the development of seawater desalination by the SDCWA and several of its member agencies must be understood as an attempt to maintain water supply whilst circumventing the political disagreements and dysfunctionalities of the broader water governance context.

Secondly, an historical reading of water governance in the West points to desalination as a political-economic fix. The large-scale infrastructural development of the waters of the desert Southwest was predominantly undertaken to support agricultural expansionism (Reisner 1986, Worster 1985). The largest and most secure rights to Colorado River water are, for instance, held by the established irrigation districts on both sides of the US-Mexico border. The legal and political structures that support the rights-based water governance model are both deeply entrenched and intransigent. The extraordinary post-war growth of coastal cities, from Los Angeles to Tijuana and the corresponding changing geographies of water, have however, seen the re-orientation of accumulation towards urban centres (Henderson 1998). In contrast to the enormous challenges that faced San Diego and the Imperial Irrigation District in negotiating the region's first long-term agriculture-to-urban water transfer, desalination offers a potential quick fix because it avoids both the problem of over-allocation and of allocation inertia that beleaguer riparian water governance. In a word, desalination is a technological fix for overcoming barriers to accumulation in San Diego. In this sense, I have argued that desalination emerges at a disconnect between the inertia of modes of water circulation vis-á-vis capital circulation, and for now at least, diffuses a stress-point between two competing, and increasingly incompatible, forms of capital accumulation.

Divergent water-energy futures

The second phase of analysis focussed discussion down to the fierce political disagreements that flared around the development of the Carlsbad desalting plant between (broadly) the environmental community on one hand, and the County Water Authority and Poseidon on the other. The desalination question, because it cuts to the heart of current debates on nexus –or integrated– approaches to environmental governance, has become emblematic of divergent water-energy politics in California. The purpose of chapter six was to tease apart an apparent contradiction. The battle over whether or not desalination represents an ecologically, politically, economically and socially viable water source option for San Diego, which has been on-going for 15 years, appears at face value to indicate a genuine struggle between antithetical visions of future resource governance. Yet despite this, I argue that these intense struggles do not really matter politically.

Desalination developments in North America and comparable contexts, where they have been opposed, have generally been fought on the narrow issue of brine discharge and its potentially harmful effects on local marine life. In California, by contrast, an organised coalition of regional, state and national environmental groups have challenged the desalination 'solution' on three more fundamental related issues: the energy intensity and associated greenhouse gas emissions of the desalting process; cost, financing and public ownership concerns; and the marine impacts of impingement and entrainment during seawater intake. The various technicalities associated with each of these issues have been disputed in California's courts since the early 2000s. Taken together, they express divergent notions of relative resource scarcities, and divergent visions of how San Diego should manage water and energy (and the connections between them) in the twenty-first century. These different visions have been reduced to a discursive battle between sustainable water governance as diversified supply or as priority-based loading order. Proponents of the former argue that desalination is an important, if relatively small, component of a resilient supply portfolio, whilst those in favour of a water loading order argue that not only is desalination the most energy intense, expensive and ecologically destructive water source, but that it is being pursued at the expense of more sustainable alternatives.

The environmental groups that have opposed the Carlsbad, Huntington Beach, Camp Pendleton and Rosarito developments argue that water management in Southern California should more fully reflect the governance mandate of the water-energy nexus. Put another way, decisions on the development of water infrastructure should reflect the embedded energy in that water, the tensions, trade-offs between water and energy embodied in that technology, and potential synergies between them. The same groups that opposed desalination have been vocal in their support of wastewater recycling, for instance –a process that utilises very similar technologies, but uses less energy and fits into a multi-benefit governance model. Herein lies the critical point. In opposing desalination, these groups have aligned themselves very closely with the techno-managerial concepts of mainstream nexus thinking. Given that the recent popularity of nexus thinking, I have argued, must be read as part of a broader shift in the logics of capital towards integrated environmental governance, a tentative conclusion –or at least suggestion– of this thesis is, therefore, that the 'progressive' environmental community in California are becoming increasingly vocal actors in the advancement of this emerging mode of accumulation.

The techno-politics of desalination

Infrastructures, especially novel infrastructures, are relationship creators. In the third and final phase, analysis focussed down further to the level of the desalting plant to consider the peculiar and particular materialities of desalination technologies, and their efficacy in re-orienting social, technical and political relationships. The primary aim was to interrogate how broad trends like neoliberalisation, privatisation and commodification, towards the re-alignment of socio-natural rationality within the logics of capital accumulation, although often discussed in abstract conceptual terms, are always deeply rooted in the particular and the tangible. Theoretically, the goal here was to explore ways in which different notions of relationality might be fruitfully mobilised to bridge the gap between the abstract and the grounded, and to explore the interplays between meta-trends and contingencies. As such, the specific example of desalination was used as a vehicle to examine the extraordinary technologies, processes and relationships that must coalesce to discipline water to the logics of the market –in a word, to change the social relations of water.

The two desalting projects analysed –the Carlsbad plant and the Rosarito plant– although emerging from different contexts and following different pathways, have developed several striking similarities. Both began as public ventures, were studied by utilities, and were initially intended to be delivered through public finance. Both were then appropriated by private companies, who secured control of the projects by purchasing or leasing the prime land adjacent to the thermoelectric power stations with which they are twinned. And both were then partially reintegrated with the public sector as PPPs. These transformations were facilitated and made possible because of the very particular technological and material configurations of large-scale desalination plants. In the desalting factory, H_2O is produced in commodity form, embodying surplus value and sold to customers. Desalinated seawater from a privately operated facility is not water in many senses of the word. It is water in a very pure form, without the usual chemical constituents of water in any phase of the hydrological cycle –and indeed, must be re-mineralised to fit the customer's specifications. Desalted seawater is also void of the cultural, legal, political and economic associations of terrestrial water. Understanding this important transformation from water to the commodity H_2O, I have argued, requires analytical dialogue between the dialectical approach of political ecology, which begins with the whole (capitalism) and excavates socio-material relations that constitute the whole, and the assemblage approach, which begins with a particular materiality and extrapolates up. This thesis, then, has attempted to grasp the complex interplays between scales of technology and politics in the creation of new forms of relationality.

Unanswered questions

This research project, like most research projects, has ended up posing more questions than it answers. Although there are many possible avenues of future research stemming from this thesis, I highlight two potential agendas: one empirical, one theoretical. Firstly, the San Diego–Tijuana area, and the border region more generally, provides a unique and illuminating empirical focus for research in political and economic geography and political ecology. The binational desalination plant, which is the first of its kind anywhere in the world, is still in the early stages of development. Indeed, one of the major limitations encountered during the course of this research was access to information on the Rosarito project. I was able to interview the companies involved in its development, but in representing municipal and government perspectives –at city, state and national levels– access to interviewees was extremely limited. One government employee told me that he had been forbidden to speak about the project, and even a Mexican Commissioner was unwilling to participate because of the political sensitivity of the project. After the plant is complete, however, access might be a little easier. The trajectory of this project over the next five years, then, will certainly provide opportunities for interesting and novel geographical research. Moreover, during the course of conducting interviews for this research, it became clear that many experts believe that the Rosarito plant represents the first major step in a trend towards more binational water projects and agreements between the United States and Mexico. Potential future opportunities for cross-border water trading could also include agriculture-to-urban transfer deals, similar to the San Diego–Imperial Irrigation District agreement, with the irrigated regions of the Mexicali Valley, or further paper transfers of rights to Colorado River water. In this sense, the desalination plant may well be a bellwether of future resource governance trends in the North American desert southwest.

Secondly, and perhaps more importantly, the recent movement towards integrated approaches to environmental governance, of which the water-energy nexus is part, certainly requires sustained critical scrutiny. Nexus thinking, in other words, is here to stay, and must be taken seriously in critical geography. This thesis represents a small contribution towards this project. Indeed, I believe this is its most important function. In particular, the tentative conclusion of chapter three, which was explored in a little more detail in chapter six, that nexus thinking represents an attempt to overcome the barriers to accumulation, deserves more attention. The underlying argument is that, because nexus approaches are essentially geared towards the optimisation of efficiencies *between* sectors and not just *within* them, and that therefore under integrated notions of resource management, connections between sectors –or certain forms of relationality– becomes the new frontier of capital. This argument was made, however, in a somewhat perfunctory manner. And although the analysis of desalination in San Diego elucidates this argument in certain respects, there is need for further rigorous empirical analysis on this front, to trace what forms of relationality are being internalised, how and with what consequences. This would, I think, be a worthwhile endeavour in the formation of a new politics of relationality.

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Appendix I: interview participants

Position	Organisation type	Date	Format
	Civil society		
Director	Local environmental group	11/09/2014 29/06/2015	In person Follow up (in person)
Staff Attorney	Environmental group	17/09/2014	Telephone
Former Director	Local environmental group	19/09/2014	In person
Co-Founder	Environmental law group	03/10/2014	In person
Executive Director, Co-Chair	Environmental group	05/11/2014	In person
Retired/activist	Environmental group	05/11/2014	In person
Former Mayor/ activist	City/ environmental group	17/11/2014	In person
Committee member	Local environmental group	29/07/2015	In person
	Government		
Principle Engineer	Water Authority	08/09/2014	In person
General Manager	Water District	09/09/2014 05/06/2015	In person Follow up (telephone)
Assistant General Manager	Water Authority	24/09/2014	In person
Director/ General Manager	City utilities department	24/10/2014	In person
Programme manager	City utilities department	30/10/2014	In person
Analyst	State of California	03/12/2014	Skype
Programme manager	City utilities department	11/06/2015	In person
General Manager	City utilities department	18/06/2015	In person
Water Resources Director	Water Authority	24/06/2015	In Person
Water and energy specialist	Water Authority	24/06/2015	In Person
Director of Water Resources	City, water and energy department	16/07/2015	Telephone
Civil Engineering Associate	City, water and energy department	16/07/2015	Telephone
Manager, Ocean and Wetlands	State of California	20/07/2015	Telephone
Unit Chief	State of California	20/07/2015	Telephone
Chief, Ocean Standards	State of California	20/07/2015	Telephone
Commissioner	State of California	30/07/2015	Telephone
	Business/industry		
Executive Vice President	Desalination company	18/09/2014	Skype
Director	Desalination company	25/09/2014	In person

Project manager	Desalination company	25/09/2014	In person
Consultant, industry expert	Industry analyst company	16/10/2014	Telephone
Senior Vice President	Desalination company	24/10/2014	In person
President	Water trading company and consultant	25/06/2015 09/07/2015	In person Follow up (telephone)
Retired	Industry expert	08/07/2015	In person
Director of Business Development	Water treatment company	23/07/2015	In person
Chief Executive Officer	Desalination company	29/07/2015	In person
Senior Engineering Advisor	Water treatment company	06/08/2015	In person
Other			
Professor of Environmental Science	University	09/10/2014	Telephone
Water Programme Director	Water think tank	29/12/2014	Skype