MONASH University

Mainstreaming Innovation: Exploring Institutional Change in the Australian Water Sector

Lara Werbeloff
Bachelor of Laws (Hons), Bachelor of Arts (Hons)

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Abstract

Urban water systems are under significant pressure in light of complex and interrelated challenges such as climate change, population growth, urbanisation and degraded water and urban environments.   In response, there is increasing consensus within academia, policy and industry spheres that conventional water management approaches, typically reliant upon large-scale, centralised and highly engineered infrastructure, are ill-equipped to meet the diverse and changing needs of our cities. Urban water scholars and practitioners are therefore calling for an urgent shift towards a more integrated approach to water management in order to deliver improved sustainability, liveability and resilience outcomes. This requires transformative change in the way urban water systems are both designed and delivered. As the means through which new practices are organised, moderated and implemented, institutions are essential to this process of broader system transformation. However, there is currently limited practical or theoretical understanding of institutional change processes in the context of transformative system change.

Against this backdrop, this PhD thesis aims to explain how institutional change unfolds in a sustainability transition. Drawing primarily on sustainability transitions scholarship and institutional theory, this research is focused through the overall research question of "how does a radical innovation become institutionalised within a sector?" In answering this question, the research seeks to (1) identify patterns and dynamics of institutional change, (2) assess the type and operation of institutional change mechanisms and (3) develop a framework describing the role of institutional change mechanisms in transformative system change.

For this qualitative research project, three empirical cases of contemporary transition in the Australian urban water sector were examined. The results provide insight into the dynamics and co-evolution of institutional change to support a transition, and identify a number of institutional change mechanisms that are key to a transition effort. The findings also provide insight into the pace and speed of transformative system change, demonstrating the importance of incremental institutional change and introducing a hybrid pattern of transformative change. Finally, the results of this research have led to the development of a framework of institutional change, providing a foundation for further examination of the mechanisms of institutional change operating in the context of transformative system change.

As one of the first detailed studies of institutional change in the context of a sustainability transition, this research advances the scholarship in this area while also offering practical guidance that can support the strategic activities of transition advocates and decision makers in pursuit of transformations towards sustainability.

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signature:

Print Name: Lara Werbeloff

Date: 26 October 2016

Thesis including published works declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes 2 original papers published in peer-reviewed journals and 2 submitted publications. The core theme of the thesis is institutional change processes. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the student, working within the School of Social Sciences under the supervision of Professor Rebekah Brown.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

In the case of Chapters 4 – 7 (inclusive) my contribution to the work involved the following:

Thesis Chapter	Publication Title	Status	Nature and % of student contribution	Co-author name(s) Nature and % of Co-author's contribution	Co-author(s), Monash student Y/N*
4	Pathways of System Transformation: Strategic Agency to Support Regime Change	Published	80%. Concept, collecting data and writing first draft and revisions.	1) Rebekah Brown, input into manuscript 10% 2) Derk Loorbach, input into manuscript 10%	No No
5	Institutional Change to Support Regime Transformation: Lessons from Australia's Water Sector	Under review	80%. Concept, collecting data and writing first draft and revisions.	1) Rebekah Brown, input into manuscript 10% 2) Chris Cocklin, input into manuscript 10%	No No
6	Using Policy and Regulatory Frameworks to Facilitate Water Transitions	Published	90%. Concept, collecting data and writing first draft and revisions.	1) Rebekah Brown, input into manuscript 10%	No
7	Building Regulatory Infrastructure to Support the Diffusion and Institutionalisation of Environmental Innovations	Under review	90%. Concept, collecting data and writing first draft and revisions.	1) Rebekah Brown, input into manuscript 10%	No

I have not renumbered sections of published papers in order to generate a consistent presentation within the thesis.

Student signature: **Date:**   26/10/16

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the student's and co-authors' contributions to this work. In instances where I am not the responsible author I have consulted with the responsible author to agree on the respective contributions of the authors.

Main Supervisor signature: **Date:**   26/10/16

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It is at times a very isolated undertaking, and I am blessed to have had the support of so many people.

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It was a real gift to be able to walk the PhD journey with Erin, Shirin, Ana and of course Christoph, my PhD partner in crime. Being able to share the highs and lows with others in the same boat has ensured I'll look back on this time with much fondness.

To Mum, whose enthusiasm and support is endless. She has eagerly read every word that I've written, listened to my rambling and evolving thoughts and brims with pride at the achievement of every small milestone along the way. I'm so grateful.

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Glossary

BCC	Brisbane City Council
BPEM	Best Practice Environmental Management Guidelines
DEWNR	Department of Environment, Water and Natural Resources
EPA	Environmental Protection Agency
GTC	Gradual Transformative Change
IWRM	Integrated Water Resources Management
MLP	Multi-Level Perspective
SEPP	State Environmental Protection Policy
SEQ	South-East Queensland
SEQRWQMS	South-East Queensland Regional Water Quality Management Study
SPP 4/10	State Planning Policy for Health Waterways 4/10
TG	Transition Governance
TM	Transition Management
USQM	Urban Stormwater Quality Management
WSUD	Water Sensitive Urban Design

1. Introduction

This chapter introduces the research question and places it within its real-world context, focusing on the challenge of contemporary urban water management and the need for institutional change to support a more integrated and holistic approach to the design and delivery of water services. The chapter outlines the scope of the research question and concludes by outlining the overall aims and objectives of this research.

1.1 The Urban Water Management Challenge

Traditionally, urban water has been managed in a technocratic way, based on principles of predictability and control. Brown et al. (2009) investigated the evolution of urban water management in cities over the last 200 years and considered a series of sustainable futures. As shown in Figure 1, they developed a typology of six dominant water management regimes that represent a nested continuum of socio-political drivers and service delivery responses; i.e., water supply, sewered, drained, waterways, water cycle and water sensitive cities.

Figure 1: Evolution of Urban Water Management Regimes
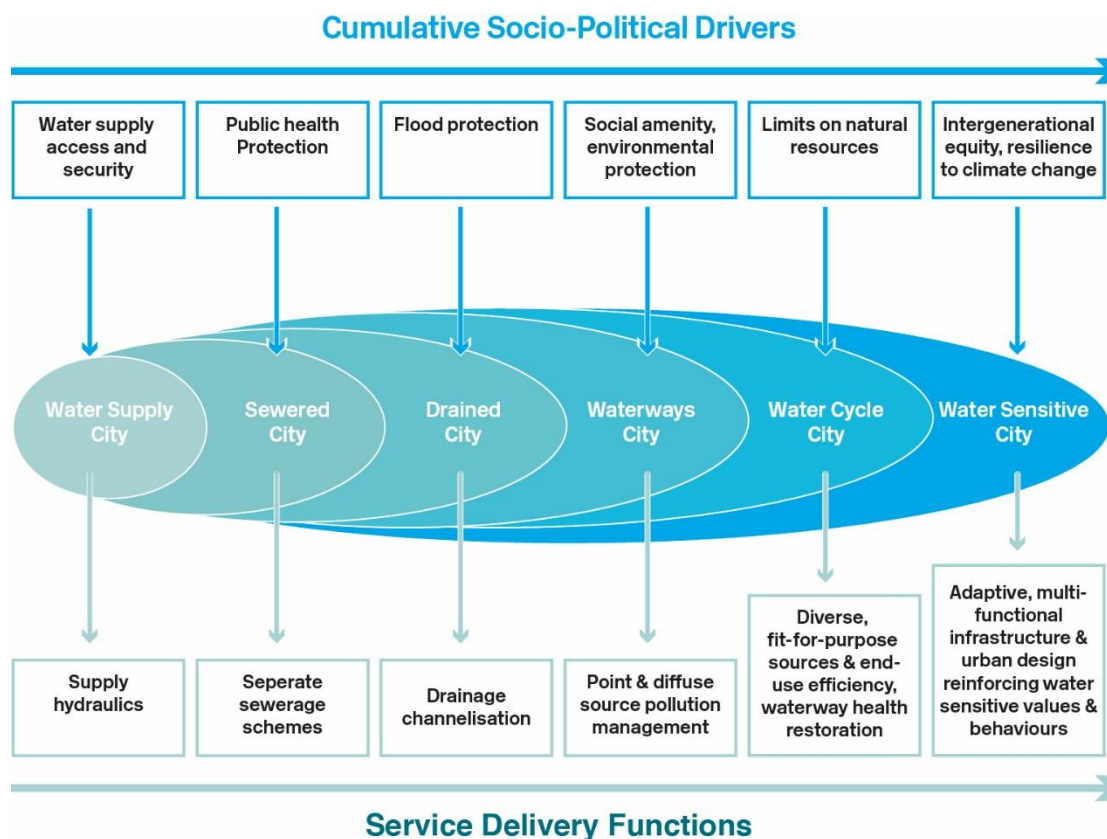(Brown et al. 2009)

The first three regimes represent the historical development of water servicing in response to the need to provide: (1) clean and reliable water supplies, (2) better public health outcomes and (3) protection from flooding. These services have typically been provided through three distinct systems for water supply, sewerage and drainage, each delivered via

large-scale, centralised and highly-engineered infrastructure that establish linear systems of service delivery with water used on a once-through basis (Gleick 2003; Newman 2001; Newman and Kenworthy 1999). Under this management paradigm, the focus is on reducing uncertainties through technical solutions, with associated risks assumed and controlled by government agencies (Schoeman et al. 2014; Pahl-Wostl 2009; Saravanan et al. 2009; Wong and Brown 2009). The corresponding urban water infrastructure in almost all developed cities exhibit these characteristics, with limited stakeholder involvement, low community water literacy and urban water services largely invisible and typically taken for granted (de Graaf and van der Brugge 2010; Truffer et al. 2010; Dominguez et al. 2009; Pahl-Wostl 2007).

Managing the water cycle in this segmented and linear way, whereby wastewater and stormwater are swiftly channelled outside of the city and into receiving waterways, has given rise to a range of unintended consequences, particularly in terms of environmental degradation (Pahl-Wostl 2015; Holling and Meffe 1996). The consequent demand on natural capital has left many cities with reduced environmental capacity to assimilate and process pollution, which in turn compromises water supply security (especially for downstream urban environments) and urban liveability. The three regimes on the right-side of the continuum (Figure 1), waterways, water cycle and water sensitive cities, represent potential pathways towards improved water management, addressing goals such as reduced environmental impact and increased water self-sufficiency.

It is now widely recognised that complex and interrelated challenges such as climate change, population growth, urbanisation, pollution and resource constraints are curtailing the effectiveness of this traditional water management approach (Brown et al. 2009; Brown 2008; Milly et al. 2008; Pahl-Wostl et al. 2007; Marsalek et al. 2001; Vlachos and Braga 2001). Further, emerging community expectations around intergenerational equity, social amenity and environmental protection also highlight the limitations of the conventional water management approach (Wong and Brown 2009; van der Brugge and Rotmans 2007; Mitchell 2006; Gleick 2000).

In response to these challenges, an alternative paradigm of water management has emerged in scientific, policy and practice domains and is embodied in concepts such as Integrated Water Resources Management (**IWRM**), representing a vision for contemporary water servicing based on principles of flexibility, diversity and integration (OECD 2016; Pahl-Wostl 2015; Grigg 2008; PMSEIC 2007). Related concepts include Integrated Urban Water Management (Mitchell 2006); Sustainable Urban Water Management (Brown and Farrelly 2009); Integrated Catchment Management (Vlachos and Braga 2001); Adaptive Integrated Urban Water Management (Pahl-Wostl et al. 2011); Total Water Cycle Management (Chanan and Woods 2006) and Water Sensitive Cities (Wong and Brown 2009). The term IWRM is used throughout this thesis to refer to the new water paradigm.

The essence of this new water paradigm is holistic management of the integrated water cycle in order to deliver improved sustainability, liveability and resilience outcomes. While the literature contains numerous definitions and interpretations of the concept (Medema et al. 2008), IWRM is most commonly defined as "a process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP-TAC 2000).

The IWRM approach views water management as a means of facilitating better liveability outcomes more broadly, using urban design and development processes to help deliver a diverse range of goals beyond conventional water servicing, including resilience to extreme events, fit-for-purpose water use, healthy waterways, urban heat mitigation, increased biodiversity, public green space and community amenity (Wong and Brown 2009; PMSEIC 2007; Mitchell 2006). It seeks to deliver these diverse benefits through an integrated mix of institutions and both centralised and decentralised infrastructure to deliver water services, protect and enhance the health of receiving waterways, reduce flood risk and create green public spaces that capture and clean water. The IWRM approach also relies on embracing uncertainty and adopting a flexible and adaptive approach to ensure robustness and resilience in the face of uncertain water futures (Wong and Brown 2009; Pahl-Wostl 2007; van der Brugge and Rotmans 2007; Vlachos and Braga 2001).

IWRM is now endorsed in the strategic planning and policy documents at national and international levels (ADB 2013; World Water Assessment Program 2009; European Parliament 2000). Within Australia, IWRM principles are contained in recent water strategy documents across a number of states (e.g.: Water for Victoria (DEWLP 2016); South Australia's Water for Good (DWLBC 2009)). Over the last two decades, the IWRM vision has become widely adopted, championed by experts in policy, practice and scholarly realms. As Jeffrey and Gearey comment, "it is difficult to overstate the extent to which IWRM has become the norm, or even…the orthodoxy in water resources management" (2006, p.2). Yet despite such widespread support, limited progress has so far been made in the realisation of this vision (Rahaman and Varis 2005; Biswas 2004).

This is in large part because of the extent to which the new water paradigm differs from the conventional approach to water management. Transforming conventional urban water management approaches and moving towards the IWRM vision requires significant change across existing institutions, infrastructures and practices. Further hampering realisation of the IWRM vision is the related phenomena of technological lock-in (Unruh 2002; Cowan and Hultén 1996; Dosi 1982), institutional inertia (Walker 2000) and path dependency (Pierson 2004; Berkhout 2002). Together these concepts emphasise the difficulty of transforming large and complex socio-technical systems, such as that for water servicing, because of deeply entrenched and co-evolved system elements, which operate in a mutually reinforcing way to embed and perpetuate the status quo.

As Unruh describes, established socio-technical systems contain within themselves the "self-reinforcing barriers to change" (2002, p.317), creating a framework for system optimisation along established pathways and inadvertently operating as a barrier for more radical change. Overcoming this 'entrapment' (Walker 2000) is complicated by the fact that over time, such technological systems become path interdependent with the surrounding economic, political, organisational and institutional frameworks, further complicating the process of transformation. The implications of path dependency are explored further in Section 2.2.

Institutional change has been identified as a key barrier in realisation of this alternative vision for water management (Wallis and Ison 2011; Huitema et al. 2009; Brown 2008; Blomquist et al. 2004). There is a growing acknowledgement that "the existing framework of policies, institutions and regulations reflects an outdated model of planning, managing, delivering and using water" (Office of Living Victoria 2013, p.9), and that significant institutional change is a necessary part of moving towards IWRM. To this end, Godden et al. note that "the constraints to achieving adaptive and sustainable water management may lie, not so much in the deficiencies of scientific or technical understanding of water resources…but in a failure to recognise the complexities of institutional, social and cultural change in water governance" (2011, p.3972).

Changing the existing institutional structures is therefore necessary to both support and facilitate a broader shift towards IWRM. Yet despite recognition of the centrality of institutional change in the realisation of a new water paradigm, it has so far received little attention in either research or practice. There is little understanding of how institutional change emerges and unfolds in the context of a system wide transformation, and in particular the mechanisms involved in this process and the extent to which these change processes can be steered. It is this gap that this research seeks to address.

1.2 Research Question
The focus of this research is on understanding how a radical innovation emerges and embeds itself within a well-established, complex system, eventually becoming institutionalised across a sector. It seeks to chart the evolution from the initial emergence of the innovation, through to its eventual embedding as business as usual. The overall question guiding this research is:

How does a radical innovation become institutionalised within a sector?

The scope of this research question is explored in more detail below.

1.2.1 Defining 'radical innovation'

A radical innovation is one that differs from traditions in a field, signifying a break with existing competencies and technologies (Kemp and Pontoglio 2011). Radical innovations are often labelled 'discontinuous' or 'breakthrough' and imply a significant shift away from or challenge to the status quo (Dahlin and Behrens 2005; Christensen and Rosenbloom 1995;

Anderson and Tushman 1990). Radical innovations are distinguished from innovations that merely optimise or refine an existing system component. By contrast, such incremental innovations typically involve minor modifications to existing processes or products and are consistent with the prevailing paradigm (Herrmann et al. 2006; Johannessen et al. 2001).

Importantly, while a radical innovation may be technical in nature, a technical dimension is not strictly necessary (Kemp et al. 2000). A 'radical innovation' in the sense it is used here could be social, institutional or technical, or rely on a combination across these dimensions. For example, an innovation such as wastewater recycling is primarily technical in nature, but relies upon complementary institutional and organisational innovations for its effective implementation. Whether social, institutional or technical in nature, a 'radical innovation' in the context used here entails "a different value orientation, new problem perception and new policy preferences" (Meijerink and Huitema 2009, p.26).

1.2.2 Defining 'institutionalisation'

The concept of 'institutionalisation' can be understood as both a process and an outcome. As a verb, 'institutionalisation' describes the process through which new ideas and practices emerge, evolve, become embedded, replicated and eventually subject to ongoing reproduction processes (either formal or informal). More specifically it is the process of how institutions change (a discussion of what is meant by the term 'institution' can be found in Section 2.2). In terms of an outcome, an institutionalised practice is one that has become part of the status quo, and as such is both self-reproducing and integrated within existing modes of reproduction at multiple levels (Jepperson 1991).

For this research, a practice is taken to be institutionalised when: (1) it is widely used within a particular sector and (2) has a foundation enabling it to persist. Thus the term does not apply to widely used practices without such a foundation (e.g.: fads or short term crazes), nor to practices entrenched in legislation but not widely used (Colyvas and Jonsson 2011). Rather, 'institutionalisation' implies some kind of permanence, in that an institutionalised practice is one that is embedded within a sector, both in terms of actual day-to-day use and within the broader structural framework, and therefore cannot be easily reversed or removed. In seeking to understand how new ideas and practices become part of the status quo, this research predominantly focuses on the process of institutionalisation, while retaining an overall view of institutionalisation as an end state.

1.2.3 Defining 'sector'

For this research, the analytical scale of a 'sectoral system' has been chosen (as compared to more micro level organisational change or macro change at the national level). The concept of the sector as used here cuts across spatial and structural boundaries to capture the totality of actors, technologies, infrastructures, organisations, networks and institutions that, taken together, structure and coordinate a particular sector (e.g.: the water industry), or sector function (e.g.: water supply). It thus builds on the concept of a sectoral system (Malerba 2002) to consider the co-evolution of and dynamic interaction between the technologies, infrastructures, institutions and user practices that structure a sector (Geels

2004). Further, an analysis at the sector scale facilitates a multi-dimensional perspective, whereby all the elements that contribute to the stability of the prevailing regime can be examined, as well as how these various dimensions influence the institutionalisation of a radical innovation.

1.3 Research Aims and Objectives

This research seeks to deepen understanding of institutional change processes in the context of a broader system transformation. The overall aim is to explain how institutional change unfolds in a sustainability transition. As a relatively new area of enquiry, the goal is to generate macro level insights about institutional change in this context. That is, the goal is breadth rather than depth. This enquiry is focused through a more specific examination of how radical innovations come to be institutionalised within a sector over time.

To achieve the overall aim, three research objectives have been identified.

Objective #1	Identify patterns and dynamics of institutional change in cases of successful institutionalisation of a radical innovation
Objective #2	Assess the type and operation of institutional change mechanisms in the institutionalisation of a radical innovation
Objective #3	Develop a framework to describe the role of institutional change mechanisms in transformative system change

These objectives are explored in the context of urban water management in three Australian cities. Further discussion of the case contexts is contained in Section 3.4.

1.4 Thesis Structure

As a thesis via publication, this dissertation does not follow the traditional structure of a monograph. This introductory chapter has framed the study within its real-world context of contemporary urban water management challenges. Chapter 2 provides the scholarly framing of this research question, and Chapter 3 outlines the overall methodological approach to this study. Further discussion of the relevant literature and methodology is contained in each of the publications, which for the most part make up the conventional results and discussion chapters of a thesis via monograph. Chapter 8 integrates the research findings and presents a framework of institutional change in the context of broader system transformation. Chapter 9 outlines the contributions and limitations of this research.

A short introduction is provided prior to the reproduction of each publication to assist the reader to navigate the text and demonstrate its contribution to the overall research question. Declarations of Authorship are also provided for each publication to indicate the percentage of the authors' involvement in the publication, in compliance with Monash

University's thesis-via-publication requirements. To maintain pagination throughout this thesis, the page numbers of publications have been altered.

2. Literature Review

Exploring the question of how radical innovations come to be institutionalised within a sector requires framing by literature that explores transformative change in complex systems generally, and processes of institutional change specifically. This section begins by exploring conceptualisations of transformative change within the sustainability transitions literature, and then moves to consider processes of institutional change as explained by institutional theory and neo-institutional theory. This chapter concludes with a brief exploration of the scholarship on environmental governance, particularly in relation to policy mixes.

2.1 Sustainability Transitions: Exploring transformative change in complex systems

The relatively young literature on sustainability transitions emerged from the early 1990s to explore processes of transformation in complex systems. With roots in complexity theory (Grin et al. 2010; Rotmans and Loorbach 2009) and innovation studies (Jacobsson and Bergek 2011; Sharif 2006), the transitions literature is a response to the persistent and wicked (Rittel and Weber 1973) sustainability challenges across sectors including water, energy, transport and food production. Sustainability transitions are large-scale transformations that fundamentally change a system's structure and/or the way in which it functions (Farla et al 2012; Grin et al. 2010; Geels 2005; Rotmans et al. 2001), typically taking place over 25–50 years (Markard et al. 2012). Transitions are contrasted with more discrete change that merely tweaks or optimises the operation of the current system. As Grin et al. describe, transitions scholarship is concerned with "radical transformation[s] towards a sustainable society as a response to a number of persistent problems confronting contemporary modern societies" (2010, p.1). Transitions scholars seek to understand how fundamental change within these established sectors come about, and if, to what extent and how these change processes can be steered or influenced.

Four dominant frameworks have emerged in the study of sustainability transitions (Markard et al 2012). These are: the Multi-Level Perspective (**MLP**) (Geels 2002; Rip and Kemp 1998); Transition Management (**TM**) (Loorbach 2010; Kemp and Rotmans 2005); Strategic Niche Management (Schot and Geels 2008; Kemp et al. 1998) and Technological Innovation Systems (Jacobsson and Bergek 2004; Carlsson and Stankiewicz 1991). Elements of both the MLP and TM are used to frame this research.

2.1.1 Multi-Level Perspective

The Multi-Level Perspective (Geels 2002; Rip and Kemp 1998) describes change in complex systems as occurring at the regime (meso) level, and influenced by developments at the landscape (macro) and niche (micro) levels. Within this model, regimes can be understood as the existing, dominant framework for the fulfilment of particular societal functions (e.g.: water provision or flood protection) (Geels 2002; Rip and Kemp 1998; Dosi 1982). A transition occurs when there is fundamental change to this existing system (Holtz et al. 2008).

The notion of regime as used in transitions scholarship originally drew on the concept of 'technological regimes' (Dosi and Orsenigo 1988; Nelson and Winter 1977) but has expanded to include the social dimensions of technology such as user preferences, power relations between actors and institutional frameworks (Holtz et al. 2008). Recognising that these 'soft' elements are equally important in explaining the dominance and persistence of particular technologies, the term 'socio-technical regime' is now preferred (Geels and Schot 2011; Geels 2004). The concept of the socio-technical regime thus refers to the co-evolved and highly stable configuration of social, institutional and technical elements within a particular sector. As Markard and Truffer describe, the MLP conceives of the regime as a "coherent, highly interrelated and stable structure characterised by established products, technologies, stocks of knowledge, user practices, norms [and] regulations" (2008, p.603). The co-evolution of these various elements is a key characteristic of regimes, and contributes to their stability. The concept of co-evolution in this context refers to the dynamic, parallel and adaptive interactions between various regime elements (across social, technological, economic and environmental systems) that shape but do not determine each other (Kemp et al. 2007; Matutinović 2007).

A successful transition relies on this co-evolved and interlinked web of infrastructures, institutions and practices reorienting to a more sustainable pattern of production and consumption. That is, it requires fundamental change to the dominant socio-technical regime. Transformation of existing regimes is a significant challenge given that they are "produced and reproduced by networks of state, civil society and market-based actors and institutions" (Smith et al. 2005, p.1504). Historical socio-technical transitions include the shift from the horse and cart to motorised transport (Geels 2005) or from sailing ships to steam ships (Geels 2002). Importantly, the conceptualisation of regime within this scholarship is consistent with structuration theory (Giddens 1984), which understands the regime not as a static entity, but one that is in a state of 'dynamic equilibrium' with actors continually producing and reproducing the regime, and thereby contributing to its dynamic stability.

Sitting below the regime are niches, which function as 'protected spaces' in which new technologies or practices can emerge and develop while being insulated from the selection pressures of normal markets or regimes (Rotmans et al. 2001). These niches have been described as incubation spaces where new practices or innovations can be trialled and optimised before broader exposure at the regime level (Geels 2002). Sitting above the regime are the macro landscape factors, such as political conditions, economic climates or demographic change, which can weaken or destabilise a regime by disturbing the coherence between its component parts (Markard and Truffer 2008). Landscape pressure can prompt shifts within a regime and/or create opportunities for niches to emerge or grow, and thus plays a role in reinforcing or undermining regime trajectories. Transformational change is understood as the result of interactions between processes at these three scales and will manifest only when developments at the macro, meso and niche level "move in the same direction" (van der Brugge and Rotmans 2007, p.253).

The MLP framework has been criticised as neglecting the role of power and agency (Geels 2011; Smith et al. 2010) and failing to take account of the everyday practices that can help maintain or transform a regime (Shove and Walker 2010). The regime concept specifically has been criticised as being a 'catch-all' category, encompassing everything that cannot otherwise be classified as a landscape or niche element (Markard and Truffer 2008), with other commentators noting that the regime is often treated as a homogenous entity rather than as comprised of a complex mix of heterogeneous actors, structures and processes (Smith et al. 2005). Despite these critiques, the MLP remains a core conceptual contribution of the transitions scholarship, with regime change the overall goal of a sustainability transition.

The MLP is complemented by a framework that explicitly links the scales identified in the MLP with a temporal dimension, proposing that transition dynamics follow an 'S-curve' whereby the system emerges from a relatively long period of stability with a period of rapid and seemingly chaotic change which is then followed by the stabilisation of a new regime (Rotmans et al. 2001). The Multi-Phase Perspective identifies the following four general phases of a transition:

- *Pre-development* – this initial phase is characterised by landscape pressure on the regime and isolated and fragmented innovations that are improperly embedded and insufficiently developed to compete with the existing regime (van der Brugge and Rotmans 2007).

- *Take-off* – during this phase innovations start challenging the status quo, but must reinforce and align with each-other to form an innovation network capable of challenging the regime (van der Brugge and Rotmans 2007).

- *Acceleration* – during this stage destabilising landscape forces and the emergence and upscaling of innovations occur concurrently and in a mutually reinforcing way, leading to rapid change (van der Brugge and Rotmans 2007).

- *Stabilisation* – in this final stage of a transition, transformation processes become optimisation processes as the new innovations are more fully incorporated into the socio-technical system (van der Brugge and Rotmans 2007).

The S-curve in Figure 2 represents an idealised transition trajectory, whereby the system transforms to a new dynamic equilibrium after moving through each of the four phases. Importantly, the concept is cyclical, such that the stabilisation phase of one transition may be the pre-development phase of a subsequent transition (van der Brugge 2009). However, the change dynamic in a given transition may instead give rise to less desirable trajectories. The 'lock-in' trajectory occurs when the regime remains stable, blocking the empowerment of niche-innovations. 'Backlash' can occur when an innovation initially appears to break through, but something causes a destabilisation and the system returns to its original state (van der Brugge and Rotmans 2007). A 'system breakdown' can occur when the regime

destabilises but innovations are not sufficiently developed to replace it (van der Brugge and Rotmans 2007).

As with the MLP, the Multi-Phase Perspective represents a first attempt to articulate change processes at different temporal stages within a transition. Whilst the boundaries between each stage are difficult to delineate, making the model hard to empirically test, the Multi-Phase Perspective remains a useful heuristic to focus attention on the temporal dimensions of a transition and the corresponding change processes. It is used to frame presentation of some of the results of this research.
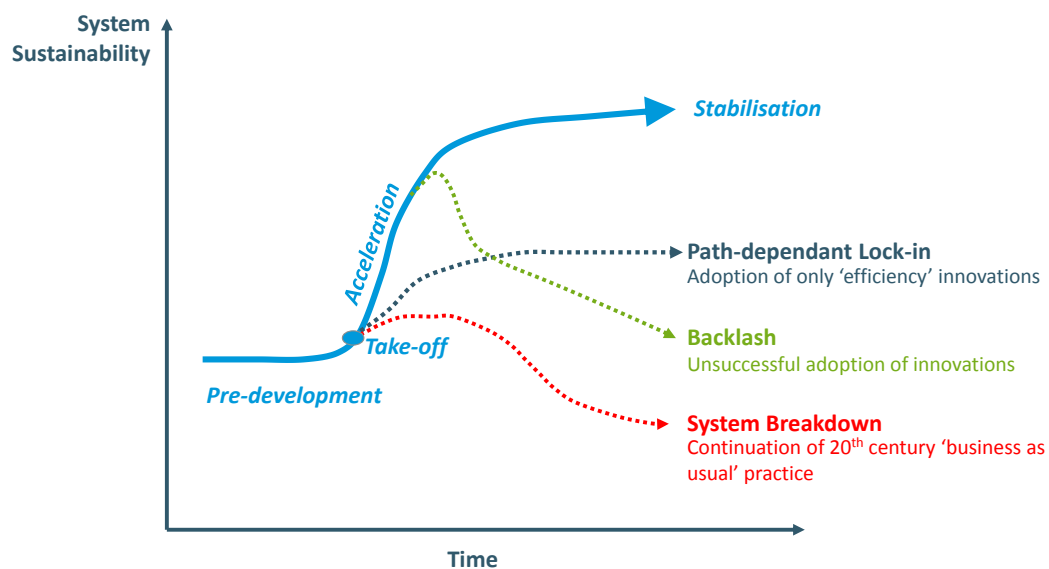
Figure 2: Possible system pathways for transformation of a socio-technical system
(van der Brugge and Rotmans 2007, p.255)

The MLP, together with the Multi-Phase Perspective, are valuable heuristics for drawing attention to change processes at different scales and across time. Given the difficulty in precisely identifying scales and phases of change in ongoing and unfolding transition processes, the MLP is particularly effective in examining historical transitions, when the demarcation between levels of change can be more clearly identified (e.g.: Geels 2005; Geels 2002). Nevertheless, the examination of contemporary transformation processes remains a valuable endeavour both for better understanding change processes in themselves, and for its potential to offer insights that can be used to inform currently unfolding transitions. Some elements of the broader transitions literature, focused in particular on transition governance, are useful in this more contemporary context, facilitating analysis of the changing dominant configurations in a system, even when the outcome of the transition is not yet clear.

2.1.2   Transition Governance and Management

Within transitions scholarship, Transition Management refers to a prescriptive governance approach whereby there is deliberate intervention in a system in pursuit of specific goals, with key actors ('transition managers') aiming to steer transition processes (Loorbach 2010; Loorbach and Rotmans 2010). The TM approach outlines a recursive process of orienting towards a long-term sustainable development vision via short-term experimental learning processes that are refined and adapted over time (Voβ et al. 2009). The TM theory, which translates academic ideas into an operational model for use in real-life policy settings, has proved controversial. Criticisms include that the attempt to manage a transition, which is necessarily a complex multi-actor, multi-factor and multi-level process, is itself implausible (Hendricks 2008; Shove and Walker 2007), and that the theory ignores the politics inherent in such a process (Grin 2012). The concept of the 'front-runner' as a central mechanism for steering change has also attracted critique, in terms of how to identify such people, on whose behalf they act, their position as either within or outside of the system they seek to change and the ethics and practicality of such front-runners using unspecified tools and levers to influence the speed and direction of change (Smith and Stirling 2010; Shove and Walker 2007).

However, the concept of transition management has also been used in a broader sense, described as "a more philosophical view on the world, featuring reflections on the network society and interpreting sustainability and collective problem solving from such a perspective" (van Raak 2016, p.7). Rather than championing the aforementioned governance approach, this broader definition of transition management examines dominant versus emerging regimes and offers more nuance in terms of exploring and understanding ongoing regime dynamics. This more general conceptualisation is adopted for this thesis, and for the sake of clarity, will hereafter be referred to as Transition Governance (**TG**).

The TG approach offers a valuable complement to the MLP framework, bringing more insight into regime level change by examining the dominant configurations within a system (Loorbach 2010; Kemp and Rotmans 2005; Rotmans et al. 2001). From this perspective, a sustainability transition involves fundamental reorientation of the underpinning 'cultures', 'structures' and 'practices' of a system (de Haan and Rotmans 2011; Frantzeskaki and De Haan 2009; Loorbach and Rotmans 2006), which refers to the dominant means of 'thinking', 'organising' and 'doing' (Rotmans and Loorbach 2009; Geels 2002). Regime change, which is the ultimate goal of a transition, therefore rests on a fundamental shift in the dominant cultures, structures and practices of a system. Although central to the study of transitions, the 'culture, structure, practice' framework has remained somewhat under-articulated, with the notable exception of van Raak (2016). Building on his recent exploration, the following section draws on related literatures to articulate the essence and scope of change within each domain.

The concept of 'culture' has been explored across a range of scholarships, including sociology (Hays 1994), discourse theory (Dryzek 2013; Hajer 1995) and institutional theory (Scott 2008; Suchman 1995). Common to these literatures is an understanding of 'culture'

as being comprised of values and perspectives shared amongst a defined social group. Drawing on Scott (2008), 'culture' is comprised of both cognitive and normative elements. The cognitive dimension refers to shared problem and solution frames, through which we derive meaning about our social world (Scott 2008). The normative element refers to deeply held values as well as norms that define the appropriate means to pursue the desired ends (Scott 2008). Together, the cognitive and normative dimensions create a shared culture among a social group that is both slow to establish and hard to change, given that these deeply internalised values and beliefs about the world are typically taken for granted as 'the way we do things'. As Beddoe et al. state, "our worldview is unstated, deeply felt and unquestioned. These unconscious assumptions about how the world works provide the boundary conditions within which institutions and technologies are designed to function" (2009, p.2484). In TG, the concept of culture follows Scott's conceptualisation, and refers to the dominant values, norms and paradigms within a system (van Raak 2016; Rotmans and Loorbach 2010a).

The culture dimension is critical to conferring legitimacy on an innovation or practice. Adopting Suchman's widely accepted definition, 'legitimacy' is understood as "…a generalised perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions" (1995, p.574). Put another way, legitimacy is the state of having consonance with the prevailing values, cognitive frameworks and rules, and is critical to the widespread acceptance of a novel practice.

Despite its centrality to the study of transitions, 'structure' remains an ambiguous and loosely defined concept (Sewell 1992) and is often used as an umbrella term to refer to a diverse range of factors that influence the behaviour of actors. The concept of 'structure' has been examined by a number of disciplines, including from legal (Freiberg 2010), institutional (Scott 2008) and environmental governance perspectives (Taylor et al. 2012; Gunningham 2009). Taken together, the scholarship characterises structure broadly, including (but not limited to) policy frameworks, direct regulation, 'quasi-regulation' such as guidelines and best practice standards, market mechanisms, information-based instruments and innovative governance arrangements such as co- and self-regulation (Taylor et al. 2012; Freiberg 2010; Gunningham 2009). In general terms, a distinction can be made between hard 'command and control' structure, that prescribes minimum standards and carries penalties for non-compliance on the one hand, and 'softer' forms of structure that incentivise or encourage behaviour in a particular direction, but have limited or no enforcement capacity on the other. The concept of structure can also be used to describe physical structures, such as infrastructure, which necessarily have an important mediating role in a regime (Rotmans and Loorbach 2010a). However, for this thesis, the concept of structure is used to refer to the institutional setting and regulatory and market rules that give shape and content to this, albeit with differing levels of enforceability.

The concept of practice refers to the dominant ways of 'doing' within a system and typically includes physical infrastructure and the associated maintenance activities. The notion of practice has also been understood at a micro scale to include individual habits and behaviours (Shove and Walker 2010; Rotmans and Loorbach 2009). However, as this analysis focuses on change at the regime or system level (Geels 2002), the more macro-level understanding of practice is adopted here.

The culture-structure-practice triplet, and its relationship to agency, has been explored by van Raak (2016) and is reflected in Figure 3. According to van Raak (2016), culture and structure exist on a continuum, rather than as a dichotomy. This recognises that the two concepts are inextricably linked, and that culture can also have a structuring effect, such that people behave in accordance with common values and adhere to social conventions. The practices in a system are influenced by both the culture and structure domains, and help create and shape both cultural legitimacy and material production. Agency exists as distinct from the culture-structure-practice triplet, but influences and recursively shapes the constellation.
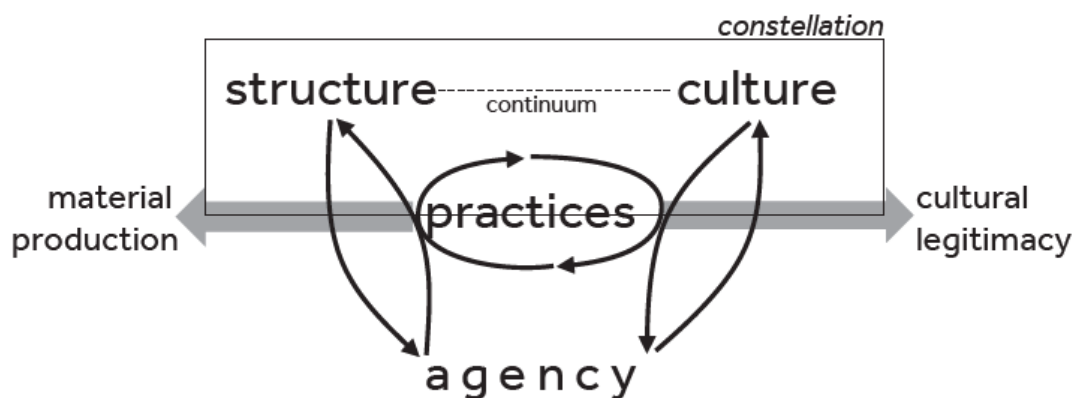
Figure 3: The Culture-Structure-Practice triplet
(Van Raak 2016, p.89)

Ultimately the culture-structure-practice framework is a useful way to understand the transition process as it draws attention to the ways in which culture and structure mutually reinforce each other to embed a new practice. The culture, structure and practice framework is used to frame presentation of the results in paper 3, presented in Chapter 7.

2.1.3 Sustainability Transitions and Institutional Change

As the means through which a new regime is organised, moderated and implemented, institutional change is fundamental to the overall goal of regime transformation. Given the conceptualisation of regimes as the highly institutionalised socio-technical structures of a system, Fuenfschilling and Truffer state that "transitions can essentially be interpreted as processes of institutional change, with a particular focus on technologies" (2016, p.298). Drawing on Giddens' structuration theory (1984), transition scholars recognise the importance of institutions in (1) providing an overarching framework for the socio-technical regime and (2) providing formal and informal mechanisms through which the behaviour of

actors is mediated (Fuenfschilling and Truffer 2016; van den Bergh et al. 2011; Geels 2004). Whilst there is widespread acknowledgement of the importance of institutions in enabling, constraining and shaping socio-technical change, the transitions literature does not yet have conceptual models or tools for describing or explaining the dynamics of institutional change necessary to initiate, sustain or steer a transition (Smith and Stirling 2010; Dolata 2009; Truffer et al. 2009). This gap in the literature is recognised by transitions scholars. As Geels describes, "institutions are a 'left-over' category in analyses" (2004, p.899). Similarly, Truffer et al. observe that "despite the prominent structural role assigned to institutions, institutional inducement and blocking mechanisms are identified in a rather haphazard manner…and are not systematically reviewed" (2009, p.5) and Coenen et al. state, "transition analysis has been limited in theorising varieties of transition processes in different geographical and…institutional contexts" (2012, p.973).

Responding to these calls for more explicit examination of institutional change in the context of sustainability transitions, there have been a few studies exploring interactions between actors and rules (Geels 2004) or the role of institutional work in facilitating broader institutional change (Fuenfschilling and Truffer 2016). These studies provide a useful starting point for understanding the importance of institutions to sustainability transitions more broadly. However, there remains a need for further work to this end, particularly to better understand processes and mechanisms of institutional change.

2.2 Institutional Theory: Defining Institutions and Path Dependency

Institutional theory is a voluminous area of scholarship, spanning a range of disciplines including political science, organisational theory, sociology, economics, science and technology and administration science. Despite these diverse disciplinary backgrounds, there is broad agreement as to what constitutes an institution, which in general terms, is understood as the established and prevalent social rules that structure the social world (Hodgson 2006; North 1990; Ostrom 2005; Woodhill 2010). Douglas North's seminal work in this area provides one of the most widely used definitions, characterising institutions as "the rules of the game in a society" (1990, p.3), which he describes as comprised of formal rules, written laws, formal social conventions and informal norms of behaviour (1990).

As such, institutions (or rules) can be both formal and informal, which refers to differing processes of development, codification, communication and enforcement (Pahl-Wostl 2009). Formal institutions are linked to governmental bureaucracies and are contained within or created by legislation or other explicit documents. They are the result of conscious human design and typically include formal enforcement mechanisms to ensure compliance. By contrast, informal institutions are the shared beliefs about the world, cognitive scripts, paradigms or recurrent patterns of behaviour that emerge endogenously over time and rely on sociocultural transmission and enforcement (Brousseau et al. 2011). Importantly, institutions are distinguished from organisations, which are treated as analytically distinct entities (Djelic 2010; Hodgson 2006). This is the approach adopted here.

Further exploring and elaborating the interaction between formal and informal institutions is Richard Scott, whose influential framework makes clear that formal institutions depend on a suite of informal rules and unwritten norms to operate. Scott's cognitive-normative-regulative framework emphasises that institutions have legal, moral and cultural dimensions, all of which interact (2008). The regulative pillar involves "the capacity to establish rules, inspect others' conformity to them and manipulate sanctions, rewards or punishments" (Scott 2008, p.52). The normative pillar is based on values and norms, which together introduce a sense of obligation in terms of defining legitimate ends and the appropriate means of pursuing those ends (Scott 2008). The cultural-cognitive pillar refers to the deeply embedded shared understanding of the world and common problem and solution framing. The cultural-cognitive dimension is often the hardest to identify, being taken for granted as 'the way we do things' and therefore beyond conscious scrutiny (Scott 2008; Berger and Luckmann 1967). Having strong synergies with the culture-structure-practice triplet, Scott's framework draws attention to the ways these three dimensions operate in a mutually reinforcing way to imbue institutions with legitimacy. From this perspective, the persistence of and compliance with institutions is often the result not only of formal enforcement mechanisms but also of factors such as social pressure, a belief in the appropriateness of the rule and a sense of moral obligation. As Connor and Dovers state, "successful institutional systems do not work through rigid and continuous enforcement of rules and application of sanctions…they are effective because there exists a general consensus on the values represented in the rules – that the rules are fair and reasonable according to these values" (2004, p.209).

Whether formal or informal, cognitive, normative or regulative, the common theme linking these alternative perspectives is a view of institutions as durable social structures that have achieved some threshold level of rigidity whereby the institution persists and operates in a relatively stable way over time, thus providing some consistency and predictability to society (Jepperson 1991; Scott 2008). That is, institutions are treated as relatively enduring features of social and political life (Hall and Taylor 1996). The term 'institution' therefore connotes stability, or at the very least an equilibrium of sorts, even if this equilibrium can sometimes be disturbed. Further, although institutions are created by human agents (whether consciously or unconsciously), they exist as distinct from individual actors, such that at an individual level, people perceive institutions as rules that must be followed. As Hodgson describes, "institutions themselves are the outcomes of human interactions and aspirations, without being consciously designed in every detail by any individual or group, while historically given institutions precede any one individual" (2006, p.8).

It is important here to clarify the concepts of 'structure' and 'institutions' as used throughout this dissertation. Although related, the terms here are used to refer to distinct phenomena (Figure 4). As explored in Section 2.2, institutions are the informal and formal rules that organise the social world. They are therefore comprised of both cultural and structural elements, such that the informal rules are contained within and reflected by the dominant cultures shared amongst a community, and the formal rules are those that are codified via instruments of government such as policy, regulation or market mechanisms.

Collectively, these 'instruments of government' are all types of structure. Structural change is therefore a necessary but not sufficient component of institutional change, and is pursued and given effect through tools such as policy and regulation. The term 'structural change' is used to refer to change to these instruments of government, while the term 'institutional change' is used to refer to the broader change across both culture and structure domains.
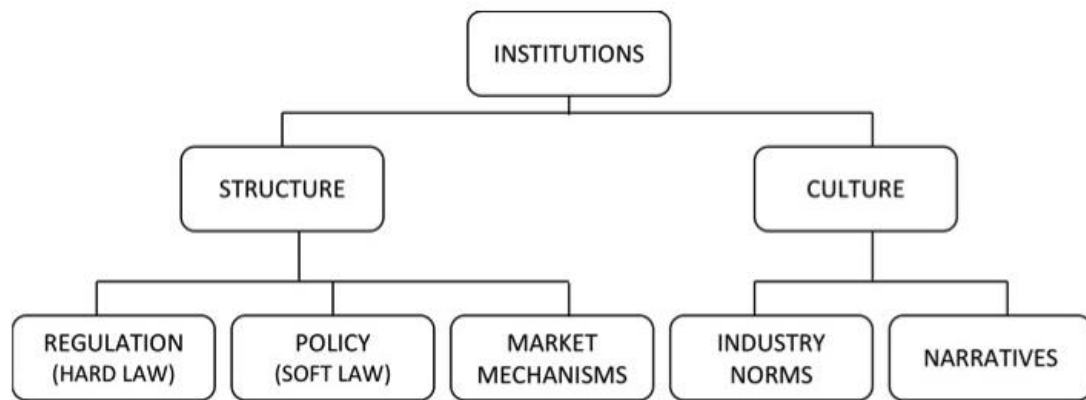
Figure 4: Relationship between the concepts of Institutions, Structure and Culture

One of the key ideas put forward by early institutional theorists was 'path dependency', a concept that has become ubiquitous in discussions about the persistence of institutional structures and the difficulty in changing them. Path dependence is based on a recognition that institutional stability is a consequence of the increasing returns that follow from an initial choice in a particular institutional direction, with the resulting positive feedback loops indirectly and inadvertently operating to create institutional inertia (Breznitz 2010). This phenomenon of positive feedback means that "the probability of further steps along the same path increases with each move down that path…because the relative benefits of the current activity compared with the once-possible options increases over time" (Pierson 2004, p.21). These increasing returns arise in many forms, including:

- the large start-up costs of formal institutions and sunk costs of associated rules and structures, so once institutions are established actors are not likely to seek to change them.

- learning and coordination effects, so that once a particular policy style or decision making approach has been institutionalised, actors accumulate knowledge about how it works, become more familiar and comfortable with it and therefore more hesitant to deviate from it.

- a broader network of institutional complementarities in terms of patterns of action and specialised competencies that develop around the existing institutional and organisational arrangements.

- power feedback mechanisms that see the architects or beneficiaries of the existing structure try and maintain their positions of power.

Contemporary institutional change is therefore necessarily mediated through the existing institutional landscape. This view that 'history matters' recognises that today's behaviour and options are constrained by the aggregation of past actions and decisions. From this perspective, "institutions…do not determine how actors perform but constitute a repertoire of acceptable course and alternatives of action that give actors a more or less wide scope in which to operate and make decisions" (Dolata 2013, p.79). As such, the path dependence concept emphasises that institutional change cannot simply be planned and implemented 'by design'. Rather, institutional change will necessarily need to respond to and integrate with existing formal and informal institutions.

The notion of path dependency has become critical to discussions of institutional change. However, the concept is ultimately more useful in explaining institutional continuity than institutional change. As Djelic and Quack describe, path dependence arguments "tend to focus on mechanisms that anchor and stabilise trajectories, while paying less attention to the sources and mechanisms of change" (2007, p.162). Pierson similarly notes that in failing to specify the mechanisms of change, "path dependent arguments degenerate into little more than a description of stability" (2004, p.49). Before exploring developments in neo-institutional theory to understand institutional change (Section 2.4), the following section outlines understandings of how fundamental, transformative change unfolds, which is common across both sustainability transitions and institutional theory.

2.3 Sustainability Transitions and Institutional Theory: Stability and Change

Although focused on regime change and institutional change respectively, two distinct conceptualisations of how transformative change unfolds have emerged as common to both areas of scholarship; punctuated equilibrium and incrementalism.

The first understands fundamental change as unfolding via a punctuated equilibrium model, which characterises the system as existing in a relatively static equilibrium, whereby incremental adjustments can be made in response to internal or external perturbations without changing the organising and underlying paradigm (Geels and Schot 2007; Smith et al. 2005). The 'punctuations' refer to abrupt periods of rapid and radical change which occasionally erupt and disturb the equilibrium (Gersick 1991). Although such system shocks could theoretically occur endogenously, such as via the failure of critical infrastructure or a change in user preferences, much more often these periods of rapid change are characterised as the result of external system shock such as nature disasters, war or financial collapse.

Following this framework, the system exists in a state of dynamic equilibrium, and incremental changes contribute to the ongoing stability of the system, with fundamental or transformative change reliant upon exogenous shocks. From this perspective, institutional or regime change is limited to rare, radical ruptures or reorientations. These models of discontinuous change use terms such as 'exogenous shocks' (Smith et al. 2005), 'critical junctures' (Capoccia and Kelemen 2007) or 'windows of opportunity' (Geels 2011; Smith et al. 2010) to refer to an alignment of circumstances that challenges the status quo and allows

a fundamentally new regime or institutional configuration to take hold.

Across both branches of scholarship, the limitations of punctuated equilibrium models of change are increasingly recognised. Firstly, they effectively exclude endogenous sources of change and are therefore unable to account for more incremental or evolutionary change models (Djelic and Quack 2007). A second and related shortcoming is that these models do not grant actors any ability to change the system during its stable phase (Breznitz 2010). In addition, the observation that "exogenous shocks do not always result in institutional change, and institutional change does not always come from such shocks" (Van der Heijden 2010, p.231), points to the stability and persistence of regimes and institutional frameworks *despite* significant system shock. Thus punctuated equilibrium frameworks, as currently presented in both transitions and institutional theory, are unable to explain the circumstances whereby, or the mechanisms through which, new regimes or institutional structures are introduced and mainstreamed.

In light of these critiques, there is a need for a more nuanced examination of regime and institutional change, particularly in absence of an unexpected system shock (Brousseau and Raynaud 2011; Dolata 2011; Mahoney and Thelen 2010; Streek and Thelen 2005; Greif and Laitin 2004). While punctuated equilibrium models offer useful insight, the framework is unable to account for all types of change, and there is a consequent need to examine gradual and endogenous change processes in more detail (Dolata 2011; Smith et al. 2010; Markard and Truffer 2008).

An alternative conceptualisation of how system change unfolds is embodied in the concept of incrementalism. First emerging in the political sciences, the concept of incrementalism was used to draw attention to the plurality of actors involved in the policy-making process and the resulting tendency to build on and modify past policies rather than introduce wholescale change (Lindblom 1979). This more evolutionary approach to both regime and institutional change is consistent with the path dependence phenomenon, whereby technologies and other innovations incrementally improve along existing trajectories, being already adapted to and compatible with the broader operating context (Geels and Raven 2006; Kemp 1994). Reflecting on insights from technology and innovation studies, Kemp notes that only rarely "did radically new products constitute a radical break with the past" (1994, p.1038).

The literature on sustainability transitions and transitions governance draws on this insight, observing that when examining change processes over long time scales, the punctuations of radical change can be easily identified. However, when examined in more detail over the shorter-term, the punctuations appear to be comprised of many small incremental changes that eventually build up to a punctuation. The characterisation of a system as being in a state of stability or change is therefore a matter of perspective. In ultimately understanding regime change as more 'evolution than revolution' (Rotmans et al. 2001), the literature on transitions governance explores the possibility of steering these incremental changes towards a broader system transformation. This is taken up more directly by TM scholars,

who advocate for the development of a radical vision, and then moving towards this vision in an incremental way (Kemp et al. 2007). Characteristic of TM is that it seeks to achieve structural change gradually, as a way to minimise the possibility of social resistance (Frantzeskaki et al. 2012; Rotmans et al. 2001).

These two archetypes of change are useful, providing broad conceptualisations of how regime change may unfold. However, in order to understand regime and institutional change in more detail, there is a need to go beyond these general descriptions and explore the mechanisms and dynamics of transformation in both models. Additionally, current scholarship generally presents these two types of change as dichotomous (e.g.: Matutinović 2007), and further exploration is needed to assess the extent to which these two models may coexist. The following section explores developments within institutional theory, and used by transitions scholars, that explore the incrementalism pathway of change in more detail

2.4 Neo-institutional Theory: Explaining Gradual Institutional Change

Recognising the limitations of traditional institutional theory in explaining the processes and mechanisms of institutional change, an emerging body of work, here referred to as neo-institutional theory, has evolved to focus more specifically and systematically on questions of institutional change (Campbell 2004). Growing out of the literature on path dependency, a number of theorists have emerged (predominantly from political science) to explore the gradual evolution of institutions (Streek and Thelen 2005; Pierson 2004; Clemens and Cook 1999; Thelen 1999). A significant contribution of neo-institutional theory to date has been identification of a process termed 'gradual transformative change' (**GTC**),[1] which recognises that institutions change in subtle and gradual ways, and posits that the bulk of institutional change occurs incrementally, yet can nonetheless have transformative, radical results. As Dolata states, "that which after ten, twenty or thirty years appears to be radical socio-technical change is in fact the result of longer search and restructuring processes…constituting radical shifts proceeding in a gradual way" (2011, p.5).

Gradual yet transformative change frameworks recognise that institutions are not rigid, static entities, but rather are continually produced and reproduced by relevant actors (Giddens 1984). As a result, each production and reproduction provides an opportunity to change, albeit slightly, the institutional framework. Even North's seminal work in this area states that the process of institutional change is "overwhelmingly an incremental one" (1990, p.83) achieved through "continuous marginal adjustments" (1990, p.101). The GTC approach suggests that these incremental changes can eventually (although may not always) add up to radical or transformative system change. From this perspective, "fundamental changes are not necessarily discontinuous or the result of a sudden shift, but can evolve out of a process of continuous incremental change" (Meijerink and Huitema 2009, p.30).

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[1] Also called 'gradual but consequential change' (Djelic and Quack 2007), 'incremental change with transformative results' (Streeck and Thelen 2005) and 'gradual transformation' (Dolata 2013).

Importantly, GTC theories provide a means of explaining endogenous processes of institutional change. Theories of GTC are also consistent with Scott's broad sociological understanding of institutions (2008), which confirms that institutional change is not simply a matter of repealing and introducing regulation. Rather, formal rules derive essential meaning and legitimacy from the underpinning cognitive and normative rules, which are both invisible and rely on socio-cultural transmission, and by their very nature evolve slowly and incrementally. To this end, Lanzara notes that "due to cognitive and behavioural inertia, an abrupt switch to a new institution or code is [often] not followed by a prompt adaptation of informal, ingrained practices and habits" (1998, p.21). Given the inextricable link between formal and informal institutions, lasting institutional change requires corresponding and complementary change in the cultural-cognitive and normative dimensions, which is only achieved slowly over time. Theories of GTC thus provide a framework that can account for this more evolutionary type of change.

Mahoney and Thelen (2010) have become leading theorists in the area of GTC, and building on the work of Streek and Thelen (2005), identified four modes of institutional change (displacement, layering, drift, conversion). They suggest that the prevailing political context, existing institutional landscape and the characteristics of key actors will determine which mode of institutional change emerges in a particular situation. Consistent with structuration theory, Mahoney and Thelen assert that gradual yet continual institutional change occurs in the 'soft space' between a rule and the interpretation of that rule by actors (2010).

Displacement, as the name suggests, occurs when there is a removal of the existing rules and introduction of new ones. Whilst this type of change will often be abrupt, it can also be a slow-moving process, such as when new institutions are introduced and directly compete with, rather than supplement, an older set of institutions (Mahoney and Thelen 2010). By contrast, layering is the introduction of new rules to supplement existing rules and occurs when "new rules are attached to existing ones, thereby changing the ways in which the original rules structure behaviour" (Mahoney and Thelen 2010, p.16). Layering involves amendment, revision or addition to existing rules, rather than wholesale replacement, and typically occurs when actors work within the existing system to introduce change, either because this is the preferred strategy, or because they lack the capacity to directly challenge the existing framework (Mahoney and Thelen 2010).

Drift occurs when the rules remain formally the same but their impact changes due to shifts in the broader environment (i.e., at the macro landscape level). This type of change could arise when the prevailing institutional framework fails to respond to changes in the broader landscape, with such inaction changing (or minimising) the impact of the institution. Conversion occurs when the rules remain formally the same but are interpreted and enacted in new ways, that is, they are strategically redeployed by actors. The strategy of conversion differs from drift in that the gap between the rules and their enactment is not driven by neglect (as with drift), but rather is produced by "actors who actively exploit the inherent ambiguities of the institutions" (Mahoney and Thelen 2010, p.17).

This provides one model through which to examine gradual institutional change. It needs to be empirically tested across diverse contexts to refine and elaborate the concepts and assess their utility in explaining change. Further exploration of this model in the context of transformative system change is contained in Chapter 8.

2.5 Applying Mechanisms of Institutional Change

In addition to providing scholarly insight into transformative system change, the sustainability transitions literature also has a strong 'real world' agenda in seeking to gain insight into the possibilities for influencing the direction and pace of transformational change to more desirable directions (Rotmans and Loorbach 2009). To this end, transitions scholars are beginning to draw from the environmental governance literature to better understand the dynamics of governance systems and more specifically, the governance of transformation (Rogge and Reichardt 2016; Pahl-Wostl 2015). There is a particular focus on environmental governance via policy mixes, which seeks to understand into how to deliberately design instrument mixes to achieve policy goals (Jordan and Huitema 2014; Howlett and Rayner 2007). As Kivimaa and Kern observe, such examination has the potential to offer insight into "policy mixes fostering 'directed' transitions towards more sustainable socio-technical systems" (2016, p.206).

The term 'policy mix' in this context refers to the 'tools of government', which is broadly defined to include the whole suite of mechanisms and instruments available to give effect to public policies, of which formal rules (institutions) are a key part (Taylor et al. 2012). In addition to traditional command-and-control regulation, this also includes policy instruments, market mechanisms, targeted information provision and voluntary measures (Freiberg 2010; Gunningham 2009; Salamon 2002).

To advance the institutional change agenda, transitions scholars are increasingly looking to literature on environmental governance to inform the design of policy mixes to best support sustainable transformation in different contexts. As a first step towards this overall goal, a number of recent studies have applied Mahoney and Thelen's institutional change mechanisms in the context of contemporary sustainability challenges.

A key contribution in this regard is the recent paper of Geels et al. (2016) that considers the operation of the institutional change mechanisms in the context of sustainability transitions. More specifically, the paper considers the typology of transitions pathways presented by Geels and Schot (2007), and examines the dynamics between actors, institutions and technology in more detail. The authors confirm that there are different pathways of endogenous change, and suggest that a transition can in fact change pathways over the course of the transition process (Geels et al. 2016). Geels et al. use the four modes of institutional change identified by Mahoney and Thelen as overall patterns of change to examine how interactions between actors, rules and technologies result in different transition trajectories (2016). The analysis therefore charectarises each trajectory as dominated by one particular mode of institutional change.

These mechanisms of change have also been applied by environmental governance scholars in relation to designing policy mixes. For example, Howlett and Rayner characterise conversion, layering and drift as factors that minimise coherence between policy instruments, thus constituting significant challenges for designing a coherent policy mix (2007). They explain these factors as the result of needing to navigate previous policy choices that have become institutionalised (Howlett and Rayner 2007). Importantly however, there seems to be some diversity with regard to the application of these mechanisms of change in the literature. For example, Howlett and Rayner (2007) use a different definition of conversion as compared to Geels et al. (2016), with the former understanding conversion as denoting change in instruments without altering goals, while the latter takes an opposite understanding that conversion occurs when policy goals are adjusted without altering instruments. Interestingly, Howlett and Rayner's characterisation of the four mechanisms has been adopted and applied by transitions scholars. For example, in examining low energy policy mixes in Finland and the United Kingdom, Kivimaa and Kern found that policy mixes for sustainability transitions should include policies both for creating strong niche-innovations and for destabilising the existing dominant regime (2016). For this research, Mahoney and Thelen's framework is adopted, and the conceptualisation of each of the mechanisms as proposed by those authors (summarised in Section 2.3) is applied.

While these papers provide a valuable foundation for exploring the role of institutional change mechanisms in the context of broader system transformation, such exploration remains in its infancy, with only a handful of studies to date. As such, there remain a number of unanswered questions. In particular, there remains scope to consider how the institutional change mechanisms operate within a particular transition pathway (rather than being used as overall archetypes of change). The studies outlined above have also only considered formal rule changes. Whilst this is a useful starting point, given that institutions are comprised of culture, structure and practice domains, it is important to understand how they all change, and how change in each domain interacts and co-evolves with change in the others if we are to develop a more comprehensive picture of how institutional change unfolds in a sustainability transition.

Figure 5 synthesises this brief introduction to the main theoretical bodies that inform this research, showing where the research question and conceptual framing is positioned within the literature.
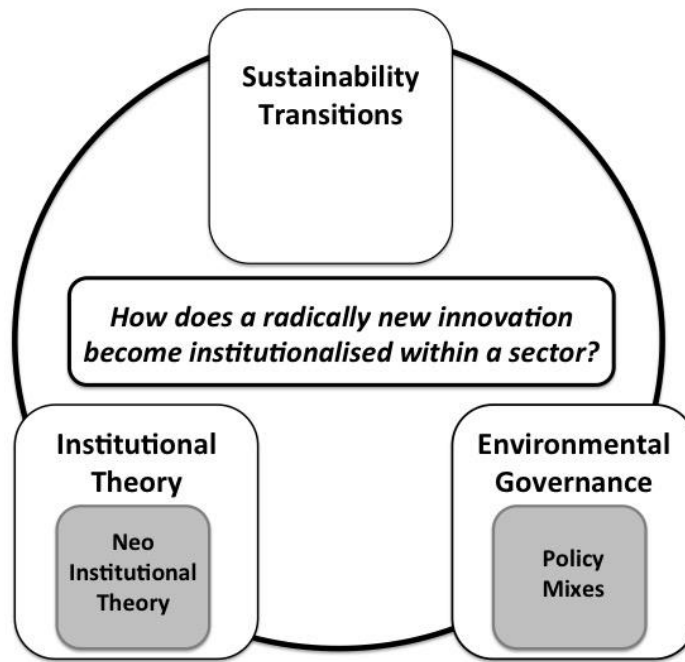
Figure 5: Theoretical positioning of the thesis

The complementary discussions unfolding in each of the sustainability transitions, institutional theory and environmental governance literatures provide valuable insights relevant to the research question. In seeking to explore institutional change processes within a complex adaptive system, the overall research question is primarily framed by the sustainability transitions literature. From this starting point, it then draws on institutional theory, and in particular the recent insights from neo-institutional theory, to assist the identification and examination of mechanisms of institutional change. In order to assist the development of practical insights that can inform real-world sustainable transformation processes, the research also draws on the environmental governance scholarship and the literature on policy mixes.

3. Research Methods

3.1 Research Approach

This research is informed by the real world challenge of transformation in urban water systems and to this end, institutionalising radically new innovations and practices as the new 'business as usual'. The concept of IWRM is introduced as an alternative vision for urban water servicing that takes a more holistic and integrated approach to water management itself while also using the delivery of water services to help meet a diverse range of sustainability and liveability outcomes more broadly. The research is therefore explicitly normative, aiming to develop insights into institutional change processes that can support and facilitate the realisation of this alternative vision.

Given the real world context of the research problem, this research embraces a pragmatist philosophy which relies on engagement with both theory and practice (Creswell 2009). Pragmatic research focuses on a particular social issue and utilises whichever research methodologies are considered most useful for revealing insights on solutions that could best address the associated problems (Patton 1990). Pragmatic approaches are also useful when both academic and practitioner knowledge are considered valuable for developing answers to practical questions (Denscombe 2008).

In adopting a pragmatist philosophy, the research was undertaken from a perspective in which core realities about urban water system problems are acknowledged (particularly in relation to biophysical dimensions), alongside understandings that these problems occur within social, historical and political contexts that involve socially constructed realities (Creswell 2009).

3.2 Multiple Case Study Design

As an under-explored area of research, the question of how radical innovations become institutionalised lends itself to exploration via qualitative methods. This is because a qualitative research approach facilitates a holistic, complex and detailed understanding of a phenomenon within its real-world context, and ensures that all relevant variables (especially those that may not be immediately apparent) are considered in the analysis (Creswell 2007).

Creswell (2009) identifies five approaches to qualitative research: narrative research, ethnography, phenomenology, grounded theory and case study research. A multiple case study design has been adopted for this research, which is regarded as a valuable methodological approach when there is limited information about the phenomenon of interest (Eisenhardt 1989), and particularly so when investigating longitudinal change processes (Van de Ven 2007).

The overall aim of this research is to identify macro level trends and patterns in relation to the institutionalisation process. As previously noted, there is currently limited understanding of institutional change processes in the context of transformative system

change. As such, this research aims for breadth rather than depth. That is, the goal is to develop a broad understanding of the process by which radical innovations become institutionalised and to articulate an overarching framework for the institutionalisation process. Case study methods produce results that can be used to both describe and explain these system changes (Yin 2009), which has the potential to then inform theoretical generalisations with implications for strategic action to support institutional change. Further, a multiple case study design enables an examination of institutionalisation across a number of contexts and therefore facilitates identification of overarching trends and patterns in the institutionalisation process.

This research approach is represented in the top right corner of Figure 6, below. A holistic multiple case study approach was adopted, whereby each case consists of a "'whole' study, in which convergent evidence is sought regarding the facts and conclusions for the case" (Yin 2009, p.56). The results of each case study are compared and contrasted in order to generate insights about the operation of institutional change in the context of sustainability transitions. The results of multiple case study research are generally considered to be more robust and therefore more compelling than a single case study (Yin 2009).
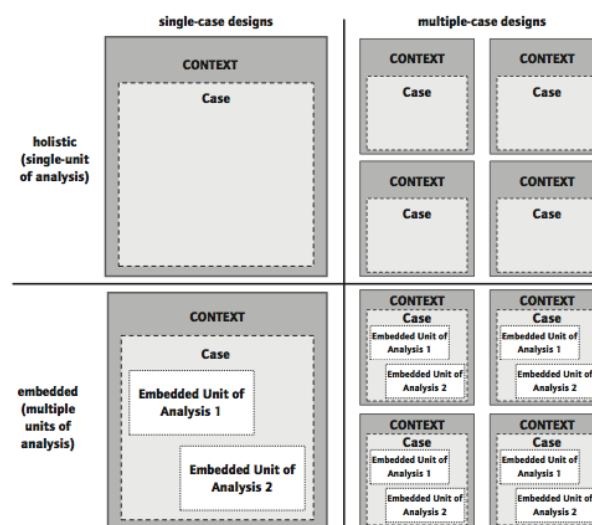
Figure 6: Case study designs
(Yin 2009, p.46)

3.3 Case Study Selection

A purposeful sampling strategy was adopted for this research (Patton 1990) in order to examine notable examples of successful institutionalisation of a radical innovation and thereby facilitate the development of a framework to explain the dynamics and mechanisms of this process. In seeking to examine longitudinal change processes, it is necessary that the phenomenon of interest, being the institutionalisation of a radical innovation, is close to completion in each case and is therefore "transparently observable" (Van de Ven 2007, p.212).

A key challenge in selecting cases is that an entire system transformation can take up to 50 years, and can therefore only be identified with the benefit of hindsight once the stabilisation phase has established a new sectoral norm. Nevertheless, an examination of contemporary cases of transformative change remains useful for generating insights into the process of institutional change in enabling sustainability transitions. In addition, the selection of contemporary case studies enables access to relevant actors and stakeholders able to speak to the institutionalisation process, as well as a wide range of records and documentary evidence, both of which can facilitate a more reliable assessment of institutional change processes.

For contemporary cases of transformation, identifying appropriate case studies is an empirical question. For this research, each of the cases must have change across the culture, structure and practice dimensions that is 'past the point of no return' so that the innovation is relatively embedded and in an acceleration phase. That is, reversal or repeal of the innovation is highly unlikely, given the cultural and structural change that sustains it.

Three Australian cities were selected as case studies for this research, as outlined below. All cases examine the evolution and embedding of a radical innovation in the urban water sector. As the transition in each city is not yet complete, it is impossible to know how the transformation will ultimately unfold. Issues of power, institutional inertia and stranded assets could all influence the outcome of the transition process, and the extent to which it is considered transformational. Yet while the change process in each city is ongoing, the transitions are each considered to have passed a tipping point (Rotmans and Loorbach 2010b), with all three cities having entered an acceleration phase, evidenced by technological and policy change, an expanded actor network and widely diffused practice change.

The case studies are:

1. Stormwater harvesting in Adelaide – this case study examines the institutionalisation of stormwater harvesting as a fit-for-purpose water source from 1990 to present.

2. Urban stormwater quality management in Melbourne – this case study examines the institutionalisation of water sensitive urban design as a means of improving stormwater quality from the 1960s to present.

3. Urban stormwater quality management in Brisbane – this case study examines the institutionalisation of water sensitive urban design as a means of improving stormwater quality from 1960s to present.

The temporal boundary of each case is determined by the emergence of a narrative around the challenge that the relevant innovation sought to address. For example, a concern about poor water quality in 1960s Melbourne led to the emergence of water sensitive urban design

as a (partial) solution, and as such, examination of the institutionalisation process in Melbourne begins from the 1960s in order to capture this emerging cultural shift.

3.4 Case Study Contexts

The geographical location of each of the case study cities is presented in Figure 7.
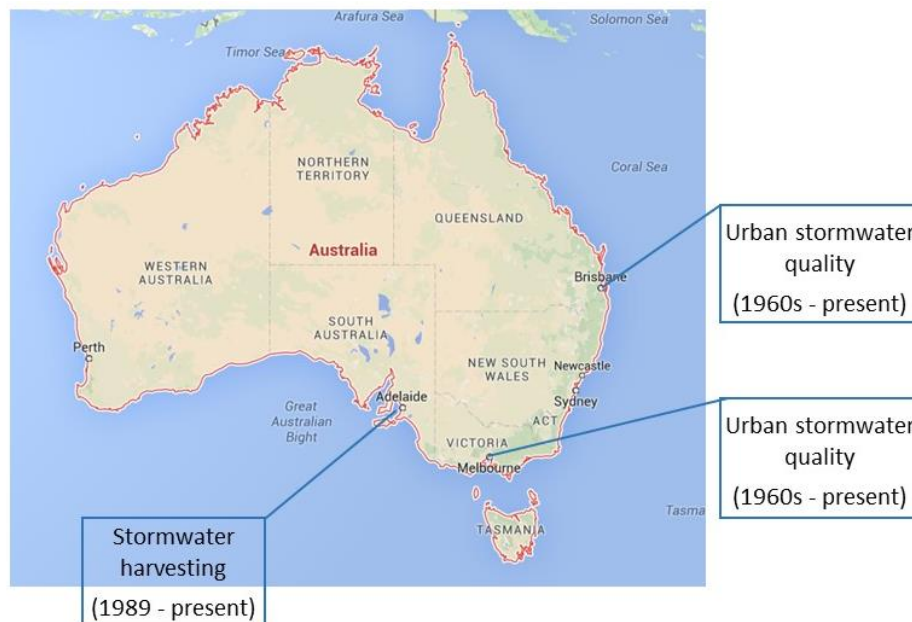
Figure 7: Case study cities

3.4.1   Melbourne

Melbourne is Australia's second largest capital city, with a population over 4.4 million. Responsibility for water quality is shared between Melbourne Water Corporation, a government-owned statutory authority that manages regional drainage (catchments greater than 60ha and trunk drainage) and the 38 metropolitan municipalities that are responsible for managing stormwater drains (catchments smaller than 60ha and minor drainage) and local stormwater pollution. An awareness of poor waterway health emerged in the early 1970s, and the water sector has gradually responded by developing and adopting a number of innovative, decentralised technologies for stormwater quality improvement that are now becoming institutionalised as part of mainstream water management across the city (e.g., Donofrio et al. 2009; Mitchell 2006; Wong 2006). This has transformed the traditional model of centralised drainage via large, highly-engineered systems towards a more integrated and decentralised approach that uses small-scale, biological treatment systems distributed throughout the city to capture and clean stormwater. This approach is known as Water Sensitive Urban Design (**WSUD**). Over the transition period, Melbourne was significantly affected by the millennium drought (1997-2009), which necessarily focused attention on water security with the potential to adversely impact the institutionalisation of this alternative approach.

3.4.2 Brisbane

Brisbane (Queensland) is situated within South-East Queensland (**SEQ**), a large, urbanised region on the Pacific coast of Australia. As with Melbourne, the case study period extends from the early 1970s when concern for water quality first emerged until the present day. Over this time, SEQ became (and remains) one of Australia's fastest growing regions, with a current population of over 3.05 million. Brisbane's transition has also involved the development and adoption of WSUD approaches as a means of improving stormwater quality across the city's waterways (Rahman and Taylor 2000). This represents a significant departure from the conventional highly-engineered and linear approach to stormwater that sought to channel stormwater swiftly out of the city and into receiving waterways, to a decentralised approach that retains stormwater in the landscape as a means of providing improved ecology and amenity outcomes.

Brisbane has had a particularly challenging transition process, significantly affected by the millennium drought, as well as severe floods in 2011 resulting in 35 deaths and AU$2.38 billion in damage (Carbone and Hanson 2012). The city was again subject to severe flooding in 2013, causing significant property and infrastructure damage. Additionally, there has been much organisational upheaval over the case study period, with a number of municipal government amalgamations. In 2008 there was also a significant sector-wide restructure, which removed bulk water and sewage responsibilities from local government (Walton 2009). However, over the entire case study period, responsibility for stormwater drainage and quality has remained with municipal councils. Brisbane City Council (**BCC**) is the largest municipal council in SEQ in terms of both area covered and population served (over 1 million residents).

3.4.3 Adelaide

Adelaide (South Australia) is the driest Australian capital city and characterised by a Mediterranean climate with moderate rainfall over winter and hot, dry summers. It currently has a population of 1.25 million. In contrast to Brisbane and Melbourne, Adelaide's transition journey is focused on the capture, treatment and storage of stormwater as a fit-for-purpose water source. In Adelaide, stormwater drainage is the responsibility of municipal councils, with water supply and wastewater services provided by state-owned entity SA Water. Beginning in the late 1980s, a number of municipal councils began investigating options for stormwater capture and reuse, and there are now a number of large-scale schemes operating across the city. The introduction and diffusion of stormwater harvesting schemes across Adelaide has unfolded swiftly, significantly assisted by the record-breaking millennium drought (1997-2009) that severely affected the south and east coast of Australia.

3.5 Research Design

The research design for this project is presented in Figure 8.
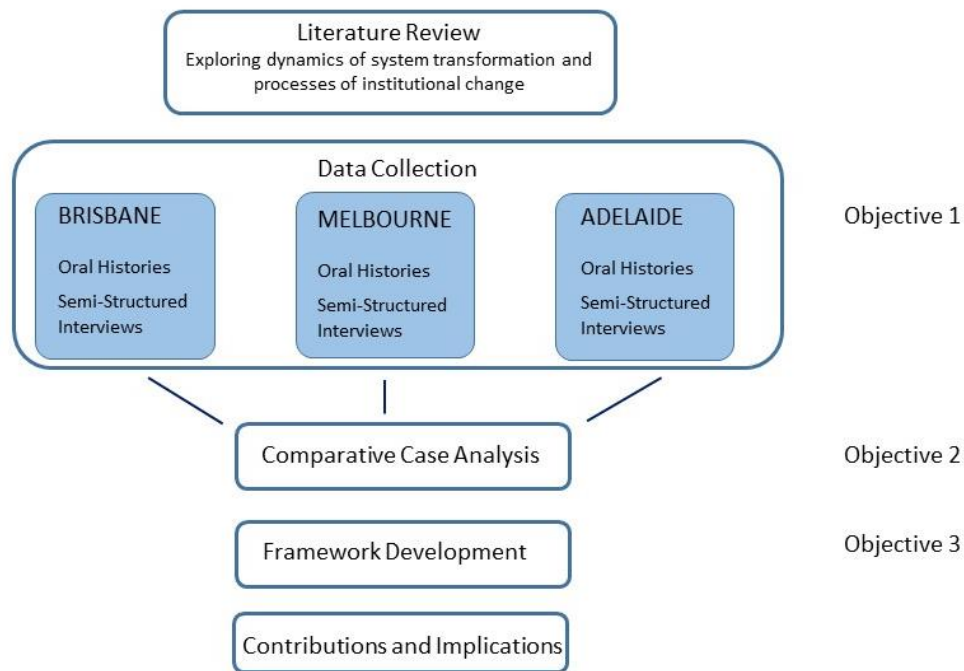
Figure 8: Research Design

3.5.1   Primary Data

Primary data was collected through oral history and semi-structured interviews with actors who had been directly involved in the changes in their respective city's urban water systems over the relevant time period. Interviewees were identified through a search of industry literature and a snowball sampling process of peer recommendation (Creswell 2007). Interviewees represented a range of perspectives and stakeholder groups, including state government, water utilities, local municipalities, private sector and academia. The individuals interviewed all held middle to senior level positions and had extensive experience in the water sector of their city. All interviewees were able to speak to various aspects of the emergence, evolution and implementation of the innovation in their city, including culture and structure changes, institutional changes and barriers and challenges to implementation of the innovation. Table 1 provides a summary of the interview details, detailing the number of interviewees from each stakeholder group.

Table 1: Interview details

	BRISBANE		MELBOURNE		ADELAIDE	
	Oral History	Semi-Structured	Oral History	Semi-Structured	Oral History	Semi-Structured
Water Utility	-	2	1	2	1	2
State Govt	-	3	1	2	2	4
Local Govt	2	2	1	3	1	5
Consultant	1	6	2	4	2	3
Academia	2	1	-	2	-	1
Civil Society (NGOs; community)	1	2	-	1	-	1
TOTAL	**6**	**16**	**5**	**14**	**6**	**16**

Interviewees were approached directly where their details were publically available, otherwise permission to contact potential participants was sought from senior organisational representatives. Interviewees were guaranteed anonymity and confidentiality to maximise their comfort and confidence in speaking freely with the researcher. All procedures associated with the interviews (including approaching potential interviewees, conducting the interviews and maintaining confidentiality) complied with the requirements of the Human Ethics Certificate of Approval (CF14/1402 – 2014000657), granted by the Monash University Human Research Ethics Committee.

The same data collection protocol was adopted in each city. This began with oral history interviews with between 5 and 6 key individuals who had direct involvement with the emergence and implementation of the particular innovation in each case. Oral history interviews were recorded as free-flowing narratives, detailing personal accounts of the emergence and growth of the relevant innovation in each city (Blaikie 2009; Fontana and Frey 2008). A detailed case history was then constructed for each city by synthesising primary data and documentary evidence. The case histories were then validated through a member-checking process, whereby the case histories were reviewed by the relevant participants in order to ensure the accuracy and credibility of the account (Creswell 2007).

Following validation, approximately 15 semi-structured interviews (Blaikie 2009) per case were conducted with key individuals across relevant stakeholder organisations able to speak to the process of cultural and structural change leading to the implementation of the relevant radical innovation. The interviewees were asked questions focused on significant transition points in the trajectory towards institutionalisation of the innovation, culture and structure changes, impediments and challenges, and how impediments to institutionalisation were overcome. In both the oral history and semi-structured interviews, the researcher asked open-ended questions designed to stimulate the personal accounts

and perspectives of the interviewees, and took the opportunity to probe for further detail to explore topics in more depth when necessary.

Primary data collection was conducted sequentially in each city, beginning in Brisbane (June – September 2014), followed by Melbourne (October – December 2014) and finishing in Adelaide (March – June 2015). Interviews were typically 45 to 90 minutes in length and were conducted in the participant's private office at their workplace. The interviews were audio-recorded by a digital recorded (with written consent from each interviewee). The recording of each interview was fully transcribed by an independent transcription contractor. Detailed notes were also taken by the researcher during the interview and summary notes were documented shortly following the interview to capture the researcher's initial reflections.

3.5.2   Secondary Data

Secondary data included academic literature, historic and current policy and regulatory documents, legislation, organisational publication and records, media materials and documentation covering each case study city's urban water sector. The documentation was collected through desktop searches of the internet and academic databases. Secondary documentation was compiled and catalogued for reliable access during the research.

3.5.3   Data Analysis

The data analysis process occurred in three stages. First, a case report was produced for each city. Second, a transition analysis of each case was undertaken and third, a comparative analysis of the three cases was conducted.

To develop the case report, the content of the interview transcripts (both oral history and semi-structured interviews) and secondary documentation was first analysed to construct a chronological account of the emergence, diffusion and institutionalisation of the radical innovation in each city. This data analysis was undertaken during and after the data collection process, iteratively developing the narrative with each new piece of evidence. A number of analytic approaches were used for development of the case report, including developing a descriptive case framework and conducting a time-series analysis to trace how events unfolded over time (Yin 2009). Data was triangulated to corroborate the findings and any contradictions were further investigated to ensure accurate interpretations were made (Creswell 2007). The case study reports, including the chronological account of the innovation and some preliminary case analysis, were then reviewed by all relevant interviewees for validation and refined accordingly.

These chronological narratives of each case were used as a base for mapping and analysing the transition process of each city, culture, structure and practice changes and institutional change mechanisms. For the second part of the data analysis, each of the case narratives was analysed using: (1) the multi-phase perspective, (2) the culture, structure and practice framework and (3) Mahoney and Thelen's institutional change mechanisms. Finally, a cross-case comparison of the innovation and institutionalisation trajectories of each city was undertaken to develop theoretical insights about the mechanisms of institutional change to

support the institutionalisation of radical innovations. The primary data were coded to identify relevant themes and patterns and a variety of analytic techniques were used to ensure the robustness of the case study comparison, including developing and examining rival explanations for the observed phenomena, pattern matching and cross-case synthesis which aims to aggregate findings over a number of single case studies (Yin 2009).

3.5.4   Validity and Reliability

To address the potential limitations of case study research, a number of verification processes were adopted to ensure the validity of the data collection and analysis. As a starting point, case study protocols were initially designed to ensure that all potential issues were considered prior to the data collection phase of the research. In addition, a database was established as a means to organise and document all the data collected during the research.

As described in the preceding sections, each of the methods in this research drew on multiple sources of evidence to develop converging lines of inquiry. Construct validity of each of the narratives was ensured by triangulating different data sources to build converging narratives from different interviewee perspectives and the secondary documentation (Yin 2009). In addition, chains of evidence were maintained so that conclusions of the research could be traced back to the initial questions (and vice versa), with clear cross-referencing to the data collection procedures and evidence obtained.

External verification of the construct validity of the narratives and preliminary analysis for each of the cases was achieved in two stages. First, the chronological case narrative was presented to each of the interviewees that had participated in an oral history interview, and collectively, were instrumental to the institutionalisation of all innovations studied. Second, the further developed case reports, which included the chronology as well as some preliminary analysis in relation to (1) transition phases, (2) culture, structure and practice changes, (3) extent of the innovation's institutionalisation and (4) the institutional change mechanisms, were sent to all interviewees (from both oral history and semi-structured interviews) for review and critique. Interviewees reviewed the preliminary conclusions presented and critiqued aspects of the analysis which was refined accordingly.

Internal validity involves seeking to establish valid and authentic causal relationships, and ensuring relationships have not been misinterpreted (Yin 2009). Rigorous analysis of the data is key to ensuring internal validity. The research therefore used a range of analytic techniques, including pattern matching and explanation building. Analysis focused on the most important aspects of the studies and interpretations addressed all the available evidence. Rival explanation were tested to further ensure internal validity of the findings.

A key concern about the case study method relates to its capacity to provide a sufficient basis for generalisation. In response, Yin (2009) notes that case studies do not represent a population 'sample' or aim to provide statistical generalisation. Rather, good case studies

provide a basis for analytic generalisation, with the goal being to expand and generalise theories.

4. Publication 1: Pathways of System Transformation: Strategic Agency to Support Regime Change

4.1 Introduction

This chapter contains the first thesis publication.   It presents a cross-case comparison across the three case study cities exploring the dominant patterns of change in each case. The paper provides a detailed exploration of the dynamics of change in each case, focusing on the co-evolution of change within and across the culture, structure and practice domains. It also examines the relationship between institutional change and agency in each case, considering how actors interacted with existing and emerging institutions.

The results indicate that each domain of change can provide significant momentum to support a transition effort. Drawing on this insight, the paper presents a typology of transitions, identifying the strengths, vulnerabilities and goals of agency characteristic of each pattern. This provides some initial insight into the dynamics of culture, structure and practice changes, and how such changes evolve to support a transition effort. The paper confirms the importance of pursuing and ultimately achieving fundamental change in all three domains in order to provide a robust and mutually reinforcing transition foundation.

The outcomes of Publication 1 contribute to the first research objective of this thesis, being to "identify patterns and dynamics of institutional change in cases of successful institutionalisation of a radical innovation".

The paper presented in this chapter has been published in *Environmental Science & Policy*.

4.2 Declaration for Thesis Chapter 4

Declaration by candidate

In the case of Chapter 4, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Formulation of the research problem, research design, data collection and analysis, interpretation of results, writing the paper	80%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
Rebekah R. Brown	Participation in formulation of the research problem, participation in the interpretation of results, providing feedback on the written manuscript	N/A
Derk Loorbach	Participation in formulation of the research problem, participation in the interpretation of results, providing feedback on the written manuscript	N/A

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work.

Candidate's Signature		Date 26/10/16

Main Supervisor's Signature		Date 26/10/16

4.3   Manuscript

Pathways of system transformation: Strategic agency to support regime change

Lara Werbeloff[a,*], Rebekah R. Brown[b], Derk Loorbach[c]

[a] School of Social Science, Monash University, Melbourne, Australia
[b] Monash Sustainability Institute, Monash University, Melbourne, Australia
[c] Dutch Research Institute for Transitions, Erasmus University, Netherlands

A B S T R A C T

There is a well-recognised need to transform existing systems of production and consumption towards a more sustainable orientation. However, there is much uncertainty about how to achieve sustainability transitions in practice, and what transition advocates and actors can do to catalyse and steer regime transformation. We therefore need evidence of how transitions are operationalised, in order to better understand the on-ground dynamics of regime change. To address this gap, this research paper examines three contemporary cases of transformational change in the Australian urban water sector and the dominant strategic approach to change adopted in each city. It focuses on the strategic behaviour of actors, in particular examining how agents navigate and respond to the opportunities and constraints of their context, and what initiatives (or combination thereof) can facilitate innovation diffusion and regime transformation. The results reveal three distinct patterns of change, each of which favour particular strategic interventions by transition proponents.

In order to incubate transformational change, the results suggest that actors may be best served by initially employing strategies that are immediately compatible with their existing context. However, examination of the strengths and weaknesses of each pattern confirm that no single strategic approach is in itself sufficient, and in order to embed a novel innovation and bring about regime change, actors will eventually need to broaden the range of interventions used. The results also reveal the possibility of a 'pattern-dependence' that actors need to deliberately work to overcome in order to fully mainstream the desired change. These findings therefore provide insight into the links between regime transformation, patterns of change and actor strategies while also offering practical guidance that can be used to inform the design and implementation of regime transformation agendas and programs.

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1. Introduction and background

Sustainability innovations are critical to addressing complex and interrelated problems such as climate change, environmental degradation and natural resource limitations. Such innovations can be technological, social or organisational in nature (Kemp et al., 2000), and should go some way to protecting or minimising the impact of human activities on the environment (Shrivastava, 1995). The increasingly urgent need to address contemporary environmental challenges is reflected in persistent calls across policy, practice and scholarly spheres for radical change in sectors as diverse as energy (e.g.: Shaw et al., 2014), water (e.g.: Brown et al., 2013), food production (e.g.: Ruttan et al., 1994) and transport (e.g.:

Geels et al., 2011). In order to meaningfully and effectively address such grand challenges, sustainability innovations must transform mainstream practice.

The relatively young sustainability transitions literature has emerged as a field of scholarship that seeks to understand transformative change processes in socio-technical systems (Rotmans et al., 2001; Geels, 2002; Kemp et al., 2007). A successful sustainability transition relies on socio-technical regime transformation, whereby the dominant means of production and consumption shift towards a more sustainable orientation. Regimes are "strongly embedded and self-reinforcing systems" (Smith and Stirling, 2010, p.13) that are comprised of "coherent, highly interrelated and stable structure[s] characterised by established products, technologies, stocks of knowledge, user practices, norms [and] regulations" (Markard and Truffer, 2008, p.603). A sustainability transition is conceptualised as a shift from

one regime to another, such that the whole network of interrelated technologies, structures, actors and practices change fundamentally and eventually establishes a new dynamic equilibrium. More broadly, it relies on transformation of the cultures, structures and practices of a system (Rotmans and Loorbach, 2009), which refers to the dominant ways of thinking (i.e.: shared narratives and paradigms), organising (i.e.: legal, organisational structures) and doing (i.e.: pilot projects, infrastructure implementation) (Geels, 2002; Werbeloff and Brown, 2016).

The transitions literature, as well as the neighbouring scholarship on science, policy and innovation studies (Martin, 2012), makes clear that regime transformation is difficult to achieve. The well-documented path dependence phenomenon (Dosi, 1982; Nelson and Winter, 1982) presents a significant barrier to regime transformation, with the consequence that innovation and change is typically incremental, rather than radical, given that an initial institutional or technical step often sets the direction towards which "problem solving activity" subsequently moves (Dosi 1982; p.153). This phenomenon of positive feedback means that "the probability of further steps along the same path increases with each move down that path . . . because the relative benefits of the current activity compared with the once-possible options increases over time" (Pierson, 2004; p.21).

Given the path dependent evolution of existing regimes, as well as the inertia that typically charectarises large socio-technical systems, the impetus for radical regime change has often been understood as a large and unexpected system shock, typically caused by factors outside the system (i.e.: drought, flood, financial market crash) (Smith et al., 2005, 2010; Geels, 2011). These 'punctuated equilibrium' models of change characterise the regime as existing in a relatively static equilibrium, during which time the system is able to make incremental adjustments in response to internal or external perturbations without changing the organising and underlying paradigm. The 'punctuations' refer to sudden, revolutionary and discrete periods of rapid change which occasionally flare up and disturb the equilibrium (Gersick, 1991), typically in response to external system shocks.

However, recent commentators have observed that in practice, many systems are largely unchanged by system shock, instead showing remarkable stability and coherence both before and after the event(s) in question (Mahoney and Thelen, 2010; Van Der Heijden, 2010; Brousseau and Raynaud, 2011; Dolata, 2011). This has given rise to a number of critiques of punctuated equilibrium models of change, noting that such theories effectively exclude endogenous sources of change and are also unable to account for more incremental or evolutionary change models (Djelic and Quack, 2007). A second and related shortcoming is that these models of change do not grant actors any ability to change the system during its stable phase (Breznitz, 2010). These critiques, coupled with the oft-observed stability of socio-technical regimes despite system shock, have led to increasing calls for examination of endogenous sources of change.

There have so far been a handful of studies examining pathways of system transformation (e.g.: Smith et al., 2005; Geels and Schot, 2007; de Haan and Rotmans, 2011). These studies present overall archetypes of change based on theoretically derived conceptualisations of how regime transformation may unfold. Although there is a bias towards exogenous explanations of change in these patterns (Geels and Schot, 2007), some notable exceptions include the 'empowerment' and 'adaptation' pathways described by de Haan and Rotmans (2011), and 'endogenous renewal' pattern of change outlined by Smith et al. (2005). In order to better understand the internal dynamics of endogenous regime transformation, there is a need for detailed empirical examination of successful cases of change. As Pahl-Wostl et al. (2013, p.44) note, in understanding regime change, we need to account for "the

interplay between institutional factors and human agency and its translation into the barriers and drivers of societal change".

Thus key to understanding endogenous patterns of regime change is the role of strategic agency, which examines how individuals and groups leverage resources to transform or create new institutions and regimes (DiMaggio, 1988; DiMaggio and Powell, 1991; Battilana et al., 2009). This research responds to calls for further exploration of how strategic agency unfolds in practice (Grin et al., 2011), examining how agents navigate and respond to the opportunities and constraints of their context, and what initiatives (or combination thereof) can facilitate innovation diffusion and regime transformation. To this end, three cases of transformation in the Australian urban water sector were explored; two cases of transition in stormwater quality management and one in stormwater harvesting. Stormwater quality management refers to the use of decentralised, biological treatment systems (i.e.: wetlands and biofilters) distributed throughout a city designed to capture and clean stormwater in order to improve the health of receiving waterways. Stormwater harvesting refers to systems that collect, treat and store stormwater for fit-for-purpose reuse.

The examination focuses on the dominant strategic approach to regime change adopted in each city and discusses the implications for practitioners in relation to innovation diffusion and regime transformation more broadly. From this analysis, three distinct patterns of regime change are identified, as well as the relative strengths and vulnerabilities of each approach. This helps to further understandings of strategic agency in the context of endogenous regime change, and also provides practical insight for cities and sectors around the world grappling with the challenge and necessity of transformation towards sustainability.

2. Research approach

A multiple case study research design was adopted (Yin, 2009) to facilitate the identification of macro level trends and patterns in relation to the transition process and the consequent embedding of a new approach or innovation. Following this design, each case study city is considered a whole case and analysed as such, followed by comparison across cases (Yin, 2009).

2.1. Case study selection

A purposeful sampling strategy was adopted for this research (Patton, 1990) in order to examine notable examples of successful institutionalisation where the phenomenon of interest, being the embedding of a new innovation or practice, is "transparently observable" (Van de Ven, 2007; p.212). A key challenge for transitions research is that an entire system transformation can take up to 50 years (de Haan and Rotmans, 2011), and can therefore only be identified with the benefit of hindsight once the stabilisation phase has established a new sectoral norm. Nevertheless, examination of contemporary cases of transformative change remains useful for generating timely insights that can inform unfolding transitions. In such a circumstance, determining appropriate case studies is an empirical question.

For this research, the selection of each case was based on scholarly observation of the comparatively advanced level of sustainable stormwater management in each city and the large number of reported stormwater treatment and/or capture systems implemented in each city. Melbourne and Adelaide are considered both national and international leaders in terms of stormwater quality management and stormwater harvesting respectively. Brisbane is generally regarded as the second highest performing Australian city in terms of stormwater quality management. In each case, there has been a fundamental shift in the dominant

cultures, structures and practices of the system (as compared to mere optimisations of a traditional water management approach) and all cities are regarded as being past the point of no return on the path towards stabilisation.

2.2. Data collection, analysis and validation

Data collection was conducted sequentially, starting in Brisbane, followed by Melbourne and concluding in Adelaide, from June 2014 to June 2015. A two-phase data collection process was adopted in each city to provide internal validation opportunities within case analyses (Blaikie, 2009; Creswell, 2009).

The data collection process began with a desktop review of historical and contemporary secondary data, including policy documents, legislation, industry reports, organisational literature from key stakeholders, media and scientific literature in order to understand the general city context and construct a chronology of change in each city. Oral history interviews were then conducted with senior individuals who had direct involvement with the emergence and implementation of the particular innovation in each case (Bris-6; Adel-6, Melb-5). The interviewees (both niche and regime actors) each had a long history in the water industry of their respective cities and could speak to significant portions of the transition period. The oral history interviews were recorded as free-flowing personal narratives, detailing significant turning points and developments in the transition journey from the interviewee's earliest involvement until the present day. Drawing on both primary and secondary data, a detailed case history was then constructed for each city and validated through a member-checking process (Creswell, 2007) to ensure the accuracy and credibility of the account.

The second phase of data collection involved semi-structured interviews (Bris-16; Adel-13, Melb-14) with representatives across a range of stakeholder groups, including state and local government, private consultancy, land development agencies, regulators, water industry and academia. Interviewees (again both niche and regime actors) all held senior or executive level positions within their organisations and were able to speak to the process of cultural, structural and practice change leading to the implementation of the relevant innovation. Questions focused on significant turning points in the trajectory towards institutionalisation of the innovation, actor strategies and the evolution of change across the culture, structure and practice domains. Transcripts were coded according to dominant themes.

An updated secondary data review and analysis was undertaken to address issues that emerged as significant and synthesised with primary data. A case report was then produced for each city and analysed individually using a range of analytic approaches, including the development of a descriptive case framework and a time-series analysis to trace how events unfolded over time (Yin, 2009). Case reports containing a case narrative and preliminary analysis were then sent back to interviewees for external validation (Creswell, 2007).

To ensure validity and reliability of the results, the cross case comparison synthesised multiple sources of evidence (Creswell, 2009) including oral histories, primary data from individual interviews and validation processes, observations from primary data collection processes and varied secondary data sources as described above. A variety of analytic techniques were adopted for the data analysis to ensure the robustness of the case study comparison, including developing and examining rival explanations for the observed phenomena, pattern matching and cross-case synthesis (Miles and Huberman, 1994; Yin, 2009).

3. Results

Presented here are brief narratives of the change process in each city. Given the complexity of transformational change, the transition narratives are necessarily simplified accounts of change, although the overall pattern of change in each case emerged from the analysis and has been validated by stakeholders in each city.

Organisational responsibility for stormwater in Australia (both in terms of drainage and quality) is predominantly with local (municipal) councils, although some state agencies can also play a role. The narratives refer to the key stakeholders in each city, which is typically a combination of state and local agencies.

3.1. Brisbane

Brisbane is the third largest capital city in Australia, situated on the Pacific coast. The subtropical city is located in South-East Queensland (**SEQ**), one of the fastest growing regions of Australia, and extends along the Brisbane River, to its mouth in Moreton Bay. The rapid population growth across SEQ over the case study period has led to a regionalisation process and consequent development of region-wide policies. While the focus of this analysis is on Brisbane, the narrative refers to developments across SEQ as needed for coherence and accuracy. Responsibility for stormwater quality is with the municipal governments, of which Brisbane City Council (**BCC**) is the largest (in terms of both geographical jurisdiction and staff) and most well-resourced in SEQ.

Overall, Brisbane's transition has seen it move from a city that channelled all its stormwater swiftly out of the city and into receiving waterways without any treatment, to a city that has distributed systems for localised stormwater detention and treatment throughout the city, regulation requiring stormwater treatment in new developments and a network of practitioners experienced with this new water sensitive urban design (**WSUD**) approach.[1]

Brisbane's stormwater quality management transition began in the early 1970s, and since that time, has followed a strongly culture-driven pattern of change. Consistent with the emergence of the environmentalism movement of the 1970s, a generalised concern for the environment played a key role in Brisbane's early transition phase. From this time, there was a growing realisation that waterways were not environmentally benign. Water quality science was increasingly seen as a legitimate and necessary area for future research and there was growing community activism in relation to water quality, focused particularly on the Brisbane River and Moreton Bay, a unique coastal environment with sea turtles and the iconic dugong.

The need for a greater understanding of waterway health led to the establishment of the Brisbane River & Moreton Bay Wastewater Management Study (1993–2001) (**the Study**), a partnership between the 6 local councils bordering Moreton Bay, the state government and a body of independent experts in order to build up scientific understanding of the Bay. The Study unfolded over a number of stages, beginning with an examination of point source pollution in the marine and estuarine environments of Moreton Bay, before expanding to also assess diffuse pollution from stormwater as well as the freshwater and tidal ecosystems in the region. The scientific inquiry was assisted by the establishment of two national research programs, the Co-operative Research Centres (**CRC**) for Catchment Hydrology and Freshwater Ecology (established in 1992 and 1993 respectively), which were critical in (1) strengthening the knowledge base about SEQ's water

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[1] Also called Low Impact Design or Sustainable Urban Drainage Systems.

environments and (2) building industry consensus about poor waterway health and possible solutions to this challenge.

The Study was a turning point in regards to waterway management in Brisbane. Not only did it facilitate a strong scientific understanding of the aquatic environment in SEQ, but it brought together all relevant stakeholders in a collaborative way to systematically and holistically investigate the state and needs of the region's waterways. As the Study came to an end, the Healthy Waterways Partnership (**Healthy Waterways**) was created to be the mechanism for ongoing engagement and became a "highly visible single entity . . . [providing] an umbrella of recognition for numerous water quality and waterways management programs and initiatives undertaken, by government agencies and other stakeholders" (Maher and Nichols, 2002, p.22).

Under this banner, a range of initiatives were implemented to maintain the visibility of and engagement with waterway health. For example, the Healthy Waterways Report Card was established to communicate the health of the region's waterways. The Report Cards graded each waterway on a scale from A+ to F, and were released annually by local politicians in a public, televised event. In other developments, new technologies and approaches for WSUD such as gross pollutant traps, wetlands and biofilters, were developed and trialled. Some significant demonstration projects locally and interstate (particularly in Melbourne) helped to build confidence in these 'soft' engineering approaches to delivering improved waterway health, and a capacity building program, Water by Design, was established in 2005 to build industry expertise in designing, constructing and maintaining WSUD assets.

Healthy Waterways was the key driving force behind Brisbane's stormwater quality improvement program. By involving all relevant stakeholders, Healthy Waterways fostered a collective commitment from all parties about the need for action in relation to waterway health, enabling relatively swift agreement on management actions to be implemented. Ultimately, the Partnership played a key role in developing a strong alignment between the relevant stakeholders, ensuring they 'spoke with one voice' to the political decision makers. Although the Partnership was regarded as both a highly credible and effective organisation, it lacked any formal authority to translate its findings into policy or practice. Instead, it relied on ongoing engagement with political decision makers to create a common culture of valuing waterway health and thereby bring about change on the ground. The effectiveness of these informal strategies of persuasion and communication was assisted by (1) the credibility of the science leaders and scientific information produced by the Partnership, (2) the strong alignment between all relevant stakeholders and shared commitment to waterway protection and (3) a receptive political leader in BCC's Lord Mayor Soorley, whose commitment to waterway health came to define his time in office.

Following this strongly culture-driven mode of change, Brisbane's transition was highly effective. From the mid-1990s to the late 2000s, the practice of WSUD had grown significantly, with projects primarily driven in a bottom-up way from local councils such as BCC or regional collaborations like Healthy Waterways. That is, implementation of projects across the city was largely based on a recognition of the importance and value of waterway health rather than because it was being mandated. Significantly, the State Planning Policy 4/10 (**SPP 4/10**) for Healthy Waterways was released in 2009, which was the first state-based statutory instrument mandating WSUD for certain developments. Responding to the growth and now-established legitimacy of WSUD practices, the State Planning Policy served to mandate WSUD more broadly, and as a consequence, both the scope of the practitioner cohort and implementation of WSUD projects rapidly expanded across Brisbane.

Yet rather than continuing on the path towards embedding WSUD as mainstream practice, three key factors converged towards the late 2000s to significantly reduce the political appetite for continued investment in the water sector, with a consequent reduction in waterway health and stormwater quality improvement initiatives. The first of these factors was the Australian millennium drought (1997–2009). In response to imminent water shortage in the mid-2000s, the Queensland government embarked on significant infrastructure investment to ensure water security. However, a number of the large-scale, centralised infrastructure projects planned or constructed have been abandoned or are not currently operating, giving rise to criticism of 'panic spending' for now white-anted water supply assets. Shortly after the breaking of the drought, the city was hit with devastating floods in 2011 and 2013, leading to a heightened interest in flood protection. However, the response is widely perceived to have reinforced a segmented approach to water management rather than preferencing more multi-functional solutions that could simultaneously deliver water quality benefits. Given the considerable spending on supply security and flood protection in recent times, there is now a reduced appetite for ongoing investment in the water sector more generally, making it hard to secure funding for stormwater quality improvement initiatives as a consequence. Thirdly, as a result of a sector-wide restructure initiated in 2008 that significantly overhauled organisational roles and responsibilities, there has also been a loss of both institutional knowledge and expertise in relation to WSUD and industry champions for this approach.

The declining interest in stormwater quality is reflected in the watering-down or repeal of structural support for WSUD. In 2013 SPP 4/10 was replaced with a new State Planning Policy that has reduced the scope of developments required to implement WSUD features (DSDIP, 2014). A rainwater tank subsidy, widely regarded as a valuable strategy for helping reduce peak flows and scouring of the catchment, was removed in December 2008 and there is no current Healthy Waterways Strategy, with the most recent strategy ending in 2012. This loss of structural support for WSUD and stormwater quality management more generally serves to reduce the visibility of the issue while also reducing organisational support for and commitment to the practice. The declining structural support for stormwater quality management suggests that Brisbane could be on a backlash trajectory. While this may change in future, so that current indications of backlash are later seen as a mere hiccup on the path to stabilisation, the loss of structural support has adversely affected Brisbane's transition to date.

Overall, Brisbane's transition pathway was driven by a change in culture that legitimised the need for an alternative practice and developed a shared community and industry valuing of the city's waterways. The middle phase of the transition saw communities of practice develop around possible solutions to stormwater quality improvement and refine technical innovations around WSUD. Successful demonstration projects eventually evolved into frequent implementation by industry leaders and a growing coalition of practitioners around WSUD. Finally, once WSUD practices were already relatively widespread on the ground, formal legislative change and enforceable industry standards were introduced to mandate and/or regulate implementation of the practice. However, many of these 'hard' structural measures that mandated WSUD occurred relatively late in the transition process, and so were not strongly embedded, leading to a weakening or reversal when there was a change of government in 2012.

3.2. Melbourne

Melbourne is Australia's second largest capital city, with a population over 4.4 million. The city is set on the Yarra River and

spreads out around Port Phillip Bay. Responsibility for water quality is shared between Melbourne Water Corporation, a government-owned statutory authority that manage regional drainage (catchments >60 ha; trunk drainage) and the 38 metropolitan municipalities that are responsible for managing stormwater drains (catchments <60 ha; minor drainage) and local stormwater pollution. Although Melbourne's stormwater quality management transition unfolded over the same timeframe as Brisbane, Melbourne has not suffered the backlash of Brisbane, and continues to work towards a full mainstreaming of WSUD. The Australian leader in terms of stormwater quality management, Melbourne's transition journey is characterised by a structure-driven approach, with transition leaders deliberately and strategically using the existing regulatory framework to pursue stormwater quality improvements.

As with Brisbane, Melbourne's transition was prompted by a scientific study in the early 1970s that revealed poor water quality in Port Phillip Bay, the receiving waterway for metropolitan Melbourne. The findings showed that nutrient loads were significantly impacting the health of the Bay, and provided the foundation for the development of the first State Environmental Protection Policy (**SEPP**) in 1975. These findings helped to build industry consensus around the need to protect and improve waterway health and highlighted the inadequacy of the current approach in addressing water quality. Consequently, there was a concerted effort to build expertise in this emerging field of water quality science, with university and professional courses credited with significantly raising the skill base of water engineering both in Melbourne and nationally. This was further assisted by the two CRCs (referred to above). A campaign led by the local newspaper played a critical role in galvanising broad support for greater water quality efforts, focused in particular on the iconic Yarra River, which was essential in providing a community mandate for action.

In contrast to Brisbane, Melbourne's transition was in large part driven by early, deliberate and frequent engagement with the broader structural framework. Early in the transition process the Water Act 1989 was introduced, outlining 13 values to underpin water management in a way that met contemporary social, economic and environmental expectations. Following this, a further Port Phillip Bay Environmental Study in 1993 specifically identified urban stormwater runoff as a key threat to waterway health and recommended a priority policy target of reducing annual nitrogen loads entering the Bay by 1000 tonnes from 1993 levels. The SEPP was subsequently amended to incorporate this goal, with the aim of meeting it by 2006. In response, Melbourne Water made an immediate decision to reduce annual inputs from both point sources and catchment sources of nitrogen by 500 tonnes each from 1993 levels. With scientific modelling showing the significant potential contribution of wetlands, Melbourne Water adopted a catchment nitrogen reduction target in its 2000 corporate plan, and subsequently allocated in excess of AU$60 million over 10 years, constructing 52 wetlands across the city.

An inter-agency Stormwater Committee was established shortly thereafter, producing a Stormwater Agreement that articulated the responsibilities for improved stormwater quality management across the Environment Protection Agency, Melbourne Water and local councils. The Committee also produced the Urban Stormwater Best Practice Environmental Management Guidelines (**BPEM**), which came to articulate the new regulatory standard for development across Melbourne. In determining the best practice standards to be included in BPEM, there was debate within the Committee about the option of setting sustainable stormwater runoff loads as compared to setting receiving water quality objectives. Whilst the latter was seen as more comprehensive, agreement was reached to adopt the more pragmatic approach of runoff loads, which was considered more immediately achievable and therefore more effective to initiate a swift practice change. The BPEM guidelines became an agreed set of objectives that were considered to satisfy the revised SEPP requirements, and were enforced through Melbourne Water or EPA approvals.

Providing further structural support for the growth of WSUD practices was Melbourne Water's introduction of a stormwater offset scheme in 2005. The scheme was the first of its kind in Australia and required developers to meet stormwater quality objectives either by implementing best practice measures onsite or by making an offset payment for works undertaken elsewhere in the catchment. The offset contributions fund a rolling annual program of water quality initiatives.

Another significant regulatory change was an amendment of the State planning provisions to mandate onsite stormwater management for all new residential sub-divisions across Melbourne (clause 56). This played a key role in mainstreaming WSUD across the city. However, the clause 56 requirements only apply to greenfield residential development, and not urban renewal through infill development. To further embed the WSUD practice, some leading local governments (including those that border the Bay) collectively pursued further amendments to mandate WSUD for *all* development within their jurisdiction, which have recently been approved.

Overall, Melbourne's transition is characterised by an early, frequent and deliberate engagement with the broader regulatory framework. As the scientific knowledge about the health of the receiving waterways grew, the regulatory requirements were continually amended to introduce increasingly stringent requirements. While a professional and community culture around waterway protection also grew over this period, the changes to the structural framework were central to growing a community of practice around WSUD and ultimately driving Melbourne's stormwater quality improvement transition.

3.3. Adelaide

Adelaide is the driest Australian capital city and characterised by a Mediterranean climate with moderate rainfall over winter and hot, dry summers. In contrast to Brisbane and Melbourne, Adelaide's transition journey is focused on the capture, treatment and storage of stormwater as a fit-for-purpose water source and has followed a strongly practice-led approach. Also distinguishing Adelaide is the comparatively shorter transition period, beginning only in the late 1980s.

Adelaide's transition journey was pioneered by the City of Salisbury, a municipal government and now a well-recognised leader in stormwater harvesting. Motivated by over-extracted groundwater systems and the ongoing need to irrigate public open space, Salisbury began experimenting with stormwater treatment via a network of drainage detention basins and storage of the treated water product in limestone aquifers. Early pilot projects proved successful and Salisbury proceeded to implement some harvesting schemes. These early Salisbury schemes began operation prior to the establishment of a state environmental regulator, and given the novelty of the practice at this time, did not require any other approvals. Whilst this regulatory vacuum enabled scientific investigation and experimentation, it also created uncertainties. The absence of any licensing authority necessarily gave rise to questions about ownership over the treated water, and these early schemes took a leap of faith that treated water injected into the aquifers (for storage purposes) would later be able to be extracted.

Despite these challenges, the Salisbury schemes proved the viability of stormwater harvesting and played a key role in establishing the legitimacy of this new practice. From here, other

councils began investigating the feasibility of schemes in their own areas. A number of high profile demonstration projects, sometimes in partnership with third parties such as jockey clubs or golf courses, helped to build a community of practice around the value and feasibility of this alternative approach.

The millennium drought had a particularly critical impact in Adelaide, and helped galvanise broad-based support for alternative water schemes as a means of ensuring the city's long-term water security. The design and implementation of a number of storm-water harvesting schemes was greatly assisted in Adelaide by a number of Commonwealth grants. With significant expertise in stormwater harvesting, Adelaide was well placed to make use of Commonwealth funding that was made available to develop alternative water schemes as a means of 'drought-proofing' Australian cities for the future. Over two rounds of Commonwealth funding, Adelaide managed to secure the bulk of available grants that were critical to the construction of a number of large-scale schemes across the city.

There are now a number of stormwater harvesting schemes operating across Adelaide, supplying fit-for-purpose supply for outdoor water use and public open space. Yet despite the widespread practice, the regulatory framework structuring the stormwater schemes remains relatively underdeveloped. This is reflected in the fact that water extractions from harvesting schemes are currently subject to a fixed term license granted at the discretion of the Minister, creating ongoing uncertainty regarding future extraction allowances. This uncertainty is likely to continue into the short to medium term as the city develops a water allocation plan to try manage the cumulative impacts of the

existing schemes, particularly in terms of artesian pressures. Further, there is widely perceived to be a policy vacuum in relation to stormwater harvesting, with no agency responsible for driving ongoing integration of the schemes or providing overall strategic oversight.

This practice-driven pattern has characterised Adelaide's transition, with the structural framework still working to adequately and comprehensively regulate a practice now well established on the ground. The initial emergence of stormwater harvesting was not in response to a stated policy goal or regulatory incentive, but rather the result of pioneering experimentation. As the practice grew, the structural and regulatory support remained relatively shallow and the current regulatory framework is largely the sum of a number of stop-gap measures designed and intended to be short-term fixes. By adopting a practice-driven approach, Adelaide has established itself as a leader in stormwater harvesting in Australia over a very short transition period.

A chronological comparison of the transition journey in each city is presented in Fig. 1, showing the different types of initiatives favoured in each city to embed the innovation, as indicated by the circular, diamond or rectangular shaped boxes on the image.

4. Discussion

Central to the realisation of transformative change is a fundamental reorientation of the dominant cultures, structures and practices of a system (de Haan and Rotmans, 2011). The focus of this paper is on exploring how these changes unfold in practice and the role of agency in this process. Despite the different patterns
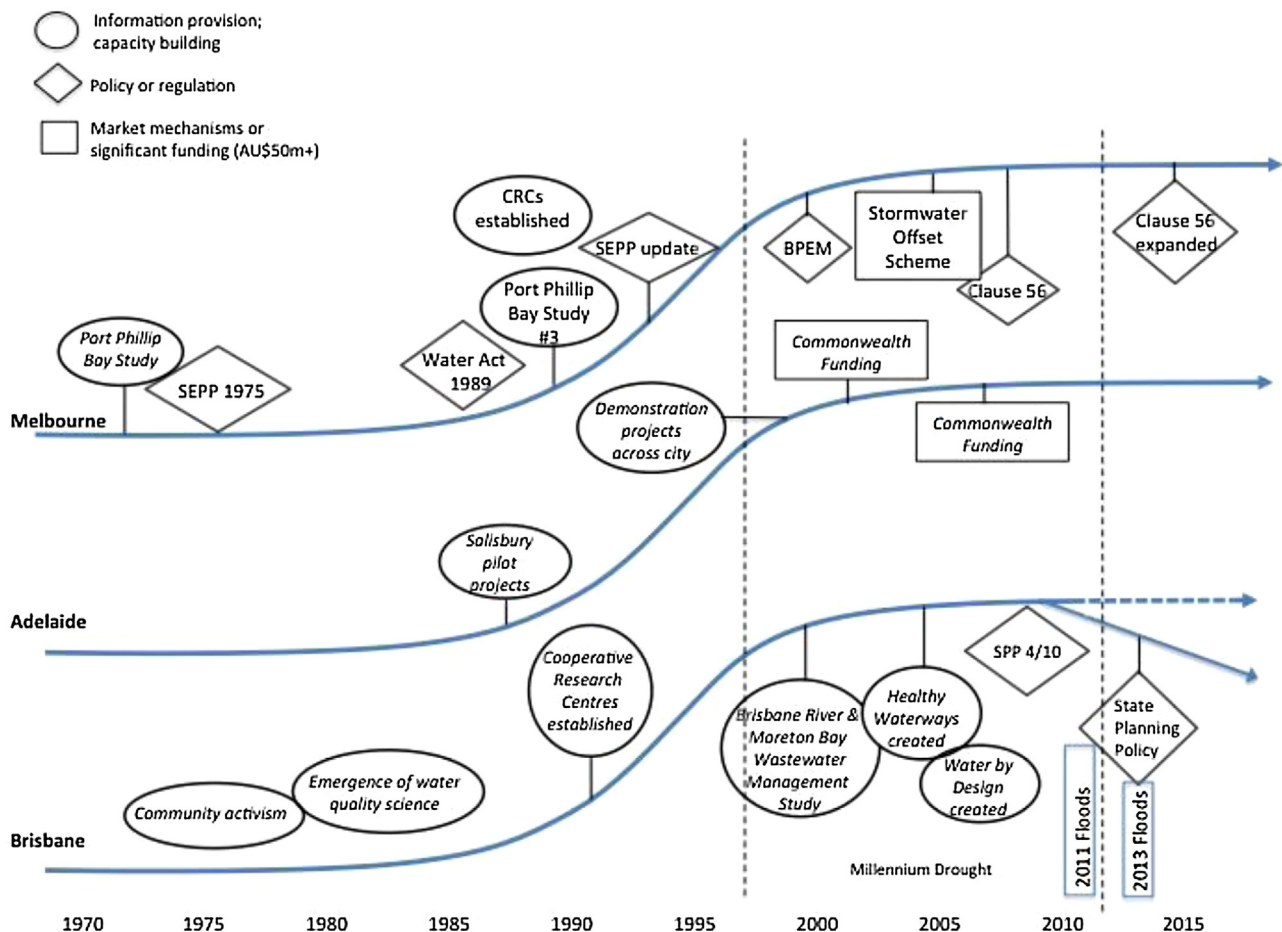

Fig. 1. A chronology of transformational change in Melbourne, Adelaide and Brisbane.

of change exhibited in each case study city, all have gone a significant way towards embedding a new and radical innovation. This suggests that there can be a number of pathways towards stabilisation, confirming the implicit assertion of transitions theory that there is no 'one size fits all' approach to transitions. Rather, transformational change will unfold in a context-specific way, depending on factors such as the existing city framework and environment, regime players and actor strategies.

Importantly, summarised and presented here are generalised patterns of change. While each city was characterised by one *dominant* type of change, transition efforts were not contained solely within one domain. Providing a more nuanced depiction of developments across each of the culture-structure-practice domains in each city, Fig. 2 shows that although each city has a particular strength in one domain, efforts across all domains evolved over time and can now be seen (albeit to differing extents) in each city. The differing sizes of each of the circles indicates the relative strength of efforts in each domain across the cities.

Given the complex, difficult and drawn-out nature of transition processes, how should cities and transition advocates seek to effect transformational change? That is, where to begin? The results of this study provide some insight in this regard. It suggests that the approach taken to initiate and build momentum around regime change should be determined with reference to the existing city context. With the results showing that a culture, structure or practice driven pattern of change can each bring about significant transition progress, cities may be best served by initially working within their context and adopting strategies that are immediately compatible with the existing framework.

A culture-driven pattern of change is mostly likely to occur in a context where there is a strong, collaborative network of stakeholder representatives, or the possibility of establishing such a network. To maximise the potential impact of the culture-driven pattern, the network should include political or other decision-makers, although a supportive political context could be sufficient. This type of change pattern relies on strong interpersonal relationships between those in the network, and the establishment of mutual respect and trust. Given the importance of bridging organisations in facilitating transformational change (Brown et al., 2013), the network would ideally include a mix of science and industry stakeholders, to provide a pathway for the inclusion of scientific findings into industry policy and practice.

A structure-driven pattern of change would typically arise in circumstances where some of the key actors driving transformational change occupy senior or influential positions within powerful or core stakeholder organisations. The formal authority held by these organisations means that amendment of the existing structural framework is a particularly accessible option. However, pursuit of this approach necessarily rests on some threshold level of cultural support. Perception of unilateral amendment to the regulatory framework, without some widespread popular support for the cause, is unlikely to ultimately be successful. As the case of Melbourne demonstrates, this pattern of change is not about unilateral imposition of a radically new agenda by a powerful organisation, but rather rests on deliberate and continual engagement with the existing regulatory framework to seek opportunities to amend or redeploy some component parts.

Finally, a practice-driven pattern of change may generally emerge in the context of a crisis or game-changing event that crystallises the need for a new approach. As in Adelaide, an extended drought was critical to the widespread acceptance of the need to capture, treat and use stormwater (historically considered a nuisance or waste stream). Alternative crisis situations could include a devastating flood that highlights the limitations of traditional flood management systems and sparks a new practice of 'making room for the river', as in the Netherlands (Ministry of Transport, Public Works and Water Management, 2000), or a nuclear accident as with Fukushima, Japan that prompted a solar and wind revolution in Germany (Rajgor, 2012). A context in which funding or subsidies are available for implementation of a new innovation could also facilitate a practice-driven pattern of change.

Thus in order to build the initial momentum around transformative change, change advocates should reflect on their city context and work within this existing framework to initiate change, noting that there may be additional circumstances that could favour a particular pattern of change. Although engagement across all three domains will ultimately be necessary in order to fully embed the transition, pursuing change initially within one domain can, as the results demonstrate, help bring about transformational change that is 'past the point of no return'. Beyond this threshold, it will be necessary for actors to broaden transition strategies to ensure a solid foundation is built across all of the culture, structure and practice domains. Yet reaching this threshold level is perhaps made more achievable by focused efforts in the domain that best suits the prevailing context.

However, the results also suggest that change concentrated predominantly in one domain can only take a transition so far. For true transformational change, there needs to be a mutually
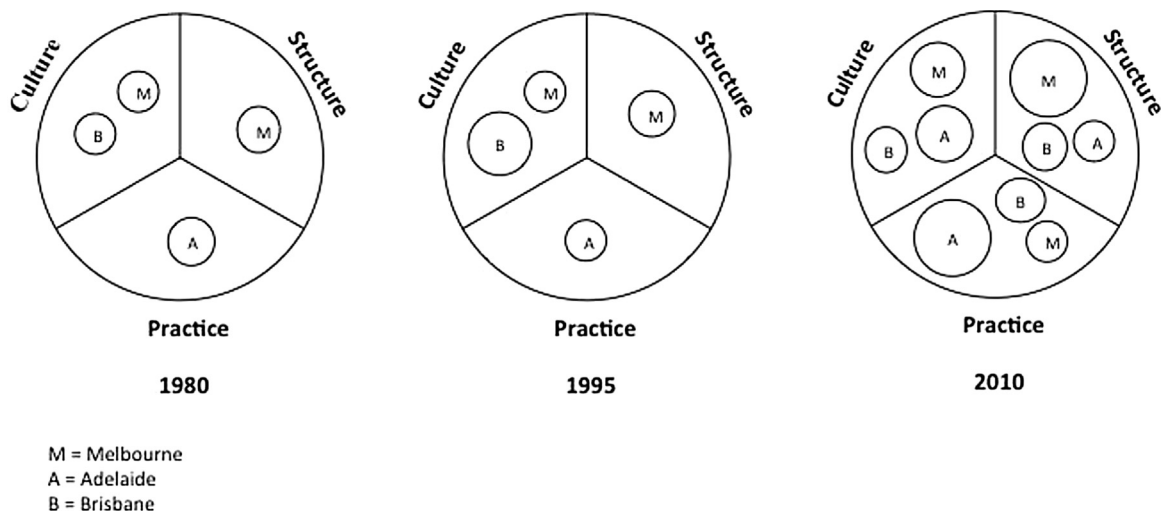

M = Melbourne
A = Adelaide
B = Brisbane

Fig. 2. Evolution of emerging Cultures, Structures and Practices in each city.

reinforcing shift in the dominant cultures, structures *and* practices of a system. As such, in order to ensure full mainstreaming, cities (and therefore transition advocates) will eventually need to engage more deliberately with strategies across all domains. Yet the results also suggest that successfully transitioning cities may exhibit a 'pattern-dependence' that can hinder the development of this more balanced foundation. As with path dependence, an inertia or blindness can inadvertently develop which may limit the perceived range of available options, leading transition actors to pursue strategies and approaches that have previously been successful, to the exclusion of a more diversified approach (Berkhout, 2002; Pierson, 2004). For example, Brisbane's significant success with culture-led change saw relatively late engagement with structural support. Similarly Adelaide's strongly practice-led change process has also given rise to a relatively under-developed structural foundation, creating some uncertainties about the ongoing operation of schemes. Actively engaging with initiatives across each domain will be necessary both to guard against this risk of pattern-dependence, and to fully embed the sought-after change. This is also important as no single pattern of change is a silver bullet. An approach that builds the foundation for transformative change across all of the culture-structure-practice domains can help mitigate the limitations of agency focused predominantly on one domain change.

A vulnerability of agency in a culture-led pattern of change is the dependence on individual change agents and personalities. The effectiveness of a collaborative network can be easily diminished or destroyed by a change in the composition of the network, or a shift in the broader political landscape. Creating and maintaining a common culture and ethos around waterway protection across a multi-stakeholder network, including the political decision-makers, was critical to the success of Brisbane's stormwater quality transition. Rather than relying on enforcement power, or mandating WSUD approaches, the approach of transition leaders was more tailored and network based, relying on building trust through regular engagement with stakeholders in order to obtain the necessary funding and political support. However, when the landscape changed and the once receptive political climate shifted,

the effectiveness of this approach was curtailed. Without any formal authority or mechanism for translating its findings into policy or practice, the Healthy Waterways Partnership was effectively reliant upon the interest of political decision-makers. The limitations of relying exclusively on 'soft' methods of influence became apparent during a sustained period of misaligned values with a government dominated by an economic efficiency agenda. Greater engagement with structural frameworks that embeds change in policy and regulation can be a valuable means of providing a more long-lasting (and less-personality dependant) foundation for the growth and implementation of a new innovation or practice.

A limitation of agency in the context of a structure-led pattern of change is the reliance on some threshold level of broad popular support for a new approach. A risk of agency that exclusively or predominantly relies on a structure-led pattern of change is that the new approach is not sufficiently internalised by a broad range of stakeholders and embodied in the shared narratives and paradigms of a sector. Pursuing structure-driven change may be a preferred approach once broad popular support has been established, indicating a threshold level of change in the culture domain. Agency that favours a structure-led approach may also lead to more rigid application of the new approach that is not appropriately tailored to the city context.

A potential vulnerability of practice-driven agency, particularly in the context of crisis, is that the new approach may be tailored to address the specific crisis at hand and thereby miss opportunities for delivery of multi-functional benefits. Crisis response maximises the likelihood of a truncated period of reflection and strategic planning, with the focus understandably on addressing the immediate risk. In such a context, and taking a worst-case scenario, it is possible that the potential risks associated with the new practice are not being appropriately managed. Alternatively, it can lead to a lack of strategic planning and general integration with the broader operating context. Such was the case in Adelaide's stormwater harvesting transition, which expanded rapidly given the need for water security during an unprecedented drought, but which has been implemented in isolation from stormwater quality

Table 1
Agency associated with 3 patterns of change.

	Focus of Agency	Strengths	Vulnerabilities
Culture-led	Creation of a strongly aligned multi-stakeholder network or bridging organisation between industry, science and policy spheres, promoting the alternative discourse	A foundation of mutual respect and goodwill can streamline the process of establishing the legitimacy of a new approach. Inclusion of policy and/or decision makers in the network can help maintain visibility of issue and create an efficient 'pathway to implementation'	It is very network and personality dependant. A reconfiguration of the network or loss of some key actors that undermines the cohesion and collaboration of the group could significantly limit the overall effectiveness of the network or its ability to drive transformational change
Structure-led	The transformation of institutional settings. Typically, by actors with strong positional authority (i.e.: a government agency or another core regime player) who use their position to influence or change application of aspects of the existing regulatory framework	Provides a strong and reliable foundation for a new practice while also conferring legitimacy on the new approach. Regulatory change is an effective way of rapidly expanding implementation of the new practice	To facilitate a smooth implementation process and maximise acceptance of the new rules, a structure-led pattern is best combined with comprehensive, regular and tailored stakeholder engagement which can be resource intensive
Practice-led	Innovation, entrepreneurship and change in practice. Makes use of a crisis, window of opportunity or available funding for implementation of a new innovation or solution to a social problem	Fast-tracks the implementation of a new approach and development of a professional network. May be easier to optimise the innovation or new approach once there is tangible infrastructure on the ground	If implemented as a crisis response the new approach may: • not be appropriately tailored to its context • miss opportunities to learn by doing and then optimise • lack strategic integration with broader landscape or across individual schemes • not be sufficiently managing risks

considerations and without sufficient regard for integration with other alternative water schemes. Whilst opportunities obviously exist following the immediate crisis to introduce some strategic oversight and tweak the new practice to deliver multi-functional benefits, retrospective amendment is necessarily a greater challenge given the well-known phenomena of institutional inertia and path dependencies. Table 1 summarises the overall goals, strengths and vulnerabilities of agency associated with each pattern of change.

As the results of each case show, pursuing change within one domain can help facilitate significant progress towards a transition. However, it will ultimately be insufficient to ensure total mainstreaming an innovation. As transition theory makes clear, transformational change relies on a reconfiguration of the dominant cultures, structures *and* practices within a system.

As such, change within each domain will eventually become necessary. These results suggest that transition actors should work within their existing framework to build the initial case for and momentum around a transition. Transition advocates should reflect on the context of their city and pursue a culture, structure or practice driven pattern of change accordingly. However, once a city is clearly 'on the path to transition', it is important to remember that change will ultimately be required across all domains. Therefore, change advocates should simultaneously try and recognise which pattern is evolving in their city and proactively address its weaknesses by deliberately pursuing initiatives to build change in the other dimensions. Indeed, ensuring a strong foundation across each domain can help minimise the vulnerabilities of each pattern of change and will ultimately provide the strongest chance of success.

5. Implications and conclusions

Whilst it is widely agreed that transitions are complex, multi-faceted processes, and despite a growing body of empirical cases of transition, there has so far been limited cross-case comparison to identify patterns of change and strategic agency opportunities. This paper builds on overaching theoretical patterns of change already identified (Geels and Schot, 2007; de Haan and Rotmans, 2011) and considers the on-ground dynamics of regime transformation. The findings of this research provides insight into (a) the co-evolutionary dynamics of culture, structure and practice change and (b) how transition actors can better respond to and make use of their existing context to bring about change in each dimension.

The results help practitioners identify a road-map for transformational change by reflecting on the general context of their city and suggesting possible strategies for pursuing culture, structure and practice change. Further, the paper also confirms that while one dominant pattern of change can facilitate significant progress towards an overall transition goal, transition advocates will ultimately have to pursue strategies across all three domains in order to ensure full mainstreaming of a new approach. Although the identification of transition patterns is necessarily a simplification of the change process, it nevertheless provides a valuable lens through which to analyse current and ongoing change processes, in turn helping change advocates identify strategic leverage points and opportunities for more deliberate intervention to bring about the desired change.

These results raise questions about what a mixed pattern of transition would look like, and how to best bring in elements of other domains in a context that favours one pattern of change. This is both a theoretical and a practical challenge, and will require experimentation across different city contexts. These results can also act as a starting point for the development of pattern-specific strategies for actors, as well as a suite of complementary strategies to be used in a mixed-pattern approach. In order to start addressing these questions, the next steps for this research are to examine the instruments and mechanisms of change used by transition advocates in order to develop a typology of strategies to bring about change in each domain. Examination of additional cases of change will assist in further development of the patterns of change and types of agency, as well as test their application across other sectors.

Acknowledgements

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5. Publication 2: The Role of Structure in Facilitating Regime Transformation

5.1 Introduction

Publication 1 (Chapter 4) looked across all three case study cities in order to identify broad patterns of transformative change. The next publication focuses more specifically on the structure domain, exploring different types of structure and the sequencing of structural mechanisms that may support a transition.

Fundamental structural change is key to the overall goal of regime transformation, and it is therefore valuable to understand more precisely the components of structural change and how they may interact. As outlined in Section 2.2, structural change is one component of a broader institutional change process (alongside cultural change). However, as the component of institutions that can be deliberately modified or amended (typically by government agencies), a more nuanced conception of structural change is useful in order to inform the scholarship on regime transformation as well as the strategic actions of transition advocates and decision makers.

Through a comparison of structural change in the cities of Melbourne and Brisbane, the paper demonstrates the importance of regulation in supporting a transition effort, and provides some recommendations in relation to the timing and sequencing of structural initiatives that may support a transition.

The outcomes of this paper contribute to the second research objective of this thesis, being to "assess the type and operation of institutional change mechanisms in the institutionalisation of a radical innovation".

5.2 Declaration for Thesis Chapter 5

Declaration by candidate

In the case of Chapter 5, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Formulation of the research problem, research design, data collection and analysis, interpretation of results, writing the paper	80%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
Rebekah R. Brown	Participation in the formulation of the research problem, participation in the interpretation of results, providing feedback on the written manuscript.	N/A
Chris Cocklin	Participation in the interpretation of results, providing feedback on the written manuscript.	N/A

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work.

Candidate's Signature		Date 26/10/16

Main Supervisor's Signature		Date 26/10/16

5.3 Manuscript

Institutional change to support regime transformation: Lessons from Australia's water sector

Lara Werbeloff,[1,2] Rebekah Brown,[3] Chris Cocklin[4]

[1]*School of Social Sciences, Monash University, Melbourne, Australia*
[2]*Co-operative Research Centre for Water Sensitive Cities, Monash University, Australia*
[3]*Monash Sustainable Development Institute, Monash University, Australia*
[4]*James Cook University, Queensland, Australia*

Abstract
How do cities transition towards sustainability? We know that institutional change is fundamental to regime transformation, and a necessary part of any sustainability transition. However, insight into the role played by institutional change processes in such transitions is currently limited. A more nuanced understanding of institutional frameworks and their components is necessary, both to advance understanding of institutional change in the context of transitions, and to inform strategies for guiding such processes. To this end, we examine two contemporary cases of transformative change in Australia's urban water sector, exploring the evolution of institutional change in each city.

This paper offers insights into the process of regime transformation, by providing guidance on types of institutional structures and the ways structure-change initiatives can be sequenced to support a transition. The results reveal the importance of regulation in embedding regime change, and suggest that engagement with structural frameworks should begin early in transition processes to ensure the timely introduction of supporting regulation. Our findings also highlight the inextricable link between culture- and structure-based change initiatives, and the importance of using a diverse range of institutional change mechanisms in a mutually reinforcing way to provide a strong foundation for change. These findings not only provide a foundation for further scholarly examination of institutional change mechanisms, but can also serve to inform the strategic activities of transition-oriented organisations and actors.

Introduction and background
Around the world, cities are grappling with the challenge of moving towards sustainable development. The pressures of climate change, urbanisation, and natural resource degradation are being felt in sectors as diverse as energy provision, food supply, transport, waste, and water management. Across the board, the message is clear: current approaches are ill-equipped to effectively resolve these problems. Addressing these challenges in a way that integrates principles of sustainability to improve the resilience of our cities, environmental health and community well-being outcomes is widely acknowledged to be an immense challenge (UNESCO 2009; OECD 2011).

Radical transformation is needed if cities are to meet the needs of their growing population in a way that also integrates sustainability into systems for delivering essential services. The

relatively young literature on socio-technical transitions (Rotmans et al. 2001; Geels 2002; Kemp et al. 2007) explores the concept of radical transformation towards sustainability and offers valuable theoretical insights into this process. Sustainability transitions are large-scale transformations that fundamentally change a system's structure and/or the way in which it functions (Grin et al. 2010), as opposed to more discrete changes that merely modify or optimise some aspects of the way an established system operates. The literature further defines sustainability transitions as a multi-dimensional transformative change process, whereby a system shifts towards more sustainable modes of production and consumption, typically spanning 25 to 50 years (Markard et al. 2012). In this paper, we closely examine two such sustainability transitions, unfolding in Australia's water sector from 1970 to the present day.

Sustainability transitions are radical transformations that require regime change. In transitions literature, regime refers to dominant and entrenched approaches for delivering resources, goods, and services (Holtz et al. 2008), composed of mutually reinforcing elements that co-evolve over time and serve to anchor existing systems, such as those for energy or water provision. That is, the regime represents the status quo of how essential services are delivered within a system. The regime is further defined as a 'coherent, highly interrelated and stable structure characterised by established products, technologies, stocks of knowledge, user practices, norms, [and] regulations' (Markard and Truffer 2008, p.603). The mutually reinforcing and interconnected nature of established regime elements not only poses an obstacle to regime change, but highlights the need for case studies which investigate regime change processes when they do occur, in order to shed light on the underlying mechanisms through which regimes change and transitions unfold.

The regime concept derives from the Multi-Level Perspective (MLP), wherein it occupies the meso-level of a nested hierarchy, which also identifies micro-level niches and the macro-level landscape as scales at which transition processes take place within a given system (Rip and Kemp 1998; Geels and Schot 2007). The MLP posits that transformative change is driven by interactions at and between these different scales (Rip and Kemp 1998), with regime change produced in part by top-down pressure from the landscape and bottom-up pressure from the niches. Crucially, transformative regime change is conceptualised as a process of co-evolution and mutual adaptation within and between these levels, which manifests only when developments at each level 'move in the same direction' (van der Brugge and Rotmans 2007, p.253).

The landscape-regime-niche distinction has been widely adopted by transition scholars, attesting to the heuristic usefulness of the MLP (e.g.: Vanloqueren and Baret 2009; Verbong and Geels 2007; Jacobsson and Lauber 2006). Nevertheless, a number of commentators have pointed out some limitations of this model (Geels 2011), with critiques in terms of the role of power and agency in the MLP (Genus and Coles 2008; Smith et al. 2005), the failure to take account of everyday practices (Shove and Walker 2010) and the lack of specificity in describing the 'regime' concept making it difficult to empirically test (Smith et al. 2010; Genus and Coles 2008; Markard and Truffer 2008; Geels and Schot 2007; Berkhout et al. 2004). However, the MLP remains the foremost framework for engaging with the issue of scale and distinguishing between change processes taking place at different levels. A key advantage of this model is that it provides 'a language for organising a diverse array of considerations into narrative accounts of transitions' (Smith et al. 2010, p.442). The regime concept in particular remains a

valuable heuristic for identifying and examining the dominant structures and configurations operating within a given sector – a necessary first step to understanding transformative change and how it unfolds. After all, regime change is essential to any transition effort, and ultimately the measure of its success. Yet despite its central role, relatively little is currently known about how this process unfolds in practice, or the mechanisms that support and accelerate it (Smith et al. 2010).

We intend the present paper as a step towards addressing this gap in the scholarship, by building on the conceptual foundation provided by the MLP through a comparative case study of two long-running, contemporaneous sustainability transitions taking place in the Australian water sector. In particular, we examine the role played by institutional structures in building, changing and stabilising regimes. In this paper, we identify key institutional structures (as distinct from physical infrastructures or actor networks that can also have a structuring effect) that support and underpin an existing regime, and consider how these structures can assist regime transformation. Our exploration of the role of institutional change in supporting a broader regime transformation is guided by three main aims: The first is to shed light on the range of institutional mechanisms that support and influence regime change, and consider their interactions. The second is to provide insights into how the sequencing of institutional change mechanisms impacts regime change. Our third and final aim is to offer some practical insights for individual and organisational actors interested in influencing and driving regime change.

For the purposes of the present paper, we define institutions as established and durable formal and informal rules that organise the social world, following the established sociological tradition (Woodhill 2010; Hodgson 2006; North 1990). As such, institutions are central to all regimes, being the means through which a regime's constituent dominant practices are organised, moderated, implemented, and enforced. Institutions can be broadly divided into two categories: structure-based and culture-based (Scott 2008), which operate synergistically in influencing regimes. Both are equally important dimensions of institutional change, with changes in the structural dimension typically formalising and codifying changes that have occurred in the cultural domain. Institutions are central to regimes, as they provide emergent practices with a foundation enabling them to persist via both formal and informal means of compliance and enforcement. Embedding new practices or technologies in institutional frameworks is therefore a critical step towards successful regime transformation.

The concept of structure has been extensively examined in scholarship, across literatures including sociology (e.g., Scott 2008), public administration (e.g., Hood et al. 2001) and science and technology studies (e.g., Faulkner 2008). This paper draws on a distinction between two sub-categories of institutional structure found in legal studies, specifically the field of international law (Shaffer and Pollack 2010; Abbott and Snidal 2000), in relation to hard and soft law. Hard law refers to legislation or other enforceable, formal regulatory instruments (Weeks 2014). Such frameworks can play a key gatekeeping role in embedding and regulating sustainable transformations, determining what is required in relation to the new practice, the terms of participation, and the minimum standards of conduct. By contrast, soft law refers to a diverse range of non-enforceable, non-binding policy instruments, such as guidelines, codes of practice, and conventions (Weeks 2014). Soft law is typically developed by government ministries or public sector organisations, to guide decision-making and incentivise action in a particular direction. Despite its name, soft structural instruments are not an ineffectual 'poor

cousin' to more formal regulation. Although neither binding nor enforceable, soft law can nevertheless be a highly effective means of shaping conduct, as it provides an overall framework for action, articulates short and medium terms goals, and both reflects and reinforces cultural norms.

Financial and market incentives operate alongside policy and regulatory instruments as important structural mechanisms. Economic instruments are widely regarded as a key part of addressing sustainability challenges, as they provide flexibility and efficiency in pursuing environmental goals (Taylor et al. 2012). Rather than making a particular behaviour or use of technology mandatory, financial incentives allow stakeholders to achieve environmental goals at lower cost, within parameters that ensure the protection of the common good (Tietenberg 1990). We therefore include economic factors, alongside hard and soft law, in our analysis of structure-based institutional measures.

It is widely noted by transitions scholars (Grin et al. 2010; Rotmans et al. 2001) and institutional theorists alike (Scott 2008; North 1990) that structural change alone is not enough to facilitate and embed regime transformation. Both regulation and policy derive their legitimacy from culture – the underlying norms and values shared by the community and/or the relevant industry, which inform how goals and the appropriate means of pursuing them are defined (Scott 2008). The cultural dimension of a regime is often difficult to identify, being largely invisible and taken for granted as 'the way we do things', which makes it both powerful and highly influential. As Connor and Dovers point out, 'successful institutional systems do not work through rigid and continuous enforcement of rules and application of sanctions…they are effective because there exists a general consensus on the values represented in the rules – that the rules are fair and reasonable according to these values' (2004, p.209).

The relationships between institutions and the tools of structural and cultural change described above are illustrated in Figure 1. As the cultural components of institutions tend to be deeply embedded, while structural components are more open to deliberate change, investigating how mechanisms of structural change can be used to support regime transformation is more likely to yield translatable, practical insights. For this reason, we have chosen mechanisms of structural (rather than cultural) as the primary focus of this paper. However, as the two domains are inextricably linked, the impact of cultural factors will also be considered.
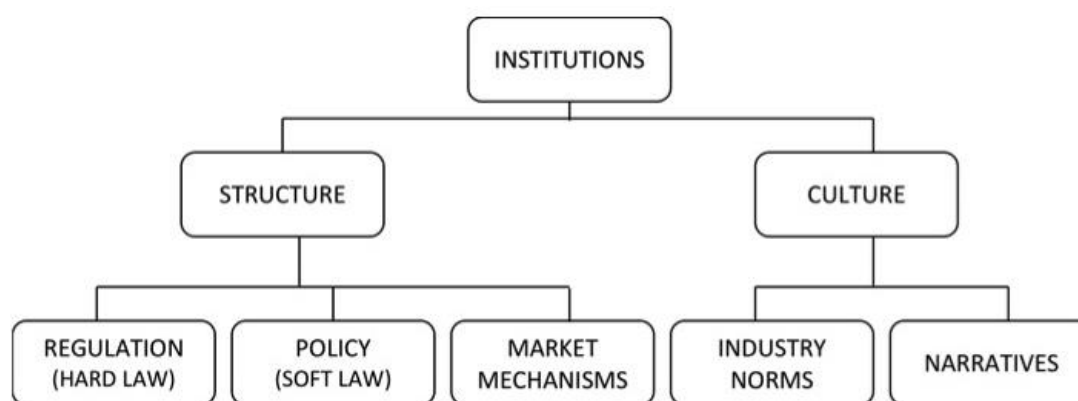

Figure 1. Institutions, their structural and cultural domains, and change mechanisms

Building on the emergent body of work exploring institutional change in the context of sustainability transitions (Fuenfschilling and Truffer 2016; Fuenfschilling and Truffer 2014; Geels 2004), we examine the evolution and impact of different types of structural change mechanisms over the course of a transition. Despite the pivotal role institutional change plays in the process of regime-building, this promising subject has seen only limited exploration within the transitions literature to date (Coenen et al. 2012; Truffer et al. 2009). In particular, there is a currently limited insight into how regime transformation can be operationalised, and what roles institutional change plays in this process. As institutional change is known to be both an indicator and facilitator of regime change, a closer analysis of the role of institutions holds great promise to shed new light on regime change.

In light of the above, we seek complement and enrich existing transitions scholarship, by analysing transformative change at the regime level, focusing predominantly on hard and soft legal measures, and drawing on market mechanisms and culture to complement our analysis. Importantly, institutions do not change themselves, and instead rely on the strategic intervention of actors. However, our goal for this research was to examine different types of institutional structures and how they can be used by actors to support regime transformation, rather than the actors themselves.

Drawing on two contemporary cases of transformative change in the Australian water sector, we examine the evolution of the structural framework over the course of each transition, examining the timing and sequencing of various initiatives and its implications for regime transformation. The cities of Brisbane and Melbourne are both presently undergoing a stormwater quality transition, described in more detail below. Notably, while the two cities share a broad socio-political context and have undergone similar changes over the same time-period, the process of regime transformation has produced two dramatically different outcomes. This divergence hinges on the differing approaches to the use and sequencing of structural mechanisms adopted in each city.

The work of regime-building ultimately holds the key to successful sustainability transitions. The present study offers insights into this process, identifying key structure-based institutional mechanisms and providing guidance on both the types and sequencing of structure-based initiatives that may to support a transition in practice. In doing so, this paper contributes to the scholarship on the role of institutions in regime transformation, while also providing practical insight for transition advocates seeking to bring about enduring change towards sustainability.

Methods
To explore the role of structural mechanisms in regime change, we adopted a comparative case study design. Given the exploratory nature of this research, a purposive sampling approach was used (Patton 1990). Two Australian capital cities, Melbourne and Brisbane, were chosen as case studies. Beginning in the 1970s, both cities have undergone a transition in relation to urban stormwater quality management (USQM), from a traditional model of centralised drainage focused exclusively on stormwater quantity towards a more integrated approach that introduced distributed 'green' treatment processes in order to improve stormwater quality and thereby meet a range of ecological, aesthetic, and amenity objectives (Wong and Brown 2009).

However, the cities have had significantly different outcomes in relation to the overall success of the transition. While Melbourne is now regarded as a national and international leader in relation to USQM, Brisbane has suffered a number of setbacks in recent years, leading to a reduced political appetite for continued investment in 'green' initiatives in the water sector overall and a consequent decline in the embeddedness of the transition. However, despite these difficulties, Brisbane has not returned to a pre-transition state in relation to USQM, and on-ground practice remains ahead of many other cities in Australia and beyond. Nevertheless, the significant and notable decline of structural and cultural commitment to USQM experienced by Brisbane offers a salient point of comparison to Melbourne.

Examinations of contemporary cases of transformational change are inevitably complicated by the fluidity inherent in transition periods, making a comprehensive perspective of the transition possible only in retrospect, once the new regime has achieved some level of stability. Despite this, we consider Melbourne to have passed a threshold level of social and institutional support, with the USQM transition widely perceived to be in a stabilisation phase (Brown et al. 2013). Brisbane's state of incomplete and unstable transition, alongside the wealth of contextual factors shared by the two cities, makes for an illustrative juxtaposition.

Case Study Contexts
Brisbane, the capital of the state of Queensland, is the largest city in South-East Queensland (SEQ), an administrative region along the Pacific Coast of Australia, covering a coastal strip approximately 220km wide and 100km long. The case study period for both cities begins in 1970, when concerns about water quality first emerged, providing the foundation for the subsequent focus on USQM, and continues until the present day. Over this time, SEQ became one of Australia's fastest-growing regions, with a current population of more than 3.05 million. Rapid population growth led to a period of regionalisation which saw, for the first time, the development of region-wide policies. Although the focus of this analysis is on urban stormwater quality, with Brisbane as the locus of interest, the scope of the case study was expanded to include SEQ in order to capture the effects of this regionalisation process in as much as they affected Brisbane. However, issues relating to rural diffuse pollution relating to the large agricultural regions of SEQ fall beyond the scope of this analysis. Responsibility for stormwater rests with SEQ's municipal governments, of which Brisbane City Council (BCC) is the largest in terms of both area covered (over 1,360km2) and population served (over one million residents).

Melbourne, the capital of the state of Victoria, is Australia's second-largest city, with a population of more than 4.4 million. The city is situated on the Yarra River and spreads out around Port Phillip Bay. Responsibility for water quality is shared between Melbourne Water Corporation, a government-owned statutory authority that manages regional drainage (catchments >60ha; trunk drainage), and the 38 municipal governments that are responsible for managing stormwater drains (catchments <60ha; minor drainage) and local stormwater pollution.

Data collection, analysis, and validation
A multi-stage data collection and analysis process was adopted for this research. Data collection was undertaken sequentially, beginning in Brisbane and followed by Melbourne. As a first step, we conducted oral history interviews with key individuals who had been directly involved in the emergence and evolution of the stormwater quality transition (Brisbane, 6;

Melbourne, 5). These charted the interviewee's recollection of significant changes in urban stormwater quality management, from their initial involvement to the present day. We then cross-referenced the resulting oral history transcripts with historical and contemporary secondary data, including policy materials, industry reports, organisational materials from relevant industry bodies, and professional associations, media reports and available scientific literature, to construct a case history of the evolution of stormwater quality management in each city. The resulting case narratives were sent to the same interviewees for external validation, to ensure the accuracy and credibility of the account (Creswell 2007).

During the second phase of data collection, we conducted semi-structured interviews (Brisbane, 16; Melbourne, 14) with key individuals from relevant stakeholder organisations, who were able to speak about the process of cultural and structural change in the evolution of USQM. Participants were identified through snowball sampling (Creswell 2008), which involved finding potential interviewees through recommendations from key people in each city's water sector. All participants held senior positions in their organisations and were directly involved in stormwater quality management, representing a range of stakeholder groups including state and local government, water utilities, academia, environmental organisations, and the private sector.

Interview transcripts were coded through an iterative process of thematic identification. We then triangulated the primary data with other sources of secondary evidence to develop an account of the transition process. We compiled a case report for each city, using a range of analytic approaches, including developing a descriptive case framework and conducting a time-series analysis to trace how events unfolded over time (Yin 2009). The case reports, which included preliminary analytical findings, were distributed to all interviewees in the relevant city in order to identify any gaps in the analysis, and refined accordingly (Creswell 2007).

Results
The findings of this comparative study are graphically represented in Figure 2, which lists the most significant cultural and structural changes in each city. This timeline charts the evolution of USQM in Brisbane and Melbourne, from a largely utilitarian system approaching urban waterways primarily as a means of stormwater and pollutant conveyance, to one of distributed treatment systems that provide a range of benefits in terms of water quality improvement, aesthetics, and amenity via the practice of Water Sensitive Urban Design (WSUD). The timeline is supplemented by brief narrative accounts, which further explore the role of institutions in guiding the evolution of regime change in each city and the differences between them, focusing specifically on the three structural mechanisms of hard law, soft law, and financial or market incentives, as well as cultural change. The results are arranged using the four temporal phases identified by the multi-phase perspective: predevelopment, take-off, acceleration, and stabilisation (van der Brugge and Rotmans 2007).

MELBOURNE   **BRISBANE**

	MELBOURNE	BRISBANE
PREDEVLOPMENT (1970-1989)	❖ Emergence of waterway health as an issue; legitimisation of water quality science • Port Phillip Bay State Environment Protection Policy (1975) • Waters of Victoria State Environment Protection Policy (1988) • Water Act (1989) ➢ AU$12m to 'clean-up, beautify and restore' creeks and rivers	❖ Emergence of waterway health as an issue; legitimisation of water quality science • Clean Waters Act (1971)
TAKE-OFF (1990-1999)	❖ Tagged Litter Study (1991) ❖ Melbourne Parks & Waterways est. (1993) ❖ Inter-agency Stormwater Committee est. ❖ Successful large-scale demonstration project, proving the value of WSUD for water quality improvement without compromising drainage during rainfall (1998) • Waters of Port Phillip Bay State Environment Protection Policy (1997) • Best Practice Environment Guidelines (enforced through development approvals)	❖ SEQ Water Quality Management Study – large scale collaborative research program • Environment Protection Act (1994) • Water Policy (1997) • SEQ Regional Growth Plan (1998) ○ Urban Drainage Manual (1992) ○ BCC's Urban Stormwater Management Strategy (1997, 1999) ○ Moreton Bay Waterways Management Plan ○ Model Stormwater Management Guidelines ○ Stormwater Quality Control Guidelines
ACCELERATION (2000-2010)	❖ Capacity building organisation est. (2002) • Protecting our Bays & Waterways SEPP (2003) • Clause 56 – mandating WSUD for residential subdivisions (2006) ○ Local govt Stormwater Management Plans ○ WSUD Guidelines (2005) ○ WSUD Procedures: Stormwater Manual ➢ AU$22m for stormwater quality management across the city (2006) ➢ AU$10m for WSUD along Yarra River ➢ Stormwater Offset Scheme est. (2005)	❖ Capacity building organisation est. (2005) • BCC's Stormwater Code and City Plan (2000) • State Planning Policy for Healthy Waterways (2009) ○ Healthy Waterways Strategy (2001-2006; 2007-2012) ○ Urban Stormwater Quality Management Guidelines (2010)
STABILISATION (2011-PRESENT) / **RETREAT (2011-PRESENT)**	❖ Strong industry and community culture of waterway protection • Expanded Clause 56 in a number of local governments (2013) • SEPP and BPEM under review – stricter requirements expected	❖ Waning industry and community culture of waterway protection • Relaxed State Planning Policy (2013) ○ No Healthy Waterways Strategy ➢ Repealed Rainwater tank subsidy

❖ Culture-building initiatives   ○ Soft law (policies/guidelines)
• Hard law (regulation)   ➢ Financial

Figure 2. Comparative timeline of initiatives used in each city

Culture

Brisbane's transition began with a concentrated period of cultural change, which saw the emergence and growth of concerns for waterway health among community members and industry frontrunners. This was initially focused around Brisbane's Moreton Bay, a unique marine environment home to turtles and the iconic dugong. A number of awareness campaigns and active community groups helped establish a clearer connection between environmental health and the community's broader quality of life.

From this foundation, water quality science was increasingly seen as a legitimate and necessary area for further research, and as a result, the take-off phase saw the establishment of a large-scale, collaborative scientific research program aimed to improve understandings of regional water quality issues. This ten-year staged program of scientific research, the South-East Queensland Regional Water Quality Management Study (SEQRWQMS), examined both point and diffuse source pollution, identifying the main contaminants and developing strategies for mitigating and preventing the damage these cause. Two significant national water quality science research programs also commenced during the take-off period, the Co-operative Research Centres (CRCs) for Catchment Hydrology and Freshwater Ecology, which played a critical role in building industry norms around waterway protection and expertise in USQM across both cities. In addition to consolidating an industry culture of waterway protection and creating a multi-stakeholder industry network, the CRCs delivered extensive scientific findings that were widely publicised and used to inform policy and practice in both cities.

The SEQRWQMS marked a significant turning point in SEQ's waterway management. It not only facilitated a strong scientific understanding of the aquatic environment in SEQ, but brought together all relevant stakeholders under the banner of collaborating to systematically and holistically investigate the condition and needs of the region's waterways. By creating an alliance between scientists and decision-makers, the SEQRWQMS was instrumental in creating a professional culture around valuing waterways, and played a fundamental role in legitimising water quality science as a valuable area of inquiry to both government and private sector stakeholders. In order to maintain the profile of waterway issues once the SEQRWQMS came to an end, Healthy Waterways was created to be a highly visible corporate entity representing the collaborative response of government, industry, and community stakeholders to regional water quality issues.

The acceleration phase saw strong cultural support for USQM, which had come to be regarded as a necessary part of urban water management. The numbers of practitioners engaged in WSUD swelled rapidly during this time, and expanded across a diverse range of stakeholders, as this innovation broke out of its niche to become an increasingly mainstream practice. To bolster this up-scaling process, Healthy Waterways established Water by Design – a capacity-building program charged with increasing the expertise of water practitioners across the industry in designing, building, and maintaining WSUD assets. This new body played a key role in broadening the community of practice around sustainable approaches to stormwater management.

However, rather than continuing on to a stabilisation phase, Brisbane's transition lost momentum, and even reversed in parts. Three key landscape-level factors converged towards the end of the acceleration phase to undermine the level of cultural support for USQM, leading to a reduction in waterway health and stormwater quality improvement initiatives. The first of these factors was the millennium drought (1997–2009), which necessarily shifted the water sector's attention towards security of supply. Following the breaking of the drought, Brisbane suffered devastating floods in 2011 and 2013, which then focused attention on flood protection and fast, efficient drainage. The third factor contributing to the declining support for stormwater quality improvement was a sector-wide restructure initiated in 2008, which led to a loss not only of institutional knowledge and expertise in relation to WSUD, but of several industry champions for this approach.

The crisis-driven responses on the part of the Queensland Government are generally regarded by commentators within and outside the water sector as having reinforced a segmented, single-function approach to water challenges, discounting more multi-functional solutions (Werbeloff and Brown 2016; Wallington et al. 2012). Meanwhile, the substantial investment in water supply security, followed closely by a heightened focus on flood protection, served to de-emphasise stormwater quality improvement. Crucially, the considerable spending on supply security and flood protection has also served to significantly reduce appetite for ongoing investment in the water sector as a whole, making securing funding for stormwater quality improvement initiatives more difficult.

Hard Law
Queensland's first piece of environmental protection legislation, the Clean Waters Act 1971, was introduced early in the transition journey. Although poorly enforced, the Act placed controls on water pollution from sewerage for the first time, and evidences the significant cultural shift towards a concern for environmental health characteristic of the predevelopment phase.

The take-off period saw the introduction of further hard structural measures, which reflected an improved understanding of waterway health on the part of the policy-makers. The first regional growth plan for SEQ was released in 1998, providing an overarching policy framework to guide development to meet the needs of a rapidly growing population in a way that also safeguarded the region's waterways. The evolving state of knowledge about the sources of waterway pollution also came to be included in the formal legislative framework. Underpinned by a philosophy of environmental stewardship fostered by the cultural factors described above, the Environment Protection Act 1994 (EP Act) sought to regulate point source pollution for the first time, and made discharging sediment (which had been identified as a significant pollutant) into waterways an offence. As a requirement of the EP Act, the Environmental Protection (Water) Policy 1997 (Water Policy) was introduced which, among other things, required local councils to develop and implement Urban Stormwater Quality Management Plans for the first time. However, the Water Policy did not provide any further guidance as to the form, content, or implementation of the Plans, resulting in a chequered and inconsistent implementation that reflected the differing levels of commitment to USQM across the various councils.

In the acceleration phase, changes to the formal structural framework took place at both State and local scales. At the local level, the 2000 release of BCC's City Plan, an integrated spatial

plan to guide urban development across the city, was a significant step forward for stormwater management in Brisbane. The inclusion of the Stormwater Code within the City Plan enabled a more consistent approach to stormwater management in Brisbane and ensured a link between water and land planning so that diffuse source pollution was not exacerbated as impervious surface increased. The Code introduced new requirements for managing sediment and stormwater on development sites to improve stormwater quality and addressed quantity issues pertaining to runoff volume and peak discharges. Together, these documents mandated WSUD for a wide range of developments within Brisbane, and played a significant role in embedding this approach as standard practice.

At the State level, the State Planning Policy 4/10 for Healthy Waterways (SPP 4/10) was released in 2009. This was Queensland's first statutory instrument mandating WSUD for certain developments. Until this point, WSUD practices had been primarily driven from the bottom up by local councils such as BCC, rather than being mandated top-down from state or federal governments. Within SEQ, BCC represented a high point of WSUD implementation, with the rest of region characterised by more ad-hoc practice. Responding to the growth and now-established legitimacy of WSUD, the SPP 4/10 served to mandate the practice more broadly, leading both the size of the practitioner cohort and implementation of WSUD projects to expand rapidly.

Progressive loss of cultural capital in the 2000's led to a reduction in structural support for stormwater quality management, sending the process into a retreat phase. Hard structural changes in this phase have included the introduction of a State Planning Policy in December 2013, which articulates the State's interest in planning issues. The Policy replaced the SPP 4/10 for Healthy Waters and relaxed regulation by reducing the range of developments required to implement WSUD features and, in contrast to SPP 4/10, no longer has the force of a statutory guideline. Additionally, an existing rainwater tank subsidy, widely regarded by industry as a valuable strategy for helping reduce peak flows and scouring of the catchment, was removed in December 2008, reflecting a further loss of structural support for stormwater quality initiatives.

Soft Law
As demonstrated in Table 1 (below), Brisbane's transition process relied predominantly on soft, rather than hard, law approaches. As a growing understanding of waterway health emerged, the take-off phase saw the introduction of a number of local guidelines and strategies to guide the implementation of stormwater quality improvement initiatives. These could be utilised both by local councils and urban water practitioners, and articulated evolving best practice standards.

This trend continued over the acceleration phase, with a suite of soft structural measures introduced to further support the newly establishing paradigm of waterway protection. The first Healthy Waterways Strategy, introduced in 2001, served to set an overall framework to guide implementation, followed by a second version for the period 2007–2012, which detailed a range of management actions for dealing with water quality and ecosystem health impacts on SEQ waterways at local and regional scales.

Consistent with the general trend of the retreat phase, soft structural support for USQM has declined, with no current Healthy Waterways strategy. The most recent strategy ended in

2012, and a replacement has not yet been introduced. This loss of both hard and soft structural support for WSUD and stormwater quality management more generally has greatly diminished the visibility of the issue, while simultaneously reducing organisational support for and commitment to the practice.

Financial Incentives
Among the more striking aspects of Brisbane's bumpy transition journey is the relative lack of dedicated financial or market incentive mechanisms. This is not to suggest that no money was spent on USQM, but rather indicates that no significant funding was made available to support widespread implementation. This absence stands in stark contrast to the considerable financial support similar initiatives received in Melbourne.

Melbourne

Culture
Melbourne's transition was sparked by the first large-scale scientific study of Port Phillip Bay and its catchment. This five-year study found that sewage effluent and the associated nutrient loads were significantly impacting the health of the bay and highlighted the need to reduce point source pollution. This was followed by a number of additional Melbourne-specific scientific studies, their findings corroborated by those of the national research programs. The resulting mass of evidence encouraged a common commitment to waterway protection across the water sector.

Within the community, this emerging culture of waterway protection was fostered through a local newspaper's campaign about Melbourne's poor water quality, which played a key role in galvanising the community and creating a mandate for action. Across industry, the waterway protection paradigm was further reinforced through the establishment of Clearwater, a capacity-building organisation focused on growing industry expertise delivering WSUD. Coming into the stabilisation phase, Melbourne continued to be characterised by a strong community and industry culture of waterway protection and industry expertise in WSUD.

Hard Law
Melbourne's USQM transition was strongly supported by a number of hard law initiatives. Following the Port Phillip Bay study in the predevelopment phase, the state government introduced the Port Phillip Bay State Environment Protection Policy, the first State-wide legal framework for tackling point source discharges. Further strengthening the structural foundation was the 1988 introduction of the Waters of Victoria State Environment Protection Policy, which emphasised the need to protect and restore waterways, and the Water Act 1989, which identified 13 key guiding principles for interpreting and implementing the Act.

In response to findings from further scientific studies, the State Environment Protection Policy was amended in the take-off phase to include a specific target of reducing nitrogen levels in the Bay by 1000 tonnes from 1993 levels by 2006, setting long-term goals and helping to further consolidate and mainstream a cultural paradigm of waterway protection. From this point on, the issue of point source pollution was considered largely addressed and attention shifted to the challenge of diffuse pollution from stormwater.

The take-off phase also saw the creation of the Stormwater Committee, a collaborative partnership between the Environment Protection Agency, Melbourne Water, and local governments. A key output of the Committee was the Urban Stormwater Best Practice Environmental Management Guidelines (BPEM Guidelines). Despite evoking soft law in name, in practice BPEM became strictly enforced as a condition of development by the EPA and Melbourne Water – major approval agencies controlling development across the State.

An updated State Environmental Protection Policy was released in 2003, entitled 'Protecting our Bays and Waterways' and featuring expanded obligations designed to minimise stormwater pollution entering the creeks and rivers that feed into receiving bays. Local governments were also required to identify priority sources of stormwater pollution in their municipality and develop Stormwater Management Plans. A number of guidelines and strategies, outlining best practice engineering procedures in order to establish a consistent approach to WSUD across the city where published to reinforce these initiatives. A number of these publications then came to be formally enforced through development approvals.

The introduction of Clause 56 in the Victorian Planning Provision in 2006 represents a further significant step in the mainstreaming of stormwater quality management. This new clause mandates onsite stormwater management for all new residential subdivisions across Melbourne. It is widely regarded as a milestone in the transition journey, as it ensures that ongoing urban renewal and development processes reduce, rather than contribute to, stormwater pollution across the catchment.

Building on this foundation, a number of leading councils have collectively pursued local planning scheme amendments, which operate alongside the State planning scheme, to require WSUD in all development within their jurisdictions. This stands to significantly expand the impact of Clause 56, which was originally limited to greenfield residential development, and did not cover urban renewal through infill development. The proposed amendments were approved in 2015, placing this plucky handful of local councils at the vanguard of implementing this new practice.

As with Brisbane, Melbourne was also significantly affected by the millennium drought, with similar results: the priority of stormwater quality management falling in comparison to pressing water supply challenges. Nevertheless, the established robust regulatory framework continues to drive WSUD practice on the ground, whether via development approvals, Clause 56, or the offset scheme.

The State Environment Protection Policy and BPEM Guidelines are both currently under review, with updated versions anticipated to outline more stringent obligations reflecting expanded scientific understanding and introduce a range of requirements around the new USQM priority of stormwater flows.

Soft Law
Soft law measures were infrequently used in Melbourne, predominantly limited to the acceleration phase. These initiatives were largely designed to assist best practice implementation, complementing the suite of hard legal instruments that had been

introduced. Many of these policies and guidelines were outputs from the Stormwater Committee, such as the WSUD Guidelines and Stormwater Manual.

Financial Incentives

Melbourne's USQM transition has been supported by a number of sizeable financial grants, conferring legitimacy on the new practice and boosting on-ground implementation. Investment began in the predevelopment phase, with the introduction of a funding program, making over AU$12 million available to 'clean-up, beautify, and restore' creeks and rivers in Melbourne. By the end of the take-off phase, the funding had produced a number of successful pilot and demonstration projects, helping build confidence in the technical feasibility and performance of decentralised, green treatments for stormwater. On-ground implementation was also significantly boosted by an AU$60 million Commonwealth grant, which enabled the construction of 52 wetlands across the city between 2000 - 2010.

Melbourne's acceleration phase was bookended by significant financial contributions, beginning with more than AU$22 million to improve stormwater quality management across the city and concluding with a further AU$10 million for WSUD across Melbourne's iconic Yarra River. Financial support also took the form of a stormwater offsets scheme, which remains the only one of its kind in Australia and is regarded as a practice-leading approach internationally. The scheme, designed to reduce pollution associated with urban development, imposes a financial cost if developers do not meet the best practice targets outlined in the State Environment Protection Policy. The funds collected from developers are then used to implement stormwater quality improvement projects throughout the catchment.

Table 1 offers a comparison of the structural changes in Brisbane and Melbourne, showing how the transition journeys unfolded in each city. The table shows the evolution of the transition in terms of the numbers of culture and structure-based initiatives across each of the transition phases. The negative numbers in Brisbane's stabilisation phase indicate measures that reduced the scope of stormwater quality improvement initiatives.

We note that such a simple count is unable to capture the fact that some initiatives are more potent than others. However, exploration of the differing impact of various initiatives is contained in the results and discussion sections and the purpose of Table 1 is in proving a macro overview of the relative priority given to different types of initiatives across each city.

Table 1. Summary of stormwater quality management transitions initiatives

	BRISBANE				MELBOURNE			
	Culture	Financial	Soft Law	Hard Law	Culture	Financial	Soft Law	Hard Law
Predevelopment	0	0	0	1	2	1	0	4
Take-Off	6	0	7	4	9	1	0	3
Acceleration	6	0	4	2	5	4	3	7
Stabilisation	0	0	-1	-1	0	0	0	2
TOTAL	12	0	10	6	16	6	3	16

Discussion

Types of structural mechanisms and their interactions
Our investigation unearthed a number of significant differences between the two cities' approaches. Notably, Melbourne used a greater number of structure-based initiatives overall; predominantly of the hard regulatory variety. However, Melbourne shored up the effectiveness of its new hard laws with a matching number of culture-building initiatives, which helped instil legitimacy for the new regulatory requirements. By contrast, Brisbane relied predominantly on culture-based initiatives, followed by soft structural measures. Hard regulatory measures were used infrequently. No dedicated financial measures were used. This stands in stark contrast to the substantial amount of funds that Melbourne invested in WSUD implementation initiatives, which helped legitimise the practice, encouraged industry practitioners to upskill, and facilitated project implementation.

Why was Brisbane's transition journey less characterised by hard regulatory measures than Melbourne's, given the powerful influence such measures have on embedding new practices? As highlighted by Meadowcroft (2011), in the study of transformative change, context matters, and a consideration of the contextual differences obtaining between the cities can serve to shed some light on why each transition journey unfolded as it did. Importantly, the key transition actor in Melbourne was Melbourne Water – a government agency, which made the pathway of structural change a particularly available and viable one. By contrast, the driver of the transition in Brisbane was Healthy Waterways – a multi-stakeholder network spanning the science and industry sectors. Although Healthy Waterways was highly influential, its network did not directly include political decision makers, making it reliant on regular interactions with a receptive government to influence decisions and ensure ongoing political support for USQM. This means that changing the hard structural framework was not a readily available option in Brisbane.

Notably, Brisbane's sustainability transition effort also faced contextual challenges arising from the process of regionalisation that unfolded over the course of its transition. New regulatory measures covered differing jurisdictions, some local, some regional, and some State. This had the effect of diffusing obligations and making enforcement difficult, contributing to the chequered approach to implementation observed across the region, which in turn created further difficulties for embedding the overall transition.

Sequencing of structural mechanisms and its implications for regime change
The results of our study also offer some insight into the impact of the way structural initiatives are sequenced on regime change. Here too, the two cities adopted markedly different approaches. A closer look at Melbourne's transition journey reveals that the predevelopment phase was structure-dominated, the take-off phase culture-dominated, and the acceleration phase once more dominated by structural measures. The structural measures in Melbourne's predevelopment phase were used to introduce a broad legal framework for waterway protection, with largely aspirational, non-enforceable goals. Launched from this springboard, the take-off phase was characterised by knowledge-building activities such as scientific research into the scope, causes, and consequences of waterway health problems. Such measures also helped to raise awareness and create shared norms and values around waterway protection. Widespread on-ground implementation in the acceleration phase was facilitated by another suite of innovative structural measures, including an offset scheme and

a planning scheme amendment – both widely credited with expanding and mainstreaming WSUD practice.

In Brisbane's transition journey, both the predevelopment and take-off phases were structure-dominated, with an equal number of culture- and structure-based initiatives featuring in the acceleration phase. However, a closer examination reveals that Brisbane had only one hard legal mechanism in play during the predevelopment phase, in contrast to Melbourne's four, and that both the take-off and acceleration phases featured a greater number of soft rather than hard legal measures.

This contrast between the two cities' sequencing strategies suggests that the temporal distribution of initiatives can have implications for the overall effectiveness of a transition effort. The more successful transformation in Melbourne leaned heavily on hard structural measures very early in the transition process and again during the acceleration phase. Although transition advocates will always be necessarily opportunistic in their approach, these results indicate that timing matters, and actors should proactively engage with regulatory frameworks to embed the fledgling transformation effort.

It is important to note that the early phases of Brisbane's transition were highly effective, despite the relative lack of hard structural measures. A strongly aligned actor-network worked to advance the waterway protection agenda, and the industry was largely receptive to this shift. This suggests that the use of soft legal approaches in such a context worked very well, as evidenced by stakeholders swiftly adopting the new practices without the need for any enforcement. However, the inherent risk of this approach is evidenced by Brisbane's later transition phases. In the a context marked by wavering cultural support for waterway protection and the loss of several key industry champions, the limitations of relying on soft legal approaches become clear: While soft law mechanisms can be highly effective in driving transformative change, the differing levels of success achieved by the two cities suggest that hard legal mechanisms are important to make such change resilient.

Our study revealed another key difference: Over the course of each transition phase, Melbourne engaged with a broader range of initiatives, helping to build a more diverse and therefore stronger foundation for the transition. By contrast, Brisbane instigated a greater number of initiatives, but had less overall diversity in the type of initiatives used. This finding implies that a wide-ranging portfolio of supporting initiatives may have a more beneficial impact than the overall number of initiatives used.

Importantly, the transitions we examined were not deliberately planned and executed. Rather, the change processes unfolded organically, with each city using the approaches and mechanisms available given its context. The most significant difference between the two cases relates to use of structural mechanisms, highlighting the opportunity to derive practical learnings relating to how soft and hard structural measures can be deployed strategically to support regime change.

Supporting regime change in practice
What practical guidance can transition-oriented actors and organisations derive from examining the sustainability transitions of these two cities? Our analysis suggests three major

lessons for strategic use of institutional measures to support regime change. Firstly, our results signify that policy and soft structural measures do not, by themselves, provide a sufficient foundation for building lasting transformational change. However, soft structural measures may be particularly useful in the early transition phases, to foster acceptance and support of the new practice. Crucially, as the Brisbane case clearly demonstrates, a timely switch to hard regulatory measures is necessary in order to mainstream the new practice and facilitate on-ground implementation. While use of soft law can assist a transition effort, the Melbourne experience suggests that such measures may not be strictly necessary. Melbourne had very few policy-based initiatives, which figured primarily in the acceleration phase. Despite this, Melbourne had the more successful transition effort, suggesting that the absence of soft structural measures can be compensated for by alternative mechanisms. In particular, the role of financial support and market mechanisms should not be underestimated, such incentives having played a critical role in expanding and embedding USQM practice in Melbourne.

Secondly, the results indicate that timing matters. The key regulatory measures introduced in Brisbane to mandate WSUD more broadly came relatively late in the acceleration phase and were weakly embedded. This made them vulnerable to repeal or reversal – precisely the scenario that transpired with the change of government in 2012. Melbourne's transition trajectory suggests that frequent and proactive engagement with the regulatory framework may be more effective. Melbourne's earliest regulatory efforts were focused on articulating principles to guide action and interpretation of legal obligations, as well as outlining an aspiration for waterway health. Although not enforceable, Melbourne's early legal measures formed a solid foundation on which enduring regime change could be built. They played an important role in codifying the emerging culture around waterway protection, and provided a flexible framework that could be amended and updated to reflect the latest scientific knowledge. In short, the Melbourne case suggests that introducing an aspirational and perhaps imperfect legal framework early on is preferable to delaying and waiting for more data to inform the development of a more detailed regulatory framework. While a newly emerging culture can, in part, be codified through policy, including it in regulation sends a stronger signal of the issue's importance. To support this process, early and proactive engagement with relevant government agencies can also be beneficial for pursuing regulatory change. This is particularly important where the actors seeking to drive regime change are not involved in the governance of the existing regime.

Finally, the results confirm that structure does not function in a vacuum. Rather, any structural initiative relies on broad cultural support and legitimacy, and needs to be seen as furthering the collective values and aspirations of the community to ensure uptake. It is worth remembering that despite its extensive reliance on hard regulatory mechanisms, Melbourne had an equal number of culture-based mechanisms, suggesting that concerted effort was made to build the underpinning cognitive and normative foundation which helped sustain the transition.

Conclusion

Institutional change is central to both regime transformation and sustainability transitions more broadly. Our study builds on a recent institutional turn in transitions scholarship by examining the evolution of institutional change across two current and contemporaneous transitions. In doing so, it offers a more nuanced understanding of the structural and cultural components of institutions, and examines their role in facilitating regime change. The results

highlight the importance of using structure-based institutional measures in building regime transformation, and indicate that soft law alone is insufficient for supporting a transition and that hard regulatory measures play a critical role in embedding regime change. With respect to hard regulation, the timing of regulatory initiatives matters, with the results suggesting that engaging with legal frameworks early in the transition process will more effectively support overall regime change.

Our findings also offer practical insights for innovators and transition proponents. In highlighting the importance of hard legal measures to a transition effort, the results suggest that actors should focus their strategic efforts on proactively influencing regulatory frameworks in order to facilitate regime change. However, further case study research is needed to assess and refine these principles in relation to sustainability transitions in other sectors. To provide more comprehensive guidance on how regime change can be strategically influenced, it is also necessary to assess a broader range of institutional change mechanisms, and examine their interactions over time. The resulting more detailed understanding of institutional change in the context of regime transformation would offer valuable insights that could be used by transition advocates to guide change processes.

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6. Publication 3: Using Policy and Regulatory Frameworks to Facilitate Water Transitions

6.1 Introduction

Publication 2, presented in the previous chapter, examined the structural domain across two case study cities, revealing the importance of direct regulation in enabling and facilitating structural change and a sustainability transition more generally. The next paper provides an in-depth exploration of the co-evolution of culture, structure and practice change in Brisbane, the least successful transition of the three cities examined for this research.

Through this in-depth empirical exploration of a 'transition in struggle', the paper reveals lessons in relation to the dynamics and sequencing of structural and cultural changes to best support a transition. This publication adds to the scholarship an examination of a less desirable transition trajectory, in turn offering guidance on how to avoid or minimise such a trajectory and instead keep progressing towards stabilisation of a transition.

The outcomes of this paper contribute to the second research objective of this thesis, being to "assess the type and operation of institutional change mechanisms in the institutionalisation of a radical innovation".

The paper presented in this chapter has been published in *Water Resources Management*.

6.2 Declaration for Thesis Chapter 6

Declaration by candidate

In the case of Chapter 6, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Formulation of the research problem, research design, data collection and analysis, interpretation of results, writing the paper	90%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
Rebekah R. Brown	Participation in the formulation of the research problem, participation in the interpretation of results, providing feedback on the written manuscript	N/A

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work.

Candidate's Signature		Date 26/10/16

Main Supervisor's Signature		Date 26/10/16

6.3 Manuscript

CrossMark

Using Policy and Regulatory Frameworks to Facilitate Water Transitions

Lara Werbeloff[1,2] · Rebekah R. Brown[3]

Abstract There are persistent calls across policy, industry and academia for urban water transitions in order to deliver increased sustainability, liveability and resilience. However, realisation of such transformational change is difficult, and there are a number of undesirable or unsuccessful transition trajectories that can manifest. Drawing on a contemporary stormwater quality management transition in South-East Queensland, Australia, this qualitative research paper provides an empirical exploration of a transition in struggle. The paper examines why and how this transition trajectory unfolded, focusing specifically on the evolution of culture, structure and practice changes from the 1970s to the present-day. The paper makes two scholarly contributions, firstly confirming the dynamic nature of transformational change and indicating the need to design transition initiatives across the culture, structure and practice domains to co-evolve and thereby build a robust and mutually reinforcing transition foundation. The results also reveal the critical role of regulation in providing a safety net for the transition and enabling continued progress even when commitment to policy goals wavers. These results also provide practical insight for practitioners engaged in the implementation of transition processes, and reveal the need for transition advocates to deliberately and proactively engage with regulatory frameworks to embed a novel practice.

Keywords Sustainability transition · Stormwater · Regulation · Policy · Structure

1 Introduction and Background

Urban water systems are under increasing pressure from a range of complex and interrelated challenges, including climate change, population growth, degraded urban streams, resource

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✉ Lara Werbeloff
  lara.werbeloff@monash.edu

1 School of Social Science, Monash University, Melbourne, Australia

2 Cooperative Research Centre for Water Sensitive Cities, Monash University, Melbourne, Australia

3 Monash Sustainability Institute, Monash University, Melbourne, Australia

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constraints and changing community preferences (Vlachos and Braga 2001; Pahl-Wostl et al. 2007; Brown 2008; Brown et al. 2009). These challenges are impeding the resilience and effectiveness of traditional urban water management frameworks and attention is therefore turning towards more integrated and sustainable management approaches. It is now widely acknowledged by academics, policy makers and industry leaders that a contemporary urban water management framework must respond to issues including water security, flooding risk, urban heat island and degradation of urban waterways while also providing aesthetic benefits, improving amenity and enhancing liveability (Mitchell 2006; UNESCO 2009; Brown et al. 2011; Pahl-Wostl et al. 2011; OECD 2011).

In order to more effectively integrate sustainability into urban water systems, radical transformation is needed. The relatively young literature on socio-technical (Rotmans et al. 2001; Geels 2002; Kemp et al. 2007) and socio-ecological (Folke et al. 2005; Olsson et al. 2006) transitions explores the concept of transformation towards sustainability and provides valuable theoretical guidance on how such change processes may unfold. A 'sustainability transition' is a transformative change process whereby a system shifts towards more sustainable modes of production and consumption (Smith et al. 2010; Markard et al. 2012). Typically taking place over 25–50 years, transitions are large-scale transformations that fundamentally change a system's structure and/or the way in which it functions (Grin et al. 2010), and are contrasted with more discrete change that merely tweaks or optimises the operation of the current system. Central to the realisation of a sustainability transition is a fundamental reorientation of the existing 'cultures', 'structures' and 'practices' within a system, referring to the dominant means of 'thinking', 'organising' and 'doing' (Geels 2002; Rotmans and Loorbach 2009).

The concept of 'culture' has been widely examined (eg: Hays 1994; Suchman 1995; Hajer 1995; Dryzek 2005; Scott 2008) and refers to values and perspectives shared amongst a defined social group. More specifically, 'culture' comprises both cognitive and normative elements (Scott 2008). The cognitive dimension refers to shared problem and solution frames, through which we derive meaning about our social world (Scott 2008). The normative element refers to deeply held values as well as norms that define the appropriate means to pursue the desired ends (Scott 2008). Together, these two dimensions create a shared culture among a social group that is both slow to establish and hard to change, given that these deeply internalised values and beliefs about the world are typically taken for granted as 'the way we do things'. Although intangible, 'culture' is an important component of transformational change, playing a critical role in conferring legitimacy on new practices, which is understood as "…a generalised perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions" (Suchman 1995, p.574).

'Structure' is an ambiguous and loosely defined concept (Sewell 1992), often used as an umbrella term to refer a diverse range of factors that influence stakeholder behaviour. The concept has been extensively explored from legal (Freiberg 2010), institutional (Scott 2008) and environmental governance perspectives (Gunningham 2009; Taylor et al. 2012) and includes policy frameworks, direct regulation, 'quasi-regulation' such as guidelines and best practice standards, market mechanisms, information-based instruments and innovative governance arrangements such as co- and self-regulation (Gunningham 2009; Freiberg 2010; Taylor et al. 2012). In general terms, a distinction can be made between (a) 'soft' forms of structure (such as policy frameworks or best practice guidelines) that incentivise or encourage behaviour in a particular direction, but have limited or no enforcement capacity and (b) hard 'command

and control' structure (such as regulation), that prescribes minimum standards and carries penalties for non-compliance.

Both types of structure work in combination to support a broader transition effort. Policy frameworks signal the importance of an issue, in turn directing funding and other resources towards the exploration of possible solutions. Policy change can take a number of forms. Hall's seminal tripartite typology (1993) identified first-order change (routine adjustments to existing policies), second-order change (change in policy instruments to meet existing goals) and the comparatively rare third-order change (changes to the goals themselves). However, the vast scholarship on policy transitions makes clear that change on paper will not necessarily bring about change in practice (Meijerink and Huitema 2009; Brouwer 2015). As Barrett and Fudge note, "policy does not implement itself" (Barrett and Fudge 1981, p.9) and needs to be enacted via instruments to achieve the articulated policy goals. Regulation is one such instrument, helping put policy into action. As such both types of structure are necessary, and together with culture can be used in a mutually reinforcing way to provide a strong foundation for transformational change.

Finally, the concept of practice refers to the dominant ways of 'doing' within a system and typically includes physical infrastructure and the associated maintenance activities. For example, in the water sector the dominant way of 'doing' has traditionally seen a reliance on centralised, highly engineered, linear and siloed infrastructure that is mono rather than multi-functional (Pahl-Wostl et al. 2011). The notion of practice has also been understood at a micro scale to include user habits and behaviours (Shove and Walker 2010; Rotmans and Loorbach 2009), however as this analysis focuses on change at the regime or system level (Geels 2002), the more macro-level understanding of practice is adopted here.

Taken together, the culture-structure-practice framework is a useful way to understand the transition process as it draws attention to the ways in which culture and structure mutually reinforce each other to embed a new practice. Yet despite a recognition of the importance of embedding change within all three domains, little attention has been given to the dynamics of that change process (Pahl-Wostl 2007). In particular, it is unclear how change within each dimension (a) unfolds in practice, and (b) interacts with change in other dimensions. There are also questions around the sequencing of change across the culture, structure and practice dimensions. Examination of contemporary water transitions can therefore provide greater understanding of the on-ground dynamics of transformational change, in turn offering valuable insight for transition advocates and industry practitioners seeking to enable broader transitions in the water sector.

In conceptualising how transition processes may unfold, a number of overarching patterns of change have been identified (e,g., Rotmans et al. 2001; Geels and Schot 2007; de Haan and Rotmans 2011). To this end, the multi-phase perspective is a key theoretical contribution of the sustainability transitions literature and identifies four distinct (but non-linear) temporal phases of an idealised transformative change process: predevelopment, take-off, acceleration and stabilisation (Rotmans et al. 2001).

This idealised transition trajectory is represented by the 'S-curve' in Fig. 1, whereby the system transforms to a new dynamic equilibrium after moving through each of the four phases. Given the multi-dimensional and dynamic nature of transformative change processes, realisation of this ideal transition pathway is by no means inevitable. As the transitions scholarship makes clear, complex systems such as that for water servicing are characterised by a web of infrastructures, practices, regulations, markets, policies and institutions that have co-evolved over time and serve to anchor the status quo (Smith et al. 2005). Re-orienting this complex

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network in a seamless and mutually reinforcing way towards more sustainable outcomes is a significant challenge. As Fig. 1 demonstrates, a number of less desirable transition patterns have also been identified. Indeed of the four transformative change trajectories identified above, it is striking that only one leads to positive change on the ground. This suggests that system changes will not always be synergistic and there will likely be both big and small hurdles on the pathway towards stabilisation, some of which may threaten to derail the transition entirely. Accordingly, there is a need for greater attention to (a) understanding why and how these less desirable trajectories emerge, and (b) identifying strategies to minimise the negative effects when they do in order to facilitate ongoing progress towards successful transformation.

To this end, this paper presents an empirical examination of a case of transition in struggle, drawing on an urban stormwater quality transition in South-East Queensland (**SEQ**), Australia. While the outcome of the transition is not yet clear, after significant initial success, the transition has suffered some 'institutional reversal', with key initiatives being diluted or repealed. Using the culture-structure-practice framework to explore the evolution of the transition, the paper reveals the necessity of building a multi-dimensional foundation to support transformative change and the importance of structural frameworks in anchoring and embedding transition progress. The paper concludes with practical guidance for urban water practitioners seeking to influence transition processes.

2 Research Approach

Given the exploratory nature of this research, a purposive sampling approach was used (Patton 1990) to identify a single longitudinal case study (Yin 2009). The evolution of urban stormwater quality management (**USQM**) in SEQ, from a traditional model of centralised drainage focused exclusively on stormwater quantity towards a more integrated approach that introduced distributed 'green' technologies such as wetlands and biofilters to improve stormwater quality and thereby meet a range of ecological, aesthetic and amenity objectives (Wong 2006; Brown et al. 2009), was considered a useful case for a detailed exploration of a trajectory of institutional reversal. SEQ was regarded as a leading example of the implementation of stormwater quality improvement, both within Australia and internationally. However, a sector-wide restructure in 2009 and devastating
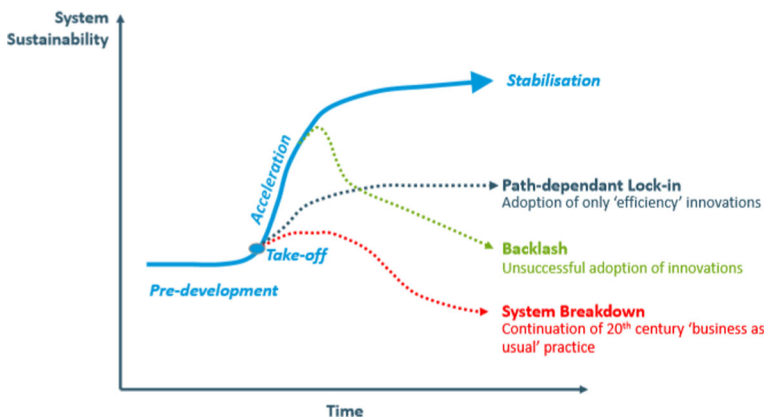

Fig. 1 Possible transition trajectories. (Van der Brugge and Rotmans 2007, p.255)

floods in 2011 and 2013 all had significant impact on SEQ's water sector and are generally regarded by industry practitioners as having led to a reduced appetite for continued investment in 'green' initiatives in the water sector overall. Whilst there has not been an outright rejection of USQM, there has been a significant reduction in socio-institutional support, with many innovative stormwater quality initiatives being rescinded or reversed, in turn leading to reduced implementation on the ground.

2.1 South-East Queensland Case Context

South-East Queensland is a large, urbanised region on the Pacific coast of Australia. It covers a coastal strip approximately 220 km wide and 100 km long, and includes Queensland's state capital city, Brisbane. The case study period extends from the early 1970s when, consistent with the emergence of the global environmental movement, concern for water quality first emerged amongst community and industry frontrunners, until the present day. Over this time, SEQ became (and remains) one of Australia's fastest growing regions, with a current population of over 3.05 million. Rapid population growth led to a period of regionalisation which saw the development of region-wide policies for the first time. While the analysis focuses on SEQ to capture this regionalisation process, the large agricultural regions of SEQ and consequent issues associated with diffuse rural pollution are beyond the scope of this analysis (Fig. 2).

Over the case study period there has been much institutional upheaval, with local government going through a number of restructures and amalgamations. In 2008 there was also a significant sector-wide restructure, which removed bulk water and sewage responsibilities from local government (Walton 2009). However, over the entire case study period, responsibility for stormwater has remained with municipal councils. Brisbane City Council (**BCC**) is the largest municipal council in SEQ in terms of both area covered and population served (more than 1 million residents).

2.2 Data Collection, Analysis and Validation

A multi-stage data collection and analysis process was adopted for this research. As a first step, oral history interviews were undertaken with key individuals ($n = 8$) who had direct involvement with the emergence and evolution of the stormwater quality transition. These interviews charted the interviewee's recollection of significant changes in urban stormwater quality management, from their initial involvement to the present day. Historical and contemporary secondary data, including policy materials, industry reports, organisational materials from relevant industry bodies and professional associations, media reports and available scientific literature was cross-referenced with the oral history transcripts to construct a case history of the evolution of stormwater quality management in SEQ. The resulting case narrative, which identified key turning points in the transition journey and charted the institutional reversal trajectory, was sent to the same interviewees for external validation in order to ensure the accuracy and credibility of the account (Creswell 2007).

For the second phase of data collection, semi-structured interviews ($n = 20$) were conducted with key individuals across relevant stakeholder organisations able to speak to the process of cultural and structural change in the evolution of USQM. The interviews focused on culture, structure and practice changes within each transition phase. Participants were identified through snowball sampling (Creswell 2008), which involved finding potential interviewees
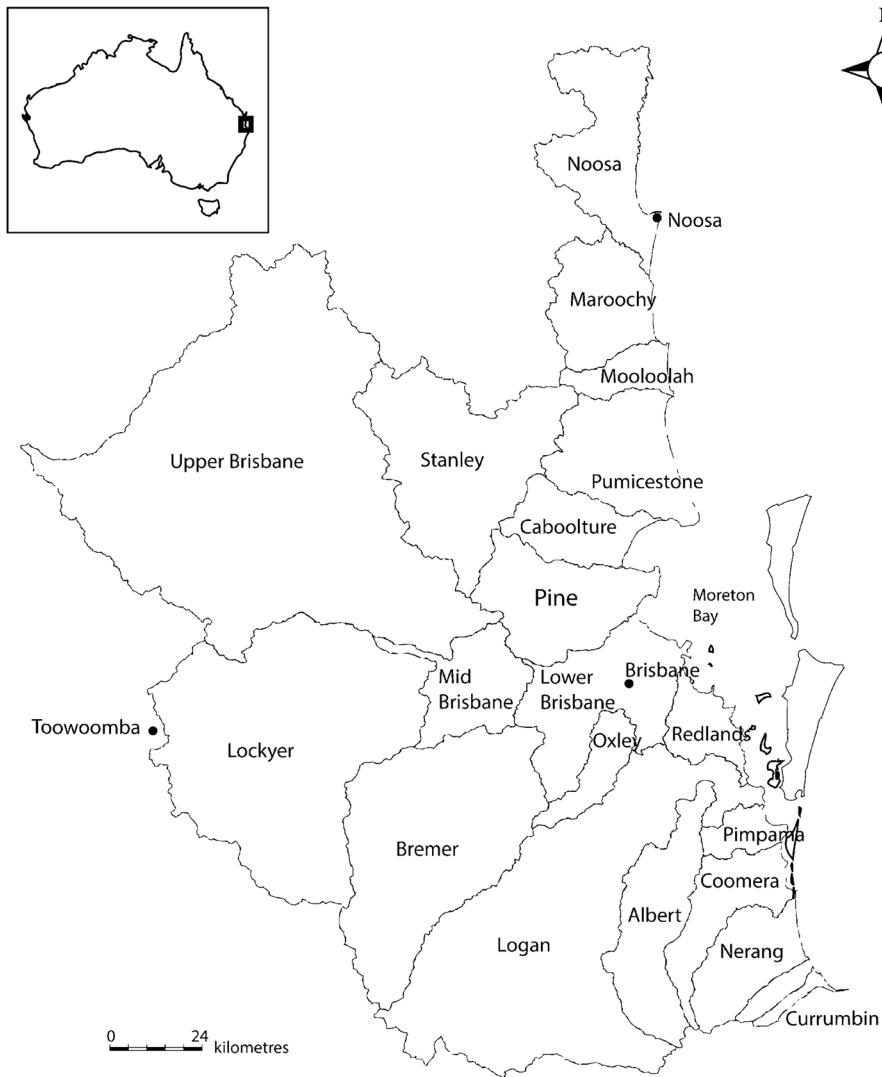
Fig. 2 Map of South-East Queensland and its catchments (Dutra et al. 2014, p.1071)

through recommendations from key people in SEQ's water sector. All participants held senior positions in their organisations and were directly involved in stormwater quality management in SEQ across stakeholders including state and local government, water utilities, environmental organisations, engineers, land developers and academia.

Interview transcripts were coded through an iterative process of thematic identification. The primary data was triangulated with other sources of secondary evidence to develop multiple accounts of the transition process. A case report was compiled using a range of analytic approaches, including developing a descriptive case framework and conducting a time-series analysis to trace how events unfolded over time (Yin 2009). The case report, which included preliminary analytical findings, was distributed to all interviewees in order to identify any gaps in the analysis and refined accordingly (Creswell 2007).

3 Findings

The findings are presented as a narrative account of the development of urban stormwater quality improvement practices in SEQ, using the four transition phases (predevelopment, takeoff, acceleration and stabilisation, here replaced by 'institutional reversal') (Rotmans et al. 2001) and focusing particularly on culture, structure and practice change. The timeline charts the evolution of USQM, from a largely utilitarian system that viewed urban waterways as a means of stormwater and pollutant conveyance, to one of distributed treatment systems that provide water quality improvement, aesthetic and amenity benefits.

3.1 Predevelopment (1970–1989)

The predevelopment phase was dominated by a change in the culture domain, which saw the emergence and growth of a concern for waterway health amongst community and industry frontrunners. From this time, water quality science was increasingly seen as a legitimate and necessary area of research and this phase laid the foundation for the subsequent evolution of stormwater quality initiatives.

3.1.1 Culture

Reflecting the global emergence of the environmental movement in the 1970s, the predevelopment phase in SEQ was characterised by an increasing awareness of, and concern for, the environment. Whilst this phase was not concerned with stormwater specifically, it was marked by increasing community activism and the early engagement of industry in relation to water quality, challenging the traditional management approach that was largely unconcerned with waterway health. For the first time, there was an emerging awareness that waterways were not environmentally benign and it was from this foundation that a concern about stormwater subsequently evolved.

The SEQ community was highly engaged in relation to water issues, focused in particular on the iconic Moreton Bay, which later became a RAMSAR listed wetland. There were also local catchment groups operating along the Brisbane River, an iconic river running through the state's capital, used predominantly as a transport and waste corridor during this time. Further raising the profile of the Brisbane River were some non-government organisations that undertook early scientific studies on the health of the river and that were also engaged in public and political advocacy for more integrated catchment management.

3.1.2 Structure

Reflecting this growing concern for environmental health, Queensland's first piece of environmental protection legislation, the *Clean Waters Act 1971*, was introduced in this period. Although poorly enforced, the Act placed controls on water pollution from sewerage for the first time, and evidences the significant cultural shift towards a concern for environmental health that charectarises this predevelopment phase.

3.1.3 Practice

Acting on scientific studies demonstrating the impact of point source pollution on the Bay, the predevelopment phase saw large-scale upgrades to SEQ's wastewater treatment plants.

3.2 Take-off (1990–1999)

This phase is characterised by significant investment in scientific research and the consequent growth in understanding waterway health. By the end of the take-off phase, there was a clear understanding that stormwater was adversely impacting the health of the waterways and a strongly aligned coalition of science, policy and industry practitioners working collaboratively to develop appropriate responses and solutions.

3.2.1 Culture

The take-off phase saw the establishment of a large-scale, collaborative scientific research program to better understand regional water quality issues. This staged program of scientific research, the South-East Queensland Regional Water Quality Management Study (**SEQRWQMS**) initially focused on identifying the limiting nutrients in the marine and estuarine areas of the Moreton region, and later expanded to include the freshwater catchment areas of the Moreton region as well as the fresh and tidal waters in the north and south of SEQ. The study also examined both point and diffuse source pollution.

The SEQRWQMS was a turning point in regards to waterway management in SEQ. It facilitated a strong scientific understanding of the aquatic environment in SEQ, while also bringing all relevant stakeholders together in a collaborative way to holistically investigate the condition and needs of the region's waterways. By creating an alliance between scientists and decision-makers, the SEQRWQMS was critical in creating a professional culture around valuing waterways and played a fundamental role in legitimating water quality science as a valuable area of inquiry. In order to maintain the profile of waterways once the SEQRWQMS came to an end, 'Healthy Waterways' was created to be a highly visible corporate entity, representing the collaborative response of government, industry and community stakeholders to regional water quality issues. Complementing the growing body of scientific knowledge, two national industry-academia research collaborations also commenced during this period and were critical in: (1) strengthening the knowledge base about SEQ's water environments, and (2) building industry consensus about poor waterway health and possible solutions to this challenge.

3.2.2 Structure

The take-off period saw the introduction of more formal structural support for this improved understanding of waterway health. The first regional growth plan for SEQ was released in 1998, providing an overarching policy framework for guiding development to accommodate a rapidly growing population. It recommended the maintenance and enhancement of water quality within the metropolitan area's waterways with emphasis on Moreton Bay and the Brisbane River.

This new state of knowledge about the impacts on waterway health was also included in the formal legislative framework. Underpinned by a philosophy of environmental stewardship, the *Environment Protection Act 1994* (**EP Act**) sought to regulate point source pollution for the first time and also made it an offence to discharge sediment to waterways, which had been identified as a significant pollutant.

As a requirement of the EP Act, the *Environmental Protection* (*Water*) *Policy 1997* was released (**Water Policy**) which, among other things, introduced a requirement that local councils

develop and implement Urban Stormwater Quality Management Plans. However, the Water Policy did not provide any further guidance as to the form, content or implementation of the Plans and it was therefore at the discretion of each individual Council how rigorously it undertook development of these plans.

3.2.3 Practice

As the largest and most well-resourced local council in SEQ, BCC was a key player in terms of improved stormwater management across the region and often set the benchmark for improved practice. For example, in preparation of its USQM Plan, BCC investigated the needs of its local waterways and consulted with the local community about their values in relation to those waterways. This enabled both increased community engagement and the development of more comprehensive plans, and became a best practice approach for other councils.

Other best practice BCC initiatives introduced during this period include the Stormwater Quality Improvement Device Program (SQID). The program initially began with installing Gross Pollutant Traps in local creeks and waterways. Although litter was not a significant contributor of water pollution, it was highly visible and a 'low hanging fruit' measure for community engagement. BCC's SQID program is ongoing, and now has approximately 70 council-owned assets, including trash racks, gully pits, gross pollutant traps and constructed wetlands.

3.3 Acceleration (2000–2010)

The acceleration phase saw widespread proliferation of USQM. With a strong scientific foundation now well established, efforts focused on urban stormwater quality improvement through Water Sensitive Urban Design (**WSUD**), an approach that mimics the natural water cycle and integrates water into urban planning and design. The acceleration phase is characterised by the introduction of structural support for WSUD and a rapid expansion of project implementation as a consequence.

3.3.1 Culture

The acceleration phase saw a significant increase in practitioners engaged in WSUD practices as this new innovation broke out of its niche and started becoming an increasingly mainstream practice. To assist this up-scaling process, Healthy Waterways established a capacity building program, Water By Design, which was charged with increasing the expertise of water practitioners in designing, building and maintaining WSUD assets and played a key role in broadening the community of practice around this new approach to stormwater management.

3.3.2 Structure

There were significant structural changes introduced over the acceleration phase. Setting an overall framework to guide implementation was the first Healthy Waterways Strategy introduced in 2001, followed by a second version covering 2007–2012, which detailed a range of management actions at local and regional scales for dealing with water quality and ecosystem health impacts on SEQ waterways.

At the local level, the release of BCC's City Plan in 2000, an integrated spatial planning document to guide development across the city, was a significant step forward for stormwater management in Brisbane. The inclusion of the Stormwater Code within the City Plan provided a more consistent approach to stormwater management in Brisbane and ensured a link between water and land planning processes. The Code introduced new requirements around the management of sediment and stormwater on development sites and also addresses quantity issues of runoff volume and peak discharges. Together, these documents mandated WSUD for a wide range of developments within Brisbane and played a significant role in embedding this approach as standard practice.

At the state level, the State Planning Policy 4/10 for Healthy Waterways (**SPP 4/10**) was released in 2009, which was the first state-based statutory instrument mandating WSUD for certain developments. Until this point, WSUD practices had been primarily driven by local councils such as BCC, rather than being mandated top-down by state or federal governments. Within SEQ, BCC represented a high point of WSUD implementation, with variable practice across the rest of region. Responding to the growth and the now established legitimacy of WSUD, SPP 4/10 served to mandate the practice more broadly, and as a consequence, both the size of the practitioner cohort and implementation of WSUD projects rapidly expanded. As one interviewee noted, "*once SPP came in, there was an absolute explosion of WSUD. It couldn't be argued away by any developer, so everyone got on with doing it*" (private consultant).

3.3.3 Practice

Some significant demonstration projects in the acceleration phase helped to build confidence in this new approach and thereby further expand the practitioner cohort. One particularly significant WSUD project was the Bridgewater Creek (Bowie's Flat) Wetland. Completed in 2002, it was the first demonstration of a wetland as a treatment train and was significant for demonstrating the potential of 'soft' engineering approaches to deliver improved waterway health. Significant WSUD demonstrations beyond Brisbane, such as Lynbrook Estate in Melbourne, were also influential.

3.4 Institutional Reversal (2011 – Present)

Rather than proceeding along the S-curve towards a stabilisation phase, the stormwater quality transition in SEQ is now wavering. Three key factors, a ten-year drought, major floods and a sector-wide restructure, converged toward the end of the acceleration phase to significantly reduce the political appetite for continued investment in the water sector, with a consequent reduction in waterway health and stormwater quality improvement initiatives. This has been observed by a number of practitioners, who stated:

> "*We've lost a lot of momentum over the last 5 or ten years. Politics have changed. Priorities have changed*" (local government).
> "*A lot of the initiatives that we had established have been closed down, so we've gone backwards. We have to start the journey again*" (science leader).
> "*Water quality has fallen off the agenda*" (industry body).

The first of these factors was the millennium drought (1997–2009), which necessarily shifted attention towards supply security. In response to imminent water shortage in the mid-2000s, the Queensland government embarked on a multi-billion dollar infrastructure program

to ensure water security. With the breaking of the drought, a number of these infrastructure projects have been abandoned or are not currently operating, giving rise to criticism of 'panic spending' for now mothballed water supply assets. Devastating floods across Brisbane in 2011 refocused attention on water issues and given rise to a heightened interest in flood protection. However, the response is widely perceived to be reinforcing a traditional and relatively siloed approach to flood protection, rather than taking the opportunity to integrate water quality considerations into a broader water cycle approach. As one practitioner described, after the floods "*the response was a very single solution approach based around flood management*" (private consultant), echoed by another who stated "*at the moment the thinking all looks very siloed. They're not thinking very laterally*" (state government).

3.4.1 Culture

These crisis driven responses are generally regarded as having reinforced a segmented approach to water challenges. With a substantial investment in supply security, following closely by an increased focus on flood protection, there has been a loss of momentum in relation to stormwater quality improvement. There is also a general perception that these largely reactive responses have hindered efforts towards more holistic water management and the integration of stormwater into broader water and land planning processes has declined. Given the considerable spending on supply security and flood protection, there is also a significantly reduced appetite for ongoing investment in the water service sector, making it hard to secure funding for stormwater quality improvement initiatives.

Not only has there been a reduction in political support and funding for stormwater quality improvement and WSUD, but as a result of the sector-wide restructure initiated in 2008, there has also been a loss of both institutional knowledge and expertise in relation to WSUD and industry champions for this approach. The restructure introduced a period of institutional and organisational uncertainty and upheaval, with the responsibility for bulk water supply and sewerage services removed from municipal councils and given to newly created state-owned entities. Whilst responsibility for stormwater remained with the municipal councils following the restructure, those connected to stormwater management and waterways in state government and the utilities have been affected, and the effectiveness of the whole system is perceived to have suffered as a result. As one interviewee stated, "*the restructure caused massive disruption and has absolutely made everything worse. It completely undermined efforts around total water cycle management*" (water utility).

3.4.2 Structure

There has also been a reduction in structural support for stormwater quality management over this institutional reversal phase. Structural change in this phase includes the introduction of the 2013 State Planning Policy which replaced the SPP 4/10 for Healthy Waters and reduced the scope of developments that need to implement WSUD features. A rainwater tank subsidy, widely regarded by industry as a valuable strategy for helping reduce peak flows and scouring of the catchment, was removed in December 2008, reflecting a further loss of structural support for stormwater quality initiatives. This loss of structural support for WSUD and stormwater quality management more generally serves to reduce the visibility of the issue while also reducing organisational support for and commitment to the practice.

Despite these reversals, WSUD continues to be required in new developments across SEQ via the *Sustainable Planning Act 2009* (expected to be replaced by the Planning Act), however councils retain significant discretion as to implementation, leading to highly variable outcomes. There is also a need to more closely link water quality targets with WSUD to maximise impact. Whilst waterway protection via USQM remains a policy goal, some of the supporting regulations giving effect to this have been diluted or repealed, representing a retreat from the acceleration phase.

3.4.3 Practice

With the loss of both cultural and structural support, implementation of WSUD over this period has also declined, with fewer developments required to manage stormwater on site. Further, projects that are implemented are currently adopting a minimum compliance approach, with developers often delivering assets that meet technical requirements but deliver limited environmental or amenity value in practice. As one interviewee described, "*the whole mindset now is one of rubber stamping assets that are of variable, and questionable, quality*" (local government).

4 Discussion

4.1 Pattern and Dynamics of the SEQ Transition Trajectory

It is apparent that SEQ's progress in embedding WSUD as standard practice has declined in recent years, with diminished support now evident in all of the culture, structure and practice domains as compared to the high point during the acceleration phase. This is evident via three factors. The first is the significant loss of cultural cohesion, with a consequent decline in the shared understanding and common narrative about the value of stormwater quality management and legitimacy of WSUD. Second, the enabling structural foundation for WSUD has declined significantly, and third, the network of experts and advocates for WSUD is significantly weakened with the result that SEQ is currently missing a cohort of engaged and experienced practitioners to drive continued progress around WSUD.

This pattern of institutional reversal in SEQ has also been empirically observed in a recent study by Head (2014), which examined parallel water challenges of water security and flood protection. Head found that despite opportunities for new thinking and practice provided by crisis events, the policy response in SEQ returned to a business-as-usual approach once the immediate crisis subsided (2014). The study concluded that "incremental change, within a technical paradigm, appears to have survived as the dominant approach", with the result that system transformation had not been realised (2014, p.43). Whether the trend of institutional reversal in the context of USQM will continue, or is merely a bump in the road on the path towards stabilisation, remains uncertain. This is the challenge inherent in analysing contemporary transitions. However, such an examination nevertheless remains a valuable endeavour for gathering timely insights that are relevant to contemporary change processes and can inform transitions currently underway.

Reflecting on the transition process in SEQ as a whole, an overarching pattern of change is evident, depicted in Fig. 3. The early transition phases were culture led, in that the initial momentum driving progress along the S-curve was a common (and growing) awareness of and

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Fig. 3 Sequence of Culture, Structure and Practice change in South-East Queensland
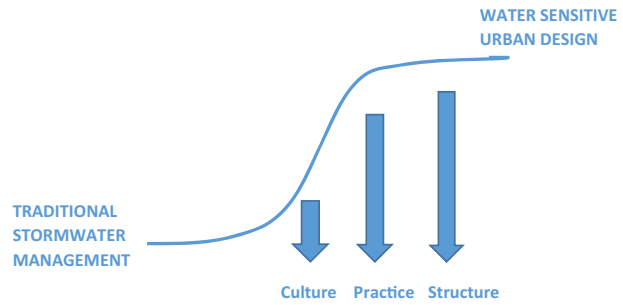
concern for poor water quality amongst stakeholders. A multi-stakeholder collaboration, later evolving into the Healthy Waterways Partnership, became a highly effective bridging organisation (Howells 2006) ensuring all stakeholders 'spoke with one voice' about the need for action in relation to waterway health, which in turn enabled relatively swift agreement on management actions to be implemented. This pattern of culture driven transformational change has been empirically observed elsewhere, notably Tàbara and Ilhan's study (2008), which found that the deliberate creation of new water cultures and identities was the trigger for a broader transition in Spanish water policy.

From this strong culture driven foundation, practice change started to emerge. Initially, this addressed point source pollution through wastewater treatment plant upgrades and later evolved into WSUD demonstrations and projects to address diffuse sources of water pollution. The importance of the strong and cohesive culture in driving this practice change is indicated by stakeholders doing more than legally required to manage stormwater quality in the early transition phases. It was only relatively late in the transition process that WSUD approaches were mandated. Although there was a supportive policy framework and the publication of best practice guidelines early in the transition process, the 'hard' structural measures that required WSUD occurred only late in the acceleration phase and were not strongly embedded.

As transitions scholarship makes clear, the systems that embed the status quo are entrenched and multi-faceted (Geels 2004; Kemp et al. 2007). Accordingly, transformational change efforts need to be deliberate and similarly dynamic to overcome this inertia. All three of the culture, structure and practice domains are equally important to embed a novel innovation and work best when used in a mutually reinforcing way to create a strong foundation for change. However, rather than following this approach, the SEQ journey was more linear, with culture as the key driver of new practice and structure used 'after the fact' to regulate it. Consequently, SEQ missed the opportunity to get the benefit of a more diverse and more robust foundation to drive transformational change. Further, the case of SEQ highlights the vulnerability of driving a transition predominantly from one domain at the expense of the others. Single instrument approaches to sustainability challenges are widely recognised as being less effective and more vulnerable (Gunningham 2009; Gunningham and Sinclair 2005), which is reflected in SEQ's transition experience. To minimise this vulnerability, initiatives in both the culture and structure domains should be pursued concurrently so that they can co-evolve and reinforce each other to drive practice change. In relying predominantly on culture-based initiatives to drive change, SEQ's transition journey inadvertently became a largely linear process and the opportunity was missed for dynamic interaction between culture and structure based initiatives, which would have provided a more robust foundation for sustainable transformation. The SEQ experience

thus shows the necessity of actively working across all domains of change to build a multi-pronged and mutually reinforcing transition foundation.

4.2 Implications for Transitions Processes and Minimising the Risk of Institutional Reversal

The SEQ case also reveals that structural change is critical to transition efforts, and can play a key role in growing and embedding a new practice. More specifically, the strategic introduction of hard structural measures such as regulation can provide a valuable safety net, helping anchor transition progress and ensuring continued implementation even in times of variable cultural support. This is particularly evident when considering the differing transition experiences of SEQ as compared to Brisbane.

Brisbane's City Plan was introduced early in the acceleration phase, which mandated WSUD for certain development, leading to an immediate increase in implementation. From this point, Brisbane became a state leader in terms of WSUD, a position it still retains, despite also experiencing a decline in support. By contrast, mandating WSUD across all of SEQ came almost a decade later, with the SPP 4/10 for Healthy Waters. Prior to this, WSUD projects were ad hoc and largely limited to industry frontrunners. The introduction of the SPP 4/10 significantly expanded the practitioner cohort engaged in WSUD. However, as it came very late in the acceleration phase, it was only weakly embedded and was replaced by the State Planning Policy only a few years later which reduced the scope of development required to adopt WSUD approaches. This case therefore highlights the important role of structural change in embedding a transition and providing a formal and enforceable foundation for transformational change.

Following the emergence of environmental regulation from the 1970s, there has been a trend towards decreasing 'command and control' regulation, with commentators noting limitations such as a lack of flexibility, high financial cost of compliance and its failure to provide a framework that facilitates innovation (Gunningham 2009; Schmidt 2014). Instead, contemporary environmental governance approaches increasingly rely on markets, the private sector, non-government organisations and civil society. However, this case highlights that there remains an important role for regulation, which Dutra et al. note makes information on water quality more credible, salient and ultimately useful (2014). While the suite of policy and market instruments available provide valuable flexibility and agility in supporting sustainable transformation, hard regulation sets a clear and enforceable minimum standard, applying to laggards and leaders alike. In addition, having this safety net can maximise the effectiveness of other, less direct, more flexible policy instruments. As Gunningham notes, "less interventionist strategies are far less likely to succeed if they are not underpinned by direct regulation" (2009, p.208). Thus, even in a context where more flexible, information and market based mechanisms are the preferred approach, direct regulation and enforcement measures remain a necessary part of the puzzle, and can in fact enhance the overall effectiveness of a sustainability transition effort.

This was a key gap in SEQ's transition approach. Despite paradigmatic third-order policy change (Hall 1993) in the introduction of waterway protection goals via USQM, SEQ failed to progress towards the timely introduction of direct regulation that would have provided a more tangible and enforceable foundation to support USQM. This highlights the need to look beyond policy goals (however radical they may be) to the policy instruments and the extent to which they are actively used to pursue policy goals. The need to introduce progressively

tighter controls to manage stormwater quality has been observed by Bryan and Kandulu (2011), who found that the ideal policy mix began with targeted information provision, was followed by an incentive program and then reinforced via a mandatory USQM code of practice. In the context of SEQ, policy frameworks and guidelines provided an overarching framework for the management of stormwater quality. This is a useful starting point. However, in and of itself, it is insufficient. There are always a diverse range of policy goals and government priorities, and many innovations or novel approaches do not ever progress further than articulation as a policy goal.

If progress along the transition curve is to continue, there is a need to move towards hard structure, being the articulation of more specific, tangible and measureable requirements and obligations. Direct regulation is central to embedding change, so that continued engagement with the practice is no longer reliant upon the goodwill or interest of stakeholders, but rather is legally required. Hard structural measures can help guard against times when the innovation falls off the political or community agenda, declines in popularity or simply gets lost in the mix of competing government priorities. In requiring ongoing engagement with the new practice and continued compliance, regulatory measures thus play a key role in anchoring transition progress. This suggests that transition advocates should deliberately focus on strategically using the structural framework to support transition efforts and proactively work to integrate novel practices into the broader legislative framework. This is a difficult and slow task, with legislative mandates identified as a key challenge for sustainable stormwater management (Roy et al. 2008). It is therefore important to begin the process of regulatory engagement early in the transition process, so as to maximise the likelihood of a timely introduction of regulatory support.

Ultimately the insufficient regulatory support for waterway health in SEQ can help explain the current phase of institutional reversal. Whilst the broad policy framework around stormwater quality improvement was in place from the take-off period, more formalised structural support in the form of enforceable (and enforced) legal obligations was only introduced towards the end of the acceleration phase. A stronger and more embedded structural foundation for WSUD would likely have enabled continued progress towards stormwater quality improvement despite the changed political climate in SEQ, or at the very least have minimised the extent of the reversal. Whilst direct regulation alone would not be sufficient to ensure the mainstreaming of WSUD, it could help maintain momentum and continue to drive practice change, even where there has been a decline in the underpinning cultural cohesion or support.

5 Conclusion

The story of SEQ's stormwater quality transition offers two key insights for advancing transitions scholarship and for policy and decision makers wanting to assist facilitation of a successful transition. First, the case confirms the dynamic nature of transformative change and highlights the need to consider culture and structure as complementary domains of change. This suggests that transition advocates should pursue initiatives in both domains concurrently in order to create a robust, mutually reinforcing transition foundation. However, the case also shows that culture and soft structural measures may be insufficient to fully support a transition effort.

The second and related insight is the importance of regulatory frameworks in facilitating water transitions. Hard structure, in the form of specific and enforceable obligations can

provide a valuable safety net and help minimise the risk of institutional reversal. These results suggest that transition advocates should proactively and strategically seek to embed change in regulatory frameworks. In order to better understand how and why an institutional reversal pathway may unfold, there is a need for further empirical exploration and theorisation across other sectoral domains, so that transitions scholarship can start to develop a more comprehensive understanding of these less desirable transition trajectories, and whether they can be steered towards stabilisation instead.

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7. Publication 4: Building Regulatory Infrastructure to Support the Diffusion and Institutionalisation of Environmental Innovations

7.1 Introduction

Publications 2 and 3 (presented in Chapters 5 and 6 respectively) have demonstrated the importance of structural frameworks broadly, and in particular, the critical role of regulation for enabling and anchoring a transition. Building on this insight, the next publication explores *how* to design regulatory frameworks to support the institutionalisation of a radical innovation.

As a core regime component, regulatory systems play an important role in shaping, enabling and constraining transformative change. In exploring the relationship between regulation and innovation in the context of transformative system change, the paper examines the extent to which regulatory systems can be designed to deliberately assist a transition effort.

The findings highlight the importance of regulation not only for innovation diffusion but also for institutionalisation, and suggest that broad and aspirational regulatory frameworks that become increasingly specific over time may provide the strongest possible foundation for a transition.

The outcomes of this paper contribute to the second research objective, being to "assess the type and operation of institutional change mechanisms in the institutionalisation of a radical innovation".

7.2 Declaration for Thesis Chapter 7

Declaration by candidate

In the case of Chapter 7, the nature and extent of my contribution to the work was the following:

Nature of contribution	Extent of contribution (%)
Formulation of the research problem, research design, data collection and analysis, interpretation of results, writing the paper	90%

The following co-authors contributed to the work. If co-authors are students at Monash University, the extent of their contribution in percentage terms must be stated:

Name	Nature of contribution	Extent of contribution (%) for student co-authors only
Rebekah R. Brown	Participation in the formulation of the research problem, participation in the interpretation of results, providing feedback on the written manuscript	N/A

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the candidate's and co-authors' contributions to this work.

Candidate's Signature		Date 26/10/16

Main Supervisor's Signature		Date 26/10/16

7.3 Manuscript

Building Regulatory Infrastructure to Support the Diffusion and Institutionalisation of Environmental Innovations

Lara Werbeloff,[1,2] Rebekah R. Brown,[3]
[1] *School of Social Science, Monash University, Melbourne, Australia*
[2] *Cooperative Research Centre for Water Sensitive Cities, Melbourne, Australia*
[3] *Monash Sustainability Institute, Monash University, Melbourne, Australia*

Abstract

The relationship between innovation and regulation typically explores the impact of regulation on innovation. Instead, this research takes an innovation-centred approach and explores how regulatory frameworks respond to radical innovations. Using a comparative case study approach, the paper examines two cases of radical innovation in the Australian urban water sector. The paper makes three contributions to the scholarship, finding that (1) regulation can not only assist with the diffusion of radical innovations, but also their institutionalisation (2) that more rather than b n less regulation can better assist the institutionalisation effort, and (3) that the design of the regulatory framework matters, suggesting that a broad and aspirational regulatory framework that becomes increasingly specific over time may provide the strongest foundation for institutionalising a radical innovation. These findings also provide practical guidance for practitioners seeking to mainstream radical environmental innovations in their city, and suggest that innovators should actively work to shape the introduction of appropriate regulation tailored to the innovation at hand.

KEYWORDS: environmental innovation; radical; regulation; water

1. Introduction and Background

Sustainable development is widely regarded as one of the defining challenges of our generation, as reflected the 17 Sustainable Development Goals recently adopted by the United Nations. To meet this ambitious mandate, radical innovations are needed in sectors as diverse as water, energy, transport and food production in order to effectively respond to complex and interrelated challenges such as climate change, population growth, urbanisation and resource scarcity. Change is therefore inevitable, and there is much work underway to develop technical, social and organisational innovations to move towards increased sustainability. Managing these change processes will inevitably require the involvement of regulatory systems, which provide key risk management functions. Yet how should regulatory systems respond to radical environmental innovations in order to maximise their impact? What is the best approach to designing a supportive regulatory architecture? These questions remain unanswered and are the focus of this paper.

The relationship between innovation and regulation has been the subject of much scholarly exploration, predominantly from an economics perspective (Freeman 1982; Porter and van der Linde 1995; Ambec et al. 2013), but more recently expanding to include management (e.g., Dewick and Miozzo 2007) and policy (e.g., Ford 2013) perspectives. Given this diversity, the literature is broad and at time confusing, in part because of poorly clarified or inconsistent terminology. To begin with, there is no accepted definition of regulation, with many varied and not always consistent definitions found in the scholarship. At its core, the concept of regulation explores the tension between private and public interests. For this paper, we understand regulation as referring to the "implementation of rules by public authorities and governmental bodies to influence market activity and the behaviour of private actors in the economy" (Blind 2012, p.392). Such intervention in the market is typically justified as a means of maximising collective welfare and ensuring sufficient account is given to the public interest (Francis 1993; Dewick and Miozzo 2002; Blind 2012).

From this foundation, some conceptualisations of regulation are limited to command-and-control measures such as technology specifications or performance standards (Managi et al. 2005; Popp 2006), while others take an expanded view to include market based measures such as taxes or trading schemes (Lange and Bellas 2005; Wu 2009). For this paper, we prefer the broader definition as it takes account of the diverse range of strategies and instruments available to governments and public bodies that can be used to advance a particular agenda. That is, such instruments are simply a means to an end. Intervention in the market can be achieved via direct regulation or economic measures alike, with both approaches seeking to 'influence market activity and the behaviour of private actors'.

'Innovation' is another widely used and often ill-defined term, leading to conflicting understandings of what constitutes an innovation. Freeman (1982) defines innovation as the introduction of a new product, process, system or device. Environmental innovation, which is the focus of this paper, is in turn understood as a new product, process, system or device that "conserves energy and natural resources, minimizes the environmental load of human activities or protects the natural environment" (Shrivastava 1995, p.185). While Freeman's and Shrivastava's definitions both focus on technical innovation, there can also be organisational or social innovations (Kemp et al. 2000). Common to all definitions however, and regardless of whether the innovation is technical, organisational or social in nature, is the concept of 'newness' (Kemp et al. 2000; Rogers 2003; Ashford and Hall 2011). That is, an innovation requires novelty and doing something qualitatively different from what has come before.

However, there can be many degrees of novelty, and there is debate in terms of how much novelty is required to constitute an innovation. Within the literature, a distinction is drawn between radical and incremental innovations. Incremental innovations typically involve minor modifications to existing processes or products and are consistent with the prevailing paradigm (Johannessen et al. 2001; Herrmann et al. 2006; Beerepoot and Beerepoot 2007; Kemp and Pontoglio 2011). By contrast, a radical innovation implies a technological discontinuity, based on a break with existing competencies and technologies (Kemp and

Pontoglio 2011). Radical innovations are those that differ from traditions in a field, and are often labelled 'discontinuous' or 'breakthrough' (Anderson and Tushman 1990; Christensen and Rosenbloom 1995; Dahlin and Behrens 2005).

Studies on radical innovation are typically framed within a 'punctuated equilibrium' model of change (Dahlin and Behrens 2005). Punctuated equilibrium models of change are characterised by sudden, revolutionary and discrete periods of rapid change which occasionally flare up and disturb the equilibrium (Gersick 1991), allowing a new innovation to establish itself. These punctuations provide a rare window of opportunity for an innovation to challenge the status quo, typically arising in response to system shocks such as natural disasters or financial collapse. However, a recognition that such system shocks do not always result in radical transformation led to the emergence of an alternative pattern of change, broadly described as 'gradual yet transformative change' (Streeck and Thelen 2005; Djelic and Quack 2007; Dolata 2013). This model presents a more incremental pattern of innovation diffusion, whereby many small changes accumulate over a long period of time to eventually add up to significant change. Radical innovation can thus emerge via two different pathways, either by taking advantage of a window of opportunity and establishing itself quickly, or alternatively via a slower and more incremental path that evolves over a longer period of time.

In exploring the relationship between regulation and innovation, conventional wisdom assumed that regulation hindered innovation, and therefore reduced competitiveness. This was first challenged by Porter (1991) whose game-changing Porter Hypothesis argued that well-designed regulation could in fact increase firm competitiveness. He stated that "the conflict between environmental protection and economic competitiveness is a false dichotomy. It stems from a narrow view of the sources of prosperity and a static view of competition. Strict environmental regulations do not inevitably hinder competitive advantage against rivals; indeed, they often enhance it" (Porter 1991, p.168). Expanding on this proposition, Porter and van der Linde argued that properly designed environmental regulations (defined broadly to include market based instruments such as taxes or cap and trade schemes) can "trigger innovation that may partially or more than fully offset the costs of complying with them" (1995, p.98).

This controversial contribution sparked a body of research exploring the relationship between regulation and innovation which remains highly relevant. Ambec et al. summarise twenty years of research on the Porter hypothesis and find that "on balance, the studies conclude that there is a positive link between environmental regulation and innovation" (2013 p.9). More specifically, they observe that the proposition that stricter environmental regulation leads to more innovation is "now fairly clear and well established" (2013 p.15). This is reinforced by Kemp and Pontoglio, who state that "the often expressed view that market-based approaches such as pollution taxes and emission trading schemes [as compared to direct command-and-control regulation] are better for promoting eco-innovation is not brought out by the case study literature or by survey analysis" (2011, p.34). Overall, studies to date have found that there is an important role for regulation in

supporting innovation. Whilst the traditional view was that regulation hindered innovation, extensive empirical exploration has revealed that the relationship is in fact much more dynamic. Rather than simply starting or stopping innovation, regulation shapes and moderates innovation across networks and industries (Kemp et al. 2000). The precise impact of regulation on innovation therefore depends on a number of factors, including the type and combination of instruments used, timing and broader operating context.

Yet despite the implicit recognition of the dynamic interplay between regulation and innovation, most studies have limited the analysis to the effect of regulation on innovation (e.g., Kivimaa 2007; Blind 2012; Ford et al. 2014). To date, there has been relatively little explicit attention on the reverse, that is, how innovation is affected by regulation. Existing studies on the relationship between regulation and innovation note that in some circumstances, innovation precedes regulation. In his study of the impact of environmental policies on the Nordic pulp, paper and packaging industries, Kivimaa finds that "the effects of environmental policies on innovations are not limited to the way in which the traditional 'policy cycle' is depicted. Instead of new technology following directly from new environmental policy, the development of an innovation may precede a policy or even exert influence over the policymaking process" (2007 p.101). Similarly, Kemp et al. state that "innovation (in the sense of an available technological solution to a problem) may pave the way and thus be the stimulus for regulation, which suggests that causality goes either way" (2000, p.39). These findings recognize that regulatory systems are necessarily influenced by progress in science and technology (Blind 2012), and as such, innovation can at times precede regulation. However, regulatory responses to innovation remains relatively under-explored.

Further innovation-centred (rather than regulation-centred) analysis has the potential to offer much insight into how regulatory systems can support innovation. This is of particular relevance to the environmental sector, where much innovation is underway to try solve complex challenges across a range of sectors. The widespread adoption of alternative technological approaches is a significant challenge, and often inhibited by the dominance of the existing technological growth trajectory (Hall and Kerr 2003). This is what makes diffusion of radical innovations, in particular, such a challenge. By their very nature, radical innovations are paradigmatically different from current approaches. Achieving market diffusion and widespread adoption is difficult. Within the existing literature, it is generally observed that regulation drives innovation *diffusion* rather than innovation per se (Kemp and Pontoglio 2011; Rennings et al. 2003), which refers to how an innovation spreads through a particular population (Rogers 2003). This paper examines two cases of radical innovation in the Australian urban water sector, the regulatory response in each city and its effects on the diffusion of the innovation. The findings of this study extend the scholarship on innovation-centred regulation while also providing practical guidance for innovators and policymakers seeking to support the diffusion of environmental innovations.
Most empirical exploration to date has been in the context of understanding the factors that impact on firm or country competitiveness, and specifically in understanding the effect of regulation in terms of helping or hindering the innovation capabilities and opportunities

(e.g., Beerepoot and Beerepoot 2007; Kivimaa 2007; Blind 2012). This paper takes an alternative view and takes a systems approach to the innovation-regulation relationship. This recognises that innovation cannot be understood purely as the result of rational and independent decision-making on the part of individual firms, but rather involves complex interactions between firms and the broader social, economic and institutional environment (Kemp et al. 2000). Taking this perspective, innovation systems literature recognises that innovations are typically developed through interaction and exchange by stakeholders operating in the same field (Beerepoot and Beerepoot 2007). Rather than assessing competitiveness of a firm or country, the goal here is to understand how innovations diffuse within a sector or society.

2. Research Approach

The overall research objective was to examine the relationship between regulation and innovation, in a context where innovation preceded regulation. This was investigated using a comparative case study research design (Yin 2009). Case study research is particularly useful when investigating longitudinal change processes (Van de Ven 2007) as it facilitates a holistic, complex and detailed understanding of a phenomenon within its real-world context (Yin 2009) and ensures that all relevant variables, especially those that may not be immediately apparent, are considered in the analysis (Creswell 2007).   The case study approach is also considered a particularly appropriate method to analyse the relationship between regulation and innovation (Kemp et al. 2000; Blind 2012).

Given the exploratory nature of this research, a purposive sampling approach was used (Patton 1990). Two Australian capital cities, Melbourne and Adelaide, were chosen as case studies. Both cities are currently in the process of embedding two radical urban water innovations, in stormwater quality management and stormwater harvesting respectively. Yet in reaching this point, the cities are characterised by different patterns of change, with Adelaide's transition more akin to a punctuated equilibrium model of change, and Melbourne reflecting a gradual yet transformative change process.

This research was designed to explore the role of regulation in supporting innovation diffusion across these different patterns of change. Following the comparative case study research design, each case study city is considered a whole case and analysed as such, which is then followed by comparison across cases (Yin 2009). An additional benefit of comparative case study research is that the results are generally considered to be more robust and therefore more compelling than a single case study (Yin 2009).

2.1 Case Study Contexts

Adelaide (South Australia) is the driest Australian capital city and characterised by a Mediterranean climate with hot, dry summers and only moderate rainfall over winter. Beginning in the late 1980s, Adelaide's transition journey was focused on the capture, treatment and storage of stormwater as a fit-for-purpose water source. A number of large-scale stormwater harvesting schemes are now operational across the city and Adelaide is recognized as a leader in this space both within Australia and internationally (Pitman 2008;

Dillon et al. 2010). The 'radicalness' of stormwater harvesting is in operationalising a new philosophical paradigm around the principle of the 'city as a catchment', which advocates utilising all sources of water within a city (including wastewater and stormwater) in a fit for purpose manner. This represents a significant departure from the conventional approach to water management that relied exclusively on potable water for all water needs and instead recognises that stormwater, traditionally viewed as a nuisance, could instead be an asset. Although consistent with the traditional large-scale centralised engineering approach, stormwater is discontinuous from previous water management approaches in its acceptance of lower quality water and a recognition of its value, particularly for outdoor use. The introduction and widespread diffusion of stormwater harvesting schemes across Adelaide has unfolded swiftly, significantly assisted by the record-breaking millennium drought (1997-2009) that severely affected the south and east coast of Australia.

Melbourne (Victoria) is Australia's second largest capital city, with a population over 4.4 million. Beginning in the early 1970s, Melbourne has undergone a transition in relation to stormwater quality management. This has seen a transformation from a traditional model of centralised drainage focused exclusively on stormwater quantity towards a more integrated approach that introduced distributed 'green' treatment processes in order to improve stormwater quality and thereby meet a range of ecological, aesthetic and amenity objectives. In contrast to Adelaide, Melbourne's innovation journey has been much slower, evolving incrementally over the last four decades. Stormwater quality management is also a radical, paradigm-changing innovation. Within traditional urban water management frameworks, waterways were conventionally viewed as environmentally benign (Brown et al. 2009), existing primarily to serve the needs of a city. Further, water quality science did not exist as a discipline, and water quality considerations were not part of water industry planning or practice. The realisation that stormwater was severely compromising the health of receiving waterways led to the innovation of Water Sensitive Urban Design (**WSUD**), in the form of decentralised, green technologies such as biofilters or wetlands for capturing and treating stormwater at local scales throughout the city. The decentralised nature of WSUD, its underpinning philosophy of environmental protection as well as the need to incorporate new disciplines such as ecology and hydrology all point to the radicalness of the innovation (Wong 2006). While the WSUD innovation is primarily technical in nature, it is supported and facilitated by broader social and organisational innovations (Kemp et al. 2000) in terms of new forms of management and an expanded network of stakeholders in relation to water quality.

2.2 Data collection, analysis and validation

A multi-stage data collection and analysis process was adopted for this research. Data collection was undertaken sequentially, beginning in Melbourne and followed by Adelaide. Primary data collection in both cities began with oral history interviews with key individuals who had direct involvement with the emergence and evolution of their city's stormwater transition (6 per city). These interviews charted the interviewee's recollection of significant changes in urban stormwater management, from their initial involvement to the present day. Historical and contemporary secondary data, including policy materials, industry

reports, organisational materials from relevant industry bodies and professional associations, media reports and available scientific literature, was cross-referenced with the oral history transcripts to construct a case history of the evolution of stormwater management in each city. The resulting case narrative was sent to the same interviewees for external validation in order to ensure the accuracy and credibility of the account (Creswell 2007).

For the second phase of data collection, semi-structured interviews (17 per city) were conducted with key individuals across relevant stakeholder organisations. All participants held senior positions in their organisations and were directly involved in stormwater management across stakeholders including state and local government, water utilities, consultants, land developers, regulators and academia. Participants were identified through snowball sampling (Creswell 2008), which involved finding potential interviewees through recommendations from key people in each city's water sector.

Interview transcripts were coded through an iterative process of thematic identification. The primary data was then triangulated with other sources of secondary evidence to develop an account of the transition process. Contradictory explanations were sought in order to understand the relationship between innovation and regulation in each transition process. A case report was compiled for each city using a range of analytic approaches, including developing a descriptive case framework and conducting a time-series analysis to trace how events unfolded over time (Yin 2009). The case report, which included preliminary analytical findings, was distributed to all interviewees in the relevant city in order to identify any gaps in the analysis and refined accordingly (Creswell 2007).

3. Results

This section outlines the evolution and diffusion of the innovation in each city, focusing on the key innovation and regulatory developments in the four distinct temporal phases over an innovation S-curve; predevelopment, take-off, acceleration and stabilisation (van der Brugge and Rotmans 2007).

3.1 Predevelopment Phase

Adelaide (1985 – 1995)
The practice of stormwater harvesting in Adelaide was pioneered by the City of Salisbury, a municipal council. Motivated by over-extracted groundwater systems and an ongoing need to irrigate public open space coupled with the relatively high price of mains water, from the mid 1980s the City of Salisbury took steps to develop its own alternative water supply. This was a significant departure from the typical role of municipal councils in relation to stormwater, which is traditionally limited to local drainage with no role at all in terms of water recycling or production. With the benefit of favourable hydrogeological conditions and plenty of open space, City of Salisbury established a number of wetlands for stormwater treatment and storage. Although the narrative of these early projects highlighted the multi-functional benefits that could be delivered in terms of water treatment, supply and

increasing community amenity, these projects were not responding to an existing industry or community mandate. Rather, these projects helped demonstrate the benefits of stormwater capture and use. Salisbury were also involved in scientific research programs into stormwater harvesting. The discovery that it was possible to inject treated stormwater into aquifers, and then later extract it for use was key to initiating this innovation. Salisbury began capturing and treating stormwater, then injecting it into its vast network of limestone aquifers.

Consistent with other cities both nationally and internationally at this time, Adelaide had no regulatory framework in relation to this practice. As a recent scientific discovery and newly emerging practice, there was no city in the world with a regulatory structure around stormwater injection and extraction over this period. As such, these early schemes worked within Adelaide's existing legal framework for urban water management at the time, which was largely centred around potable water supply. The absence of regulation in this area enabled a period of scientific investigation and experimentation, without the constraints that can come with a more detailed regulatory environment.

Whilst the regulatory vacuum during this phase enabled experimentation, it also created uncertainties. The early Salisbury schemes began operating without any licensing authority, necessarily giving rise to questions around the ownership over the injected water. In proceeding with stormwater injecting schemes, Salisbury took a leap of faith that the injected water would later be able to be extracted. The state's environmental regulator was established in 1993 (shortly after the commencement of the schemes), and began to licence the injection of stormwater into the aquifers. Licence conditions in this early phase were fairly basic, reflecting the limited understanding of the aquifer environment at this time.

Melbourne (1970 – 1989)
Melbourne's transition was prompted by a scientific study in the early 1970s that revealed poor water quality in Port Phillip Bay, the receiving waterway for metropolitan Melbourne. The findings of the study showed that nutrient loads were adversely impacting the health of the Bay, and provided the foundation for the development of the first State Environmental Protection Policy (**SEPP**) in 1975. These findings highlighted the inadequacy of the current approach in addressing water quality and helped build industry consensus around the need to protect and improve waterway health.

Consistent with the global emergence of the environmentalism movement, the state's environmental regulator, the Environment Protection Authority, was established in 1970, initially focusing on industrial pollution. Early structural changes in this phase included the introduction of the Water Act 1989, which outlined 13 values to underpin water management in a way that meets contemporary social, economic and environmental expectations. A second SEPP, 'Waters of Victoria', was introduced during this phase, emphasising the importance of protecting and restoring waterways. A funding program was also introduced, making over AU$12m available to 'clean-up, beautify and restore' creeks and rivers in Melbourne.

3.2 <u>Take-Off Phase</u>

Adelaide (1996 – 2001)
The Salisbury schemes provided a proof of concept for stormwater harvesting and demonstrated the potential of stormwater capture, treatment and re-use, particularly as a fit-for-purpose water source for irrigation. Following Salisbury's lead, other local councils then began to investigate the opportunities for stormwater harvesting in their own area, encouraged by the prospect of creating a revenue stream through the sale of harvested stormwater to local schools and industry, while also reducing the volume of mains water purchased from the State's water utility for the irrigation of public open space.

The EPA's licensing requirements continued to evolve during this time, as knowledge about the water quality and ecosystems in the aquifers improved. Licence conditions gradually became stricter and more specific, as new scientific understanding was incorporated into the licensing regime. For example, during this phase a rule was introduced that permitted scheme operators to only extract 80% of the water they injected into the aquifers, in order to address over-extraction.

An emerging concern about water quality during this phase was key to the delivery of stormwater harvesting projects across the city. To support this, a Catchment Management Levy was introduced in the late 1990s, which provided AU$2 million per year for water quality initiatives. A number of large multi-functional projects were implemented during this phase, jointly funded by the Commonwealth, the State (through the Catchment Management Levy) and a private partner. These projects typically partnered with a local business with large open space (such as golf courses or racing tracks) to deliver wetlands that provided catchment-wide water quality benefits while also creating a fit-for-purpose water source for irrigation for the local business. Another significant project that commenced during this period was the Mawson Lakes residential development, a large greenfield site that uses a combination of recycled wastewater and treated stormwater to provide a fit-for-purpose supply for residents. It also has ornamental lakes fed by stormwater and wetlands for irrigation. Thus by the end of the take-off period, technical expertise in stormwater harvesting was well developed and a number of successful projects were underway, providing a strong foundation for continued growth of the practice despite the relatively under-developed structural framework.

Melbourne (1990 – 1999)
Melbourne's take-off phase began with a number of initiatives to build a more comprehensive understanding of waterway health. There was a concerted effort to build expertise in this emerging field of water quality science, with a number of university and professional courses established to this end. This was further assisted by the establishment of two national research programs, the Co-operative Research Centres (**CRC**) for Catchment Hydrology and Freshwater Ecology (established in 1992 and 1993 respectively), which were critical in (1) strengthening the knowledge base about the city's water environments and (2)

focusing industry's attention on possible solutions to this challenge. Through these various efforts, the innovation of WSUD crystallised, offering a means of improving stormwater quality on a local scale.

In addition to the findings coming out of the national CRC research programs, a further Port Phillip Bay Environmental Study specifically identified urban stormwater runoff as a key threat to waterway health and recommended a priority policy target of reducing annual nitrogen loads entering the Bay by 1000 tonnes from 1993 levels by 2006. The SEPP was subsequently amended to incorporate this goal, providing both technical information and a philosophical position on water quality and waterway protection.

To make the issue of stormwater quality management more visible, a Stormwater Committee was established as a partnership between the Environment Protection Authority, Melbourne Water and local governments. A key output of the Committee was the Urban Stormwater Best Practice Environmental Management Guidelines (**BPEM Guidelines**). Whilst called 'guidelines', in practice BPEM became strictly enforced as a condition of development by the EPA and Melbourne Water, who were approval agencies for development across the state. Towards the end of the take-off phase, there were a number of successful pilot and demonstration projects, helping build confidence in the technical feasibility of decentralised, green treatments for stormwater.

3.3 Acceleration Phase

Adelaide (2002 – 2010)
The millennium drought played a significant role in the proliferation of stormwater harvesting schemes across Adelaide. Firstly, the severe water shortage highlighted the need to use alternative water sources in a more efficient manner, particularly to free up potable water by using lower quality sources (such as stormwater) for public open space irrigation. A second contributing factor was the construction of a desalination plant in Adelaide (online from 2013) which pushed up the price of water, in turn making alternative water schemes more financially viable. The drought also helped mobilise significant community support for alternative water schemes, with an increasingly vocal community expectation that stormwater should be captured and treated for fit-for-purpose use.

Further legitimacy for this innovation was provided by the Adelaide Coastal Water Study, a large scientific study to investigate the causes of declining water quality along the Adelaide coast. The final report (2007) found that stormwater flows were contributing to low light in the receiving waters and the consequent loss of sea grass, and recommended harvesting increased volumes of stormwater. An Urban Stormwater Harvesting Options Study was then conducted, which assessed the opportunities for increased stormwater capture and treatment across the city. The findings of the Study informed Adelaide's current stormwater harvesting target of 60GL per year by 2050 (Department of Water 2009). Over this time, two rounds of funding from the Commonwealth government were critical for the implementation of stormwater harvesting schemes across Adelaide. The first significant injection of

Commonwealth funds was provided in 2004 with a subsequent round of funding was provided over 2009-10.

Adelaide's current, yet temporary, regulatory regime for stormwater harvesting was finalised during this phase. This sees schemes requiring an injection licence by the EPA and extraction licence by Department of Environment, Water and Natural Resources (**DEWNR**). The injection licences are derived from a provision originally intended for wastewater disposal, and schemes are currently extracting water under the authority of a discretionary license from the *Natural Resources Management Act 2004* (section 128) that is renewable annually, leaving scheme operators without a firm commitment about the ownership of injected water. Much of the regulatory framework is based on temporary or repurposed rules which have been incorporated on an 'as needs' basis, leading to a somewhat piecemeal, rather than 'by design', framework. In addition, the creation of the South Australian economic regulator, ESCOSA, in 2002 now requires operators to also hold an ESCOSA license which governs the retail aspects of the schemes. For schemes that connect to residential areas, a Department of Health licence may also be required. However changes to the existing structural framework are already foreshadowed by the water allocation planning process, discussed in more detail in the 'Stabilisation' section.

Melbourne (2000 – 2010)
Melbourne's acceleration phase is characterised by a growing community of practice around WSUD, assisted by a number of high-profile demonstration projects and national conferences to facilitate the creation of a professional network. An industry capacity building organisation was established and a software modeling tool was created to enable developers to demonstrate compliance with the best practice guidelines and development conditions. A number of significant regulatory changes were introduced in this phase that played a key role in the growth and diffusion of WSUD. The first was the introduction of a stormwater offset scheme in 2005 by Melbourne Water, a government-owned statutory authority responsible for much of the state's water management. The scheme was the first of its kind in Australia and required developers to meet stormwater quality objectives either by implementing best practice measures onsite or by making an offset payment for works undertaken elsewhere in the catchment. The offset contributions fund a rolling annual program of water quality initiatives. Another significant regulatory change was amendment to the State planning provisions to mandate onsite stormwater management for all new residential sub-divisions across Melbourne (clause 56). This played a key role in mainstreaming the innovation across the city, as it introduced a new minimum standard for a significant range of development. The SEPP (Waters of Victoria) was also updated with new requirements aimed at addressing the stormwater pollution entering the creeks and rivers that feed into Port Phillip Bay. On ground implementation of WSUD was significantly boosted by an AU$60M Commonwealth grant, enabling the construction of 52 wetlands across the city between 2000 – 2010. A further AU$20m was made available via the Yarra River Action Plan, which provided funding for local councils to implement WSUD.

3.4 Stabilisation Phase

Adelaide (2011 – present)

Adelaide is currently in a stabilisation phase of its stormwater harvesting transition. A number of schemes are already well established and stormwater harvesting is widely considered a mainstream practice, with its legitimacy and value now firmly established and uncontested. The current focus for the city is on optimising the schemes already in place. For example, many of the schemes are not yet running at capacity, as there is a lack of customer demand for treated stormwater. As such, a number of municipal councils are currently working to refine their established schemes and build a customer base for the treated water. This commercialisation agenda is assisted by the recent introduction of the *Water Industry Act 2012*, which enables third party water providers (such as municipal councils) to enter the market.

There is also the opportunity now to try and integrate some of the existing schemes across municipal council areas. While many of the schemes were designed and implemented in isolation from each-other, it is now generally agreed that there could be some economies of scale benefits achieved by linking some of the projects together. Thus in this early stabilisation phase, Adelaide's focus is on introducing a layer of commerciality into the operation of stormwater harvesting schemes, and as part of that process, trying to maximise the benefits of existing schemes through integration in both geographical and operational terms.

Amendments to the existing structural framework are expected in the coming years, the impacts of which remain to be seen. The existing rules, especially in relation to extraction rights, are temporary, which has left the water industry in a holding pattern of sorts, with existing and potential new operators unwilling to invest further in stormwater harvesting until extraction rights are clarified. The first step in a more comprehensive regulatory framework is the development of a water allocation plan which will prescribe the groundwater reserves across Adelaide and allocate extraction entitlements to users in an effort to manage the cumulative impacts of the existing schemes, particularly in relation to artesian pressures. Once the water allocation plan is finalized, users will be granted longer-term licences for extraction, replacing the current fixed-term, discretionary licences. It is expected that the certainty provided by longer term licenses with clear extraction quotas will facilitate increased integration between existing schemes and operators, and also enable the establishment of an entitlement trading scheme.

Overall, Adelaide's regulatory framework for stormwater harvesting has not played a significant role in the growth and diffusion of the practice. Outside of the funding grants, there were no structural incentives for the implementation of stormwater harvesting schemes, and water is extracted from these schemes on the somewhat uncertain basis of a discretionary, fixed-term licence. On the one hand, the fairly minimal structural framework can be seen as preferable, as with limited regulatory incentives or oversight there is a corresponding lack of regulatory obstacles or constraints. However, the limitations of the

'light regulatory touch' are now evident, with existing schemes vulnerable given the lack of certainty regarding extraction entitlements.

Melbourne (2011 – present)
The millennium drought also significantly affected water management in Melbourne, and in the aftermath, focus on stormwater quality has declined somewhat, with preference instead given to supply security initiatives. Despite this, WSUD implementation continues, required by clause 56, development approvals and the offset scheme. Despite this decline in momentum, the city continues to use regulatory instruments to further support the diffusion and embedding of the innovation. This is particularly evidenced in relation to the clause 56 requirements which only apply to greenfield residential development, and not urban renewal through infill development. To further embed WSUD implementation, some leading municipal councils collectively pursued further amendments to their local planning laws to mandate WSUD for *all* development within their jurisdiction, which have recently been approved. BPEM is also currently under review, with an updated version expected to introduce flow requirements to address hydrology needs for the first time.

Overall, Melbourne's transition is characterised by an early, frequent and deliberate engagement with the broader regulatory framework. As the scientific knowledge about the health of the receiving waterways evolved, the regulatory requirements were frequently amended to introduce increasingly stringent requirements. While a professional and community culture around waterway protection also grew over this period, the changes to the structural framework were central to growing a community of practice around WSUD and ultimately playing a key role in the diffusion of WSUD in Melbourne.

4. Cross-Case Comparison

The innovations in both Melbourne and Adelaide are widely diffused. However, the regulatory response to innovation in the respective cities has been quite different. Melbourne's response was comparatively more regulation heavy. As the scientific understanding of waterway health evolved, the regulatory framework was regularly amended to reflect scientific best practice. In this way, Melbourne's regulatory framework co-evolved and was tightly coupled with current scientific understanding, such that new scientific findings were fairly swiftly incorporated into the regulatory requirements. Further, Melbourne used a diverse range of regulatory instruments to prosecute the waterway protection agenda and diffuse the WSUD innovation, including direct command and control measures such as clause 56 (which mandated onsite stormwater quality management for residential development) as well as market mechanisms in the form of a stormwater offset scheme. Importantly, these instruments were underpinned and complemented by information provision to affected stakeholders, explaining the reasons for the new regulations and helping ensure their smooth introduction.

By contrast, Adelaide's regulatory response to the innovation was more of a light touch. Following conventional wisdom, it may seem that a more hands-off regulatory approach is to be preferred, instead leaving diffusion to market forces. However, the experience of Adelaide highlights the shortcomings of this approach. Although the practice of stormwater harvesting first emerged in Adelaide in the late 1980s, three decades later the regulatory framework remains ad hoc and largely under-developed. The extraction rights of scheme operators are subject to a discretionary fixed-term licence, which must be renewed every year or two. This leaves existing schemes in a vulnerable position, as there is no certainty about the volumes of water individual schemes will be able to extract in the medium to long term, in turn affecting the financial viability of the schemes. In addition, the limited regulatory efforts to date have all been command-and-control measures, rather than making use of the broader range of regulatory instruments available. Table 1 shows the evolution of regulatory initiatives in both cities.

Table 1: Evolution of regulatory initiatives in each city's transition

	Melbourne	Adelaide
Predevelopment	Port Phillip Bay State Environmental Protection Policy (SEPP) – introduced laws protecting the water quality of the Bay. Waters of Victoria SEPP – expanded water protection provisions to all waterways across the state. Water Act 1989 – introduced 13 guiding principles around sustainable water management.	EPA established after the commencement of initial harvesting schemes and then begins licensing the injection of treated stormwater into the aquifers. Scientific knowledge about water quality in aquifers is very limited, so licence conditions are initially quite broad.
Take-Off	Schedule 6 included in Waters of Victoria SEPP – outlined aim of reducing nitrogen load by 1000 tonnes from 1993 levels by 2006. Best Practice Environmental Management Guidelines – compliance with BPEM satisfied requirements of SEPP and were enforced through development approvals.	Licence conditions for stormwater injection tightened to reflect updated scientific understanding.
Acceleration	Protecting Our Bays and Waterways SEPP – addresses stormwater pollution entering the creeks and rivers that feed into Port Phillip Bay. Melbourne Water's Stormwater Offset Scheme introduced Clause 56 Victorian Planning Provisions - mandated best practice WSUD for all new residential sub-divisions.	Current regulatory framework introduced: • Stormwater injection licence from EPA • Stormwater extraction licence from DEWNR (discretionary, fixed-term licences only) • Retail licence for sale of stormwater from ESCOSA • Licence for residential schemes from Dept of Health

Stabilisation	Five municipal councils strengthen local laws to require WSUD in all development (greenfield and infill). BPEM – revised guidelines currently under review, with a new suite of requirements regarding hydrology and stormwater flows (not included in current version).	Water allocation planning process currently underway and will provide scheme operators with more clarity and certainty around stormwater extraction rights.

Table 1 highlights the differing extent to which the regulatory system was used in each city, with a far more detailed regulatory framework in Melbourne as compared to Adelaide. Also distinguishing the cities, is the differing approach taken to the *development* of the city's regulatory frameworks to date, demonstrated by Figure 1.

Although the regulatory system responded to the innovation in both cities, and was therefore reactive in both cases, the nature of the reaction was different. Melbourne's regulatory response was initially very broad and has become increasingly specific over time. The regulatory approach began by articulating aspirational values around environmental and waterway protection. These efforts established an overarching regulatory architecture, articulating principles cast at a high level of abstraction (Ford 2013). Although unenforceable, these initial regulatory efforts signalled a new paradigm and legitimised the pursuit of waterway health initiatives. As scientific understanding evolved, the regulatory framework became increasingly prescriptive, specific and enforceable. Yet despite the breadth and generality of Melbourne's early regulation, such efforts were critical to defining the scope of the regulatory response and creating a generally applicable framework that could be refined and amended over time. These initial regulatory efforts provided a strong foundation from which to build, and created a framework whereby subsequent scientific discoveries could be relatively easily incorporated.

By contrast, Adelaide took an almost opposite approach. In Adelaide's case, regulation began in a much more targeted and narrow way, licensing individual stormwater harvesting schemes in the City of Salisbury. From this scheme-specific beginning, the regulatory framework in Adelaide has gradually expanded in scope, slowly introducing more broadly applicable requirements. A somewhat piecemeal regulatory framework has now emerged, whereby harvesting schemes require 3 or 4 licences (for stormwater injection, extraction, sale and supply to residential areas respectively), each of which are governed by different regulators. Rather than adopting the broad regulatory approach of Melbourne, Adelaide typically responded in a more narrow and scheme-specific way, each time only regulating a discrete aspect of the overall scheme without introducing principles that would proactively apply to all future schemes. In this way, the city missed the opportunity to develop an overall regulatory architecture for stormwater harvesting. Despite the eventual broadening of the regulatory regime, Adelaide is still yet to have a comprehensive regulatory framework, as indicated by the dotted line in Figure 1. Many key aspects are currently governed by 'place-holder' legislation while further studies and regulatory design are underway, which in particular will inform future extraction rights.
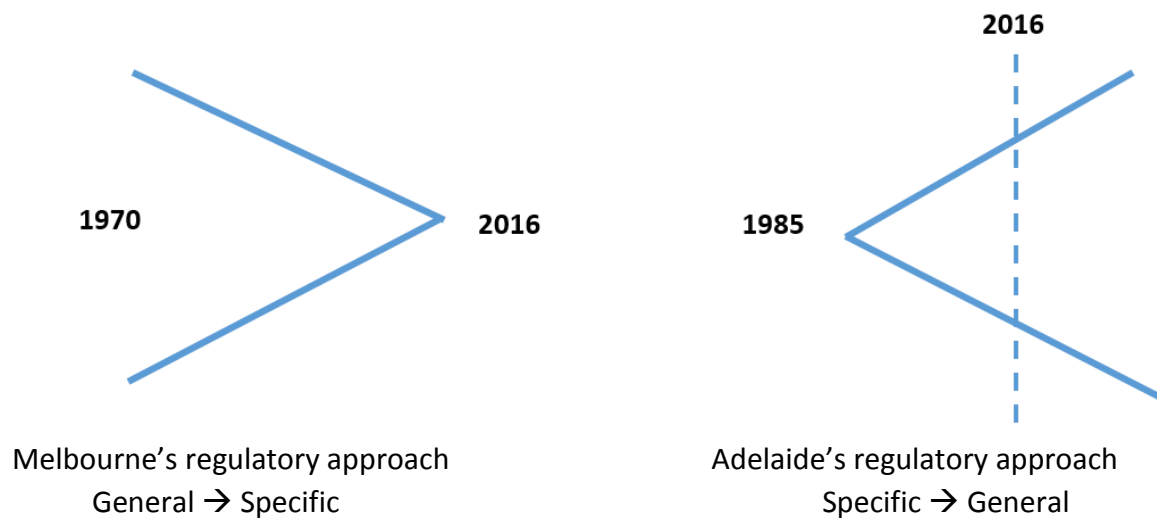
1970 **2016**

2016

1985

Melbourne's regulatory approach
General → Specific

Adelaide's regulatory approach
Specific → General

Figure 1: Differing approaches to developing a regulatory framework

The difference in relation to the overall regulatory approach can potentially be explained by the differing states of knowledge in the respective cities. Adelaide's transition began with a ready-made innovation in the form of stormwater harvesting. By contrast, Melbourne's transition began with an awareness of poor water quality in the city's receiving waterways, and evolved from that foundation to eventually develop WSUD by way of solution. As such, early regulatory efforts in Melbourne did not yet have a specific innovation to regulate, but instead were focused on adopting a precautionary approach to prohibit certain practices and introduce general principles around protection of water environments. Nevertheless, the experience of the two cities suggests that regulators should be aware of the need to create a broad and widely applicable regulatory architecture in order to support the institutionalisation of environmental innovation.

5. Discussion

To address contemporary sustainability challenges, there is a need for environmental innovations to become *both* diffused and institutionalised. The findings of this study have a number of implications relevant to the diffusion and institutionalisation of innovations, which are distinct yet related concepts. The notion of diffusion relates to how things spread or flow through a defined social group (Rogers 2003). By contrast, the concept of 'institutionalisation' focuses on stickiness, or how things become permanent (Colyvas and Johnsson 2011). The difference between the two ideas is examined by Colyvas and Johnsson who state that "the ubiquity of a practice may suggests that it has become widely accepted, but activities that diffuse may never develop a foundation that enables them to persist. In contrast, there are procedures that are institutionalised – upheld by either law or strong beliefs – but not widely used or pursued" (2011, p.27). Thus practices may be widely diffused, but not institutionalised such that they have a foundation enabling them to persist.

Yet if environmental innovations are to meaningfully contribute to solving current sustainable development challenges, both diffusion and institutionalisation are necessary.

The findings of this study offer a number of insights in relation to these processes. Firstly, the results suggest that regulation can play an important role in the institutionalisation of radical innovations. The capacity of regulatory systems to influence the institutionalisation process is consistent with contemporary regulatory (e.g., Freiberg 2010) and institutional theorists (e.g., Scott 2008) who collectively emphasise the multi-faceted nature of contemporary regulation. As Scott's seminal framework describes, institutions (otherwise known as rules) are comprised of legal, moral and cultural dimensions, all of which interact to imbue institutions with legitimacy (2008). As such, rather than mere rules, regulation is instead understood as a reflection and codification of common values, normative goals and consensus on the appropriate means to reach a desired end point.

Regulatory frameworks, with their legal, cognitive and normative component parts, are thus a key way to help embed and institutionalise innovation. The results of this study indicate that there could be a role for regulation in facilitating the institutionalisation of environmental innovations. In Melbourne, regulatory instruments helped diffuse WSUD and grow a community of practice around this innovation. Yet in addition to facilitating diffusion, Melbourne's regulatory efforts also helped embed and institutionalise the innovation, reflecting the tendency of modern regulation to "leverage compliance-enhancing non-legal forces, including normative architectures, community pressures, individual morality and market forces both by themselves and leveraged by legal mechanisms" (Ford 2013, p.81). This leads to a second and related finding, being that more regulation, rather than less, can better assist the diffusion and institutionalisation process. Melbourne's seemingly heavy-handed regulatory response as compared to Adelaide has actually resulted in more successful embedding of the innovation. While stormwater harvesting is widely diffused across Adelaide, the lack of regulatory support leaves the existing schemes highly vulnerable while also limiting the integration across schemes. This in turn is curtailing the integration of stormwater harvesting schemes with the broader water management framework in Adelaide, and also not deeply embedding stormwater harvesting as a practice.

While indicating that regulation can play an important role in the institutionalisation of innovations, the results challenge the conventional wisdom that regulation is necessary for innovation diffusion. Although regulation did help innovation diffusion in Melbourne, the case of Adelaide shows that regulation may not be essential for the diffusion process. Instead, the diffusion of stormwater harvesting in Adelaide was facilitated predominantly by significant financial grants offered by the Commonwealth to assist with water security projects. The regulatory framework remains relatively under-developed despite the proliferation of harvesting schemes across the city. Thus while regulation can assist

innovation diffusion, it may not be strictly necessary if there are other enablers such as financial support.

Taken together, the results indicate there is an important role for regulation in enabling innovation institutionalisation, and potentially diffusion as well. This suggests that in order to best support these processes, innovation leaders and proponents need to actively advocate for regulatory support. Typically, innovation and regulation are largely separate processes, with stakeholders involved in either one or the other activity. While activities in one domain are influenced by developments in the other, the respective domains are traditionally quite separate, with a distinct actor profile and skill set in each. Such was the case in Adelaide, with the stormwater harvesting innovators largely isolated from the regulators that have come to licence the harvesting and injection schemes. As such, the innovators and scheme operators in Adelaide have largely been passive recipients of regulation. This is perhaps unsurprising given that innovators typically do not see engagement with the regulatory framework as part of their remit. Rather, their focus is on refining the innovation itself.

By contrast, the innovator network in Melbourne more actively sought to shape the creation of a regulatory framework to support widespread innovation diffusion. In the Melbourne case, innovators engaged with the broader regulatory environment specifically to advocate for the introduction of supportive structural measures. Melbourne Water, a key driver of the innovation, played a critical role in lobbying for and generating regulatory change. As a government-owned authority, Melbourne Water had both credibility and access in making the case for regulatory change, likely making this pathway more accessible. This is reinforced by findings within the institutional entrepreneurship literature, which explores how actors influence the dominant institutional and rule frameworks. This scholarship confirms that influencing regulatory frameworks is key to advancing a particular agenda (Wijen and Ansari 2007), and also notes that the social position of actors can affect their ability to engage in institutional entrepreneurship, with high-status organisations better able to leverage resources to assist this effort (Greenwood and Suddaby 2006; Battilana et al. 2009). Nevertheless, the role of regulation in supporting the institutionalisation of environmental innovation, coupled with the divergent experience of Melbourne and Adelaide, suggests that in order to maximise the opportunities for diffusion and institutionalisation, all innovators, regardless of status, should actively seek to influence regulatory processes.

The findings of this study also provide some insight into *how* regulatory systems should be designed in order to support the institutionalisation of environmental innovation. One of the key differences between the cities is the overall approach to regulation, with Melbourne creating a broad regulatory framework that became increasingly specific, and Adelaide instead going from very specific regulation to increasingly general. The experience of the cities suggests that Melbourne's broad to specific approach may be more beneficial in terms of diffusing and institutionalising radical innovation. Importantly however, the cities also

differed on the overall pattern of change exhibited, with Melbourne characterised by a gradual yet transformative approach and Adelaide more consistent with a punctuated equilibrium model of change.

Given the radical and sudden nature of punctuated equilibrium models, it likely that in order take advantage of the window of opportunity, there will be limited opportunity to introduce regulation perfectly tailored to the needs of the innovation. Rather, the priority will often be to introduce something that can be refined later. However, the experience of Adelaide suggests that even in such a context, regulators should try create a broad and widely applicable regulatory architecture in order to support the institutionalisation of environmental innovation. Although the regulatory response to gradually unfolding radical innovations is more likely to co-evolve given the opportunities for reflection and refinement, the findings of this study can nevertheless inform the overall approach to the design of regulatory architecture, regardless of the pattern of change evident.

6. Conclusion and Implications

The regulatory response to radical innovation in Melbourne and Adelaide reveals a number of key insights into the relationship between regulation and innovation in a context where innovation precedes regulation. In both cases, regulation lagged innovation. That is the innovations, being stormwater quality management and stormwater harvesting, each arose independently of any regulatory incentive or requirement. As such, the regulatory framework in each city had to respond to this emerging, radical innovation. From this common starting point, Melbourne and Adelaide had different regulatory responses, with the former more regulation heavy than the latter.

The findings of this study suggest that regulatory approaches can assist with the institutionalisation of an innovation. The institutionalisation, or embedding, of environmental innovations is essential to ensure the impact of these innovations is not merely a 'flash in the pan', and instead delivers lasting benefit. The findings also indicate that more rather than less regulation will better assist the institutionalisation process. Finally, given the importance of regulatory support to the institutionalisation of environmental innovations, the results suggest that innovators should actively seek to shape the introduction of appropriate and supportive regulatory measures.

While the innovation in both cities is widely diffused, Melbourne's process of innovation diffusion and institutionalisation is ultimately more resilient, as the innovation is embedded in the regulatory framework via both command-and-control and market-based instruments. With this broad and diverse regulatory foundation, Melbourne's experience provides insight into how the regulatory framework can be used to support widespread diffusion of an innovation. Specifically, it reveals the importance of establishing a broad regulatory architecture that can be refined and modified over time to best respond to the needs of the innovation. Further scholarly examination is required in order to understand the type and sequencing of regulatory instruments that may best support this process.

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8. Institutionalising Radical Innovations: A Framework of Institutional Change

The focus of this research is on understanding how a radical innovation comes to be institutionalised within a sector. Each of the four research papers go some way to answering this question. The first paper identifies three broad typologies of change, each of which provides a pathway towards institutionalisation and papers 2, 3 and 4 reveal the importance of structural frameworks in supporting an institutionalisation process, and provide some initial insight into how to design regulatory frameworks to enable widespread innovation diffusion and institutionalisation. However, there remains a gap as to how to effect structural change, that is, via what mechanisms? This is the focus of this chapter, which addressed the third research objective of this thesis, being to "develop a framework to describe the role of institutional change mechanisms in transformative system change".

It is clear from the scholarship, and confirmed by this research, that institutionalisation rests on a dynamic and multi-pronged foundation of culture, structure and practice change. Understanding the institutionalisation process therefore relies on examining developments within and across each domain. Importantly however, change in each domain comes about differently. The key difference is that culture change unfolds in a bottom-up way, tending to emerge organically and then growing and consolidating until such time as it becomes accepted into the hearts and minds of the majority and representative of the community's shared values. Practice change often emerges in a similarly bottom-up way, with a handful of leaders or pioneers diverging from the norm and experimenting with new procedures or processes that eventually becomes sufficiently credible and reaches critical mass such that others follow suit and/or regulatory incentives or requirements are introduced.

By contrast, the structural domain, being primarily concerned with formal rules, is generally changed in a top-down way. This has an important implication for guiding sustainability transitions. While initiatives can be introduced to encourage or incentivise change in the other domains, structural change remains squarely within the ambit of government agencies and other relevant decision makers in a given system. As such, the structural domain is the only one that can be deliberately changed. Further insight into how institutionalisation of a radically new innovation can be deliberately supported through structural change is therefore highly useful.

Institutionalisation processes within the water sector rely, in particular, on structural change.   As water is both an essential service and has natural monopoly characteristics (Pahl-Wostl 2015), there will always be a strong role for direct regulation. Historically, regulation in the water sector has been very rigid, and more recently has come to be seen as hindering more integrated approaches (Godden et al. 2011; Brown and Farrelly 2009). Given the necessity of water sector regulation, the question arises as to how hierarchical regulation can be used to support and facilitate the governance of sustainable transformation. That is, is there a better way of designing direct regulation to support the institutionalisation of radical innovations?

This chapter is focused on this question of deliberate structural change and the mechanisms that operationalise the transition process. As such, it explores formal rule change. A greater understanding of the precise mechanisms that can institutionalise a radical innovation can help inform the strategic action of urban water practitioners seeking to support a transition effort through institutional change. Institutional change is often a complex and largely opaque process. Explicit examination of this process has the potential to offer insight into the range of institutional change mechanisms available, as well as how and in what context they are best used. Such an examination would not only expand understandings of how institutional change mechanisms operate in the context of sustainability transitions, but would provide practical insight for practitioners seeking to deliberately support a transition effort.

8.1 Mechanisms of Institutional Change

Responding to the call for examination of institutional change processes in the context of sustainability transitions, this chapter explores how mechanisms of institutional change operate in the context of sustainability transitions and can be used to support the institutionalisation of radical innovations. It draws on Mahoney and Thelen's framework, introduced in Section 2.4, which identified four mechanisms of institutional change. Each of the mechanisms is briefly summarised again below.

Table 2: Four mechanisms of institutional change (adapted from Mahoney and Thelen 2010)

Mechanism	Description
Displacement	Removal of existing rules and introduction of new rules
Layering	Introduction of new rules to supplement, revise or amend existing rules
Drift	Rules remain formally the same but their impact changes due to shifts at the landscape level. Occurs through neglect - when an institution fails to adequately respond to changes in its environment, minimising its overall impact.
Conversion	Rules remain formally the same but are interpreted and enacted in new ways. Occurs through strategic behaviour of actors who deliberately exploit the inherent ambiguities of institutions.

These mechanisms were derived from studies within the historical institutionalism tradition (Mahoney and Thelen 2010) and so far, there has been limited application of these mechanisms in a context of contemporary environmental challenges or sustainability transitions. As noted in Chapter 2, transitions scholars have recently begun to engage more directly with questions of institutional change, and to this end there has been some initial exploration of Mahoney and Thelen's mechanisms of institutional change (e.g., Geels et al. 2016; Kivimaa and Kern 2016). Using Mahoney and Thelen's framework, this chapter

examines how the rules changed in each city to support the emerging innovation and the mechanisms of institutional change that facilitated this process. This chapter draws on the same data and transition journeys as presented in Chapters 4-6. Rather than using the modes of institutional change identified by Mahoney and Thelen as overall characterisations of the transition journey, this research has used them in a more specific way to assess individual instances of rule change. This reflects the overall goal of this research to understand the process of institutional change and how it can be operationalised. To this end, a more nuanced and mechanistic exploration is needed, one that delves deeper and goes beyond broad characterisations of the institutional change process.

8.2 Results

A summary of the key structural changes and the institutional change mechanisms used in each city are presented in Table 3.

Table 3: Comparison of institutional change mechanisms observed in each case study city

	Brisbane	Melbourne	Adelaide
Drift	Not observed	Not observed	• Existing rules are interpreted through a new lens (i.e., sustainability; liveability), given emergence of new values in water sector and public discourse.
Conversion	Not observed	• Establishment of stormwater offset scheme –created by regulator taking a broader interpretation of their responsibilities under legislation; was created with no change to regulation or legislation.	• Environment Protection Act 1993 – licences aquifer storage and recharge schemes using provision originally intended for wastewater disposal. • Natural Resources Management Act 2004 – Local councils use this Act to pursue stormwater projects, although it has no provisions with a stormwater focus.
Layering	• Integrated Planning Act 1997– to guide infrastructure planning in developing areas, minimising effects on water quality (updated by Sustainable Planning Act 2009).	• Port Phillip Bay SEPP. • Waters of Victoria SEPP – provisions re the protection and restoration of waterways. Subsequent amendment introduced nitrogen and phosphorus reduction targets.	

	• Environmental Protection (Water) Policy 1997 – regulates stormwater pollution (updated by 2009 Policy). • Regional Framework for Growth Management – integrated plan to guide development across SEQ. • Brisbane City Plan and Stormwater Management Code – to facilitate implementation of USQM. Outlines performance criteria and acceptable solutions. • State Planning Policy 4/10 for Healthy Waterways – mandates WSUD for certain development. Replaced by State Planning Policy 2013, which reduced scope of development required to implement WSUD.	• Water Act 1989 – outlined 13 purposes of the Act to guide interpretation of obligations. • BPEM Guidelines – introduction of best practice guidelines that were enforced through development approvals. • SEPP (Protecting our Bays and Waterways) – addressed stormwater pollution entering waterways. • Clause 56 – amendment to Victorian Planning Provisions requiring WSUD in certain development across Melbourne. • Municipal Planning Laws – tightened in 6 councils to require WSUD in all development.	Not observed
Displacement	Not observed	Not observed	Not observed

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Importantly, the mechanisms of institutional change were not used deliberately or consciously in each city. Rather, Mahoney and Thelen's framework has been used as a lens through which to examine institutional change processes in more detail. Given that institutional change in the context of a broader sustainability transition remains relatively unexplored, the identification of patterns in the use of institutional change mechanisms is a necessary first step. Reflecting on the evolution of institutional change in each city reveals a number of interesting patterns.

Firstly, it is striking that the mechanism of displacement was not observed in any of the cases. While displacement is often the aim of reform efforts, in practice it may be less likely to eventuate. Even where there is a vision for significant change, a complete and abrupt replacement of failing or outdated institutional arrangements is unlikely given that "it is too costly and practically impossible to dismiss the capital stock of existing institutions and to devalue established sunk costs before new institutional arrangements have had the time to yield returns" (Lanzara 1998, p.29). As a result, it is more likely that the existing institutional framework is amended and modified in a more gradual way in order to ensure the system continues to function (i.e., the resources continue to be distributed) during the change process.

As the vast scholarship on path dependency makes clear, institutional change cannot simply be planned and implemented 'by design'. Institutions rarely, if ever, have a blank slate from which to build. Rather, change is mediated through the existing institutional framework and must respond to and integrate with existing formal and informal institutional structures. Thus, "the exploitation of existing institutionalised resources is a principle component of the apparent paradox that even (and especially) instances of transformation are marked by path dependence" (Stark 1992, p.21). Particularly in the context of the provision of essential services such as water, the wholescale replacement of an institutional framework is unlikely. Further, given that institutional reform is a resource intensive process, displacement has rarely been observed empirically. As Kern and Howlett note, institutional change has typically "developed haphazardly through processes of policy layering, or repeated bouts of conversion or drift, in which new instruments and objectives have been piled on top of older ones, creating a palimpsest-like mixture of policy elements" (2009, p.395). This confirms the observation that the institutional change process is messy, typically characterised by a complex and imperfect mix of instruments that have been re-appropriated and modified to meet new ends (Merrey and Cook 2012).

Second, the layering mechanism was the most widely used mechanism across all the cases, used frequently in both Brisbane and Melbourne. In each case, the layering mechanism was predominantly used to translate new scientific knowledge into practice. More particularly, it was generally used in a retrospective way to ensure scientific best practice was reflected in the formal rules. However, there are important distinctions in the use of this layering mechanism in Melbourne as compared to Brisbane. According to Mahoney and Thelen's framework, layering involves the introduction of a new rule (2010). However, it is silent in relation to the extent to which, and how strictly, the new rule is enforced, which the results suggest are important issues with implications for the overall institutionalisation of the innovation.

In Melbourne, many of the new rules introduced via a layering mechanism were vigorously enforced through development approvals. New water pollution reduction targets introduced in

the State Environmental Planning Policies were enforced this way, as were the subsequent updated rules introducing requirements in relation to specific pollutants. Despite the name, the Best Practice Environmental Management Guidelines also came to be enforced through development approvals. By contrast, the majority of rules introduced in Brisbane through layering were not the subject of strong, or any, enforcement, and therefore had limited impact in changing practice. This began with no enforcement of the Clean Waters Act 1971, and can be seen in the requirement for councils to develop stormwater management plans, which was pursued only haphazardly by municipal councils. The lack of enforcement is also reflected in the existing rules for WSUD under the current State Planning Policy, which sees non or under-performing assets accepted as compliant. Rules on paper are clearly not the same as rules in practice. Further discussion of the difference in enforcement across the cities and the implications of this is contained in Chapter 5.

Further, some of Melbourne's layering initiatives were comparatively far more radical as compared to Brisbane. While both cities introduced rules limiting the discharge of nitrogen and phosphorus to waterways in response to scientific studies in the respective cities, Melbourne bolstered its approach with the introduction of more radical rules to bring about a step-change in practice, such as clause 56 which required WSUD approaches in development across the State. Thus in order to understand the effect of layering mechanisms in this context, it is necessary to look beyond the introduction of the rule itself to consider the content or substance of the new layered rule. This points to the need for more nuance in Mahoney and Thelen's framework, particularly in relation to the layering mechanism, if it is to have meaning in the context of sustainability transitions.

Looking across the cases, it is also apparent that each of the three case study cities used different combinations of institutional change mechanisms, as reflected in Table 4, which considers the dominant type of change in each city (as presented in Chapter 4) alongside the dominant institutional change mechanisms used.

Table 4: Comparison between dominant domain of change and institutional change mechanisms in each city

City	Pattern of Change	Institutional Change Mechanisms Observed
Brisbane	Culture-led	Layering
Melbourne	Structure-led	Layering and Conversion
Adelaide	Practice-led	Conversion and Drift

Overall, the 'radicalness' of the transition is reflected in the approach to institutional change adopted in each city. Institutional change scholars observe that the layering mechanism tends to produce relatively conservative change that is closer to the existing institutions (Mahoney and Thelen 2010). By contrast, the conversion and displacement mechanisms typically produce more

radical change (Mahoney and Thelen 2010). Of the three cities, Brisbane has had the least effective transition, although it retains a strong foundation from which to continue pursuing improved stormwater quality management. In focusing predominantly on culture-driven approaches, Brisbane paid comparatively little attention to formal rule change. Nevertheless, some structural initiatives were introduced, each via a layering mechanism, being the most conservative of the institutional change mechanisms. Although there is some potential to use the layering mechanism to effect radical change (as the Melbourne case demonstrates), this is not how the mechanism was used in the Brisbane context.

Overall, Melbourne has so far had the most successful transition process. Although not as advanced along the S-curve as Adelaide, Melbourne has the strongest transition foundation, having made significant and largely equal progress across all three culture, structure and practice domains (as compared to Adelaide that is well advanced in practice and culture, with structure significantly lagging). To advance its transition agenda, Melbourne used the largest number of institutional change mechanisms overall, a combination of layering, both conservative and radical variants, and conversion. Similar to Brisbane, Melbourne also relied heavily upon the layering mechanism, typically to incrementally advance the stormwater quality protection agenda by ensuring scientific best practice was reflected in the formal rules. However, the layering approach was also sporadically used to introduce a more radical rule that brought about a step-change in practice, such as the clause 56 amendment. This two-fold use of the layering mechanism was highly effective, with the incremental layering establishing a robust transition foundation that could act as a safety net if the more radical layering initiatives failed to take hold. Complementing this was occasional use of the conversion mechanism, evidenced by the creation of the stormwater offset scheme and the consequent expansion of the norms of interpretation in relation to development approvals. Thus overall, Melbourne's transition effort was supported by a blend of institutional change mechanisms, some retrospectively consolidating knowledge or practices that had become widely accepted, and others more proactively seeking to bring about significant change.

Of the three cities, Adelaide has most advanced transition, which has also unfolded over the shortest time. Although there has been comparatively little attention given to structural reform, the changes that have been introduced have all been via the more radical and proactive institutional change mechanisms of conversion and drift. With very limited introduction of new rules, Adelaide's traditional urban water framework has been largely repurposed to facilitate the growth and diffusion of stormwater harvesting. That is, the current structural framework largely relies on a broad interpretation of provisions originally intended for other aspects of water management, such as wastewater disposal. It is striking that the swiftest and most radical transition used the more radical institutional change mechanisms to support the transition agenda. The 'high risk, high reward' approach adopted by Adelaide is thus reflected in the overall approach to institutional change.

8.3 Discussion: A Framework of Institutional Change

Taking a macro view of each of the case study cities, each has had significant success embedding a radically new innovation. While the ultimate outcome of each transition cannot yet be known, Adelaide's stormwater harvesting transition seems to be entering into a stabilisation phase, Melbourne's stormwater quality transition is on the cusp of a stabilisation phase, and while Brisbane has suffered some losses more recently, it retains a solid transition foundation from which to further progress this agenda.

The results show that for each of the cities to get to this point, the institutional change mechanisms were used in different ways, to bring about different types of change. The mechanisms of conversion and drift were typically used by transition leaders to progress a transition agenda. That is, these mechanisms were used proactively to change the norms of interpretation or repurpose existing rules, which rapidly advanced the transition agenda. By contrast, layering was most often used reactively to consolidate new scientific knowledge. That is, it responded to advances in knowledge, and ensured the rules reflected the evolving understandings of best practice. However, the case of Melbourne indicates that the layering mechanism can also be used in a more proactive way, to bring about a step-change in practice.

Table 5 offers some insight into the implications of each of the mechanisms in terms of what type of change it is likely to bring about, when it is best used and the contribution to the overall institutionalisation of the innovation. In doing so, the framework presented in Table 5 represents a hypothesis as to how the respective institutional change mechanisms can be used more deliberately to support the institutionalisation of a radical innovation, and a transition effort more generally.

Table 5: A Framework of Institutional Change

Mechanism	Type of Change	Manner of Use	Timing of Use	Extent of Institutionalisation
Drift	Radical	Proactive	Window of Opportunity	Shallow
Conversion	Radical	Proactive	Window of Opportunity	Shallow
Layering – variant 1	Incremental	Reactive	Regime in Equilibrium	Deep
Layering – variant 2	Radical	Proactive	Both	Moderate
Displacement	Radical	Proactive	Both	Deep

As the framework indicates, the mechanisms of drift and conversion can be used proactively to bring about radical change and thereby significantly advance a transition agenda. It is hypothesised that given these mechanisms are bringing about more radical change, their introduction may rely on (or be best served by) alignment with the broader landscape context.

However, as the case of Adelaide shows, such 'windows of opportunity' need not be the result of enormous system shocks caused by dramatic natural disasters or financial collapse. Rather, some degree of sympathetic context may be sufficient. These mechanisms are typically used in a proactive way to bring about a step change in a transition agenda. Importantly however, radical changes that are introduced proactively may not be deeply embedded or institutionalised. The research results indicate that changes introduced via these mechanisms may not necessarily have strong underpinning cultural support that is essential for deep institutionalisation, and may need to be reinforced by more incremental institutional change mechanisms that can build the necessary cultural support over time.

As described above, the layering mechanism can be used to bring about both radical and incremental change, with consequent implications for the timing and manner of use, and the extent of institutionalisation. Table 5 also includes a hypothesis as to how the displacement mechanism may unfold in the context of a system transformation. Given it rests on wholescale repeal and replacement of an institutional framework, it seems to be a mechanism used proactively to bring about radical change. In practice, it is likely that only government actors have the capacity to give effect to such change. As such, the displacement mechanism is one that can potentially be used both when there is a window of opportunity or when the regime is in apparent equilibrium, as the governing body will likely be able to create its own 'window' if necessary. Further, it is hypothesised that governments will only pursue such comprehensive change when there is a significant cultural and community mandate, thus likely leading to deep institutionalisation.

These results have a number of implications for institutional change to support sustainability transitions. Importantly, they confirm that opportunities for institutional change are not limited to rare 'windows of opportunity'. Rather, this study reveals that incremental institutional change can be highly effective for bringing about or supporting broader system transformation. The layering mechanism in particular provides an opportunity for incremental institutional change that, as the case of Brisbane demonstrates, has the potential to add up to significant change. Accordingly, transition advocates need not wait for rare and somewhat unpredictable windows of opportunity, but in making use of the layering mechanism, can instead progress a transition agenda even in times of apparent equilibrium and stability.

However, the results also confirm the importance of windows of opportunity for bringing about significant transition progress. The more proactive and radical institutional change mechanisms in particular lend themselves to being especially useful during these rare windows of opportunity, able to significantly advance a transition agenda. Yet as the case of Adelaide confirms, whilst use of these more radical change mechanisms may enable a swift transition journey, if used in isolation they may create vulnerabilities, with the resulting rules not strongly embedded. As the case of Melbourne indicates, the strongest transitions will draw on a broad range of institutional change mechanisms, both incremental and radical, reactive and proactive. This suggests that there is always 'institutional work' transition advocates can engage in to advance a transition agenda, without the need to wait for windows of opportunity.

More generally, the results confirm the value of the 'gradual yet transformative change' pathway, and suggest that such a pathway may be particularly useful in facilitating deep institutionalisation of radical innovations. Such a claim is supported by a recent study by Djelic and Quack, who investigated four episodes of national and transnational institutional change and concluded that the generation of new institutional paths were "made up of a complex accumulation of recombination episodes…and a succession of small, sometimes apparently inconsequential steps" (2007, p.181). Similarly, Dolata's investigation of socioeconomic and institutional change promoted by technological fields in the digitalisation and biotechnology concluded that even radical change typically comes about as the accumulation of small and gradual changes (2013). As he states, "even for sectors that are under immense pressure to change, radical transformation takes place only gradually over long periods of time until a new and capable socio-technical constellation has formed and achieved stability (Dolata 2013, p.28).

Transition processes arising from a gradual yet transformative change pathway have, by their very nature, the benefit of evolving slowly and incrementally over time. Each incremental adjustment provides an opportunity to integrate with the broader landscape. In such a context, the introduction of each additional 'layer' can be thoughtfully and deliberately introduced in a way that maximises consistency with the existing cultures, structures and practices. While the more radical institutional change mechanisms can bring about change swiftly, there is a potential vulnerability that the new rule may not be sufficiently embedded in the culture domain that is critical to conferring legitimacy on a new practice. To counteract this potential vulnerability, it may therefore be helpful to use these more radical mechanisms in combination with the more conservative and incremental institutional change mechanisms.

8.4 Conclusion and Implications

Institutional change is difficult, yet critical to sustainability transitions. In particular, it is essential to embedding a radical innovation. This research provides some initial insight into the operation of institutional change mechanisms in the context of a broader sustainability transition and in doing so, sheds some light on the otherwise opaque process of institutionalisation. More specifically, the framework provides a basis for designing a context-specific institutional change agenda and approach, taking into account the strengths and limitations of each mechanism, the timing and nature of its use, and the broader landscape context.

These results provide an important contribution to transitions scholarship, providing a framework for the operation of institutional change mechanisms in the context of a fundamental system change. This framework can also be used by urban water practitioners seeking to bring about a shift towards sustainability. The framework offers valuable insight into how transition advocates and proponents can engage with the formal rule framework and deliberately seek to bring about change. The contributions of this framework and the overall thesis are explored in more detail in the following chapter.

9. Contributions and Outlook

The overall aim of this research was to understand how radical innovations come to be institutionalised within a sector over time. This chapter presents the main findings of this research and articulates the major contributions to the literature.

The question of how complex socio-technical systems undergo fundamental transformation, and the role of institutional change in this process, is the focus of research across a number of literatures, most particularly, sustainability transitions, institutional theory and environmental governance. As Chapter 2 demonstrated, there are similar questions being asked by researchers across these differing areas of scholarship. As such, each of the scholarly contributions identified in Section 9.1 contribute to some or all of these literatures, as articulated below.

9.1 Scholarly Contributions

This research makes four overall contributions to the scholarship.

1) Three detailed empirical case studies of unfolding urban water transitions, revealing the co-evolution and dynamics of culture, structure and practice change and proposing a typology of transitions.

2) Provides a methodological approach for examining the dynamics of transformative change generally, and institutional change specifically, during the acceleration period of a transition.

3) Provides a framework to identify and explain the operation of institutional change mechanisms in the context of transformative system change, articulating the operation, fit and implications of each mechanism for facilitating a sustainability transition.

4) Reframes the dominant conceptualisations of transformative change and introduces an alternative, hybrid model to explain fundamental change in socio-technical systems, integrating aspects of both punctuated and incrementalism patterns of change.

Each of the contributions is discussed in further detail below.

1) *Empirical cases of transition that reveal to co-evolution and dynamics of culture, structure and practice change and proposing a typology of transitions*

It is widely recognised that institutional change is critical to enabling, constraining and shaping socio-technical regime change (Coenen et al. 2012; Grin 2010; Truffer et al. 2009). However, relatively little is currently known about how processes of institutional change unfold in the context of fundamental, transformative system change. This research has responded to calls for further examination of institutional change in the context of sustainability transitions. The first contribution of this research is in providing three in-depth cases of institutional change in a sustainability transition, providing the beginnings of an empirical foundation for further theorisation in relation to institutional change in the context of transitions.

This research has more explicitly examined the culture, structure and practice changes that have so far remained implicit in transitions scholarship. More specifically, the study has examined the dynamics of change in each of the culture, structure and practice domains, as well as the linkages and co-evolution of developments across each domain. While confirming that all transitions are comprised of culture, structure and practice changes, the results provide insight into *how* change in each domain unfolds. To this end, the study reveals that change in each domain will not necessarily unfold evenly or equally, and that a city's context (in terms of factors including existing regime dynamics, actor-network and nature of the innovation) plays a key role in shaping which domain of change dominates the transition process. Further, developments within each domain co-evolve with developments in the other domains. That is, given the inextricable links between cognitive, normative and regulatory institutions, and their manifestations via the dominant practices within a system, change processes are necessarily dynamic and responsive to shifts in the broader institutional landscape. This research has also introduced a typology of transitions, using the categories of culture, structure and practice as a means of examining and classifying transition processes.

In confirming the need for change across all three dimensions to support a broader transition effort, the results also contribute to the 'practical' agenda of transition scholarship that seeks to determine how change can be most effectively steered in a desired direction and pace (e.g.: Loorbach 2010; Huitema et al. 2009; Ellen and Wieczorek 2005). To this end, the results reveal the importance of actors actively working across all three domains to embed a radical innovation, and in particular, to overcome the bias of predominantly pursuing change in the domain most compatible with the city's prevailing context.

2) *Provides a methodological approach for examining institutional change in the context of broader transformative change during the acceleration period of a transition*

As a relatively young area of enquiry, transition scholars to date have been primarily focused on the development of overall conceptual frameworks to explain transformative socio-technical change, such as the multi-level perspective and multi-phase perspective. From this foundation, transitions literature evolved to empirical application of these broad frameworks, most commonly via examination of historical transitions (e.g.: Geels 2005; Geels 2002). In exploring three cases of transition currently unfolding, each of which are in an acceleration phase, this research extends transitions scholarship by contributing insight into the dynamics of contemporary transition processes.

This research therefore provides an overall methodology for examining the acceleration phase of a transition, which remains relatively understudied as there are not many transition processes that have arrived at this stage of maturity. Importantly, the transitions examined for this research have all rested on the introduction of radical innovations in the Australian water sector. As large-scale public infrastructure transitions, they are inevitably more government led, in part explaining the location within the acceleration domain. Further, the transition in each case was affected (and in some cases assisted by) the millennium drought across Australia from 1997-2012, which necessarily focused significant resources on the water sector. Hence, water sector transitions in Australia are relatively advanced and provide a valuable opportunity for examining contemporary transition processes.

The frameworks introduced in this research for examining unfolding transitions make a particular contribution to the Transition Management governance approach, which is now focusing more specifically on understanding the chaotic, messy change process within the acceleration phase. Initially exploring processes of vision development and experimentation in the predevelopment and take-off phases of transition as a means of exerting pressure on the regime, TM has more recently shifted to look at the next phase of transition and processes in relation to upscaling of innovation and the institutionalisation of alternative approaches (Loorbach 2014; Loorbach and Huffenreuter 2013; Loorbach and Verbong 2012). However, as a new direction for TM, there are currently limited conceptual frameworks from which to draw (Loorbach 2014). This research presents a methodological approach for examining the dynamics of change in this context, helping to more specifically identify what and how institutions change. This insight can be used to inform the development of TM, and assist in its mission of developing techniques and approaches for actively steering transition processes.

3) ***Provides a framework to identify and explain the operation of institutional change mechanisms in the context of transformative system change***

The third contribution of this research is in offering a framework to assess the dynamics of change in contemporary transitions. The need to better understand institutional change processes has been identified by a range of scholars (Grin et al. 2010; Brown and Farrelly 2009; Truffer et al. 2009; Brown 2008). This thesis provides a framework to identify and explain the operation of institutional change mechanisms in the context of transformative system change, articulating the operation, fit and implications of each mechanism for facilitating a sustainability transition (presented in Chapter 8). Through the development of the framework, this thesis has identified the conceptual links between sustainability transitions and institutional theory in relation to explaining transformative system change. This in turn contributes to deepening the transitions scholarship while also broadening institutional theory.

For the transitions scholarship, the framework provides a first step towards the identification of mechanisms of institutional change in the context of sustainability transitions and how they can be used to facilitate the institutionalisation of radical innovations. This research therefore provides a nuanced conceptual framework that allows future transitions studies to be more specific about what structures are changing, and via what mechanisms that change comes about.

In applying a theory of institutional change in a context of contemporary sustainability transitions, this research also extends neo-institutional theory, which to date has predominantly been used to explore and explain historical cases of institutional change. It contributes to the emerging body of empirical work that considers the application of institutional change mechanisms in a significantly different context from which they were conceived. Through this process, this research proposes the need for a more nuanced conception of the 'layering' mechanism in the context of unfolding transitions, noting that layering efforts can be utilised for both radical and incremental change efforts. Further, by identifying the characteristics, context conditions and implications of each of the institutional change mechanisms within contemporary transformative change processes, the research also provides insight into how each of the mechanisms may best be used to support the institutionalisation of radical innovations and a transition effort more generally.

The scholarship on both sustainability transitions and environmental governance is investigating questions around whether, to what extent, and how transition processes can be deliberately steered or governed. This research makes a contribution to both areas of scholarship in this regard, providing an analytical and conceptual basis for developing new types of governance strategies focused specifically on navigating transitions and transformative change processes. This research extends current knowledge by offering insight on how to identify the dominant domain of change in a particular context and the institutional mechanisms that may best correspond to that context. In examining the characteristics of each institutional change mechanism, as well as the conditions for fit and operation in the broader landscape context, this research can support deliberate efforts to design an optimal policy mix using a complementary blend of strategies that work holistically to support a transition agenda. That is, the framework offers a way to analyse the dynamics of institutional change in a transition, which can be used to anticipate which mechanisms may be dominant. This in turn provides insights on how to inform strategic action and transition steering processes by complementing these dominant strategies with other approaches and initiatives, in order to prevent less desirable transition trajectories. These insights can therefore be used to inform the process of institution building in a more targeted way. Given the centrality of institutional change to transitions, this more nuanced understanding of institutional change processes can inform further conceptual development of how institutional frameworks unfold and evolve.

4) *Introduces a hybrid model to explain fundamental change in socio-technical systems, integrating aspects of both punctuated and incremental patterns of change*

Within transitions scholarship and institutional theory, there remains an ongoing question about the pace of transformative change (in terms of regimes or institutions respectively), with a distinction typically drawn between punctuated equilibrium and incremental patterns of change. Both archetypes of change remain largely unexplored, with limited insight into how these patterns of change unfold in practice.

This research challenges the traditional assumption that transformative change only unfolds via a punctuated equilibrium model of change and confirms that institutions can change in gradual yet transformative ways. That is, the results suggest it is unlikely that wholescale institutional change (and by extension, regime change) comes about via one episode of radical change. This is especially so given institutional change relies, at least to some extent, on slow-moving and largely invisible cognitive and normative change. The results reveal the possibility of a 'directed incrementalism' pattern of change and provides more insight into how this process may unfold. Following this pattern, the results indicate that there is no need for each individual intervention to be radical in order to support an overall transition. Yet even in an incremental pattern of change, the overall transition effort must be oriented towards transformation. That is, although unfolding in an evolutionary way, incremental changes must nevertheless build towards something fundamentally different to the status quo, such that there is radical change over the longer term.

However, rather than discrediting the punctuated equilibrium model of change entirely, the research results confirm the importance of such windows of opportunity in supporting, enabling or fast-tracking a transition effort. Importantly, such periods of rapid change must be reinforced by subsequent institutionalisation processes in order to provide an effective foundation to support

the newly introduced change. This reveals the dynamic links between radical and incremental change processes. Rather than 'either/or' models of change, this research suggest that in practice, both types of change work in combination to facilitate a broader process of institutional change. In practice, transitions are therefore more likely to exhibit a mixed pattern, comprised of a blend of incremental and radical change. As such, the results indicate that it is possible to have a step change even within a transition process that can more generally be characterised as incremental. These results provide the foundation for a more directed transition journey, whereby the transformation process is deliberately steered in response to changes in the broader system and landscape. With this insight, it may be possible to maintain a constant pace of change or to more strategically link change initiatives with the broader landscape context. It also increases the opportunity for actors to use windows of opportunity for institutional change in a more effective way.

These results extend the transitions and environmental governance scholarships by demonstrating that governance efforts to deal with complex societal problems do not have to focus solely on radical change. The goal of a policy mix therefore need not be to realise the overall goal of the transition. Instead, incremental changes remain critically important in supporting an overall transition effort. The results therefore indicate the need to look for opportunities to guide sustainability transitions through incremental changes and demonstrate the value of using policy mixes to usher in incremental change or interim goals that help build the foundation for a broader transformation. Transition advocates thus need not wait for windows of opportunity, but can help build momentum for radical change via smaller, more incremental and evolutionary steps. However, the results also show how such windows of opportunity can be used more deliberately and effectively to progress a transition agenda, in a way that is compatible with a broader gradual yet transformative pattern of change.

In confirming the value of incremental institutional change in assisting sustainable transformations, the research extends neo-institutional theory, showing that incremental change does not necessarily reproduce the status quo and thereby contribute to stability. This confirms the need for further exploration of 'gradual yet transformative change' pathways, in order to better understand varieties and mechanisms of change within this overall pattern. Further, the results point to the need for further debate and examination as to what types of incremental change contribute to transformation as compared to stability. That is, whilst some incremental changes will reinforce the existing regime, this research demonstrates that some incremental changes can instead help build an alternative, and radically different, regime. Distinguishing between these different types of incremental change will be necessary to further extend understandings of institutional change processes and assist efforts to steer sustainable transformation.

9.2 Practical Contributions

This research is framed by the real world problem that conventional approaches to urban water management are inadequate and insufficient to effectively respond to the new operating context that is characterised by uncertainty, and requires more flexible, diverse and adaptive approaches to ensure continued liveability, sustainability and resilience. Yet despite widespread calls for a

shift towards IWRM, limited progress has so far been made in the realisation of this alternative vision. In particular, there remains a significant question around how institutional change unfolds and the extent to which this process can be steered to support a broader transition effort. Importantly, the challenge of institutional change and how to fundamentally transform complex and entrenched socio-technical systems is relevant not only to urban water systems, but also to integrated systems in the waste, transport and energy sectors that are subject to similar calls for a shift towards increased sustainability. The aim of this research was therefore not to only contribute scholarly insights into the dynamics of institutional change, but also to provide practical insight into how institutional change processes can be harnessed to support and facilitate transformation in complex socio-technical systems.

To this end, this research provides a number of insights that can be used by transition advocates and policy makers to build a multi-dimensional and robust foundation to support the introduction and embedding of radical innovations.

The first practical contribution is in revealing the importance of regulation in supporting a transition effort. In particular, the results suggest that the timing of the introduction of supporting regulatory measures matters, with regulation introduced earlier in the transition process better able to support the transition more broadly. This is because regulation not only embodies and consolidates the community's shared values and aspirations, but also carries formal means of enforcement. This suggests that transition proponents should proactively and deliberately engage with regulatory frameworks early in the transition process and advocate for regulatory change where appropriate. This is particularly important given that direct regulation can provide a valuable safety net for the overall transition effort, ensuring that even if momentum is lost in other domains, a foundation to support ongoing engagement with the new practice remains.

Secondly, the results suggest that more, rather than less, regulation better supports the transition effort. However, the notion of regulation in this context does not refer simply to direct, command-and-control regulation. Adopting a broader conceptualisation of 'regulation', consistent with developments in regulatory and institutional theory (Taylor et al 2012; Freiberg 2010), the research considered interactions between soft regulation such as policy frameworks, hard regulation such as direct regulation and economic measures such as the introduction of market trading schemes. The results confirmed that all types of regulation can assist a transition effort, and can work in combination to support the embedding of a radical innovation. This can be used to inform the strategic action of transition advocates as well as the design of policy mixes, indicating that advocacy efforts need not focus exclusively on regulation, but should seek to introduce a complementary blend of initiatives in terms of policy, regulation and market mechanisms.

As a third practical contribution, the results also provide some initial insight into how to design regulatory frameworks to support the institutionalisation of radical innovations. To this end, the research indicates that the creation of a broad, aspirational and unenforceable regulatory framework is a useful starting point for a transformative change process. The use of soft policy measures is particularly effective to this end, introducing general principles in support of a new approach, helping to reinforce an emerging culture or paradigm. From this foundation, regulatory

efforts should become gradually more specific and enforceable. This overall approach provides a means of smoothing the introduction and acceptance of radically new practices by ensuring policy and regulatory frameworks are consistent with and reflective of dominant community perceptions. It also provides a means of guarding against the excessive rigidity of institutional frameworks, by allowing new knowledge or requirements to be relatively easily incorporated into the regulatory system. This provides opportunities for reflection and refinement of the institutional framework, ensuring it remains broadly supportive of the overall transition effort.

These practical contributions are specifically relevant to policy makers and regulators having to respond to the emergence of radical innovation or seeking to influence the speed and direction of adoption. In addition, these results can be used by transition proponents and advocates and inform their engagement with the broader structural framework. In particular, the results suggest that innovation or transition advocates should actively seek to engage with the policy and regulatory domain, to maximise the chance for the introduction of supportive institutional frameworks.

9.3 Research Limitations

There are a number of limitations of this research, although many of these can be addressed through future research that makes use of the rich empirical data generated through this research.

As a starting point, it is important to acknowledge that the concept of 'institutionalised practices' does not always have positive connotations. In everyday parlance, and even in some scholarship, a reference to institutionalised practices implies rigid, staid and perhaps outdated practices or approaches. In this research, the concept of institutionalisation has been explored as a means of embedding sought-after change. However, there is a risk that over time these once sought-after practices themselves become rigid and difficult to change. This reveals a key limitation of this research, in not explicitly considering strategies for maintaining flexibility or agility in the institutional change processes to minimise the risk of such rigidity. The 'over-institutionalisation' of governance arrangements or practices is a significant risk, and has contributed to the current challenges in the urban water sector. There is a need to consider processes of institutionalisation that nevertheless retain flexibility and responsiveness to the broader operating context.

Questions of institutional change are inextricably linked to actors, whose agency is the means through which institutions change and are changed. However, this research has focused more on the mechanisms available to give effect to institutional change and has not expressly explored the dynamics of actors and actor strategies in relation to institutional change processes. While there has been some consideration and discussion of how actors interact with institutional structures, it has not been the overall focus of this research. Further, the thesis has not considered power relationships and dynamics that may also influence broader processes of institutional change. These remain highly relevant issues that should be the subject of future research in order to provide a more comprehensive picture of institutional change processes.

The Framework of Institutional Change presented in Chapter 8 is yet to be applied in practice and empirically tested. Without this, the value of the Framework as a tool for deliberately and

proactively guiding institutional change processes cannot be assessed. That is, the proposed Framework has been derived from a retrospective analysis of change processes, and it is unclear whether the mechanisms identified can be used in a proactive way. The Framework would therefore benefit from application to transitions currently unfolding in order to determine its effectiveness for informing the design of institutional change strategies and supporting a broader transformation towards sustainability. Application of the Framework to other public infrastructure sectors, such as energy or transport, could also be illustrative.

By focusing on a range of resource or service provision sectors, and engaging more directly with the effect of power dynamics and actor strategies on institutional change, future research could build on the foundation provided by this research and provide a more comprehensive understanding of institutional change in the context of a broader sustainability transition.

9.4 Future Research Agenda

As previously noted, research on institutional change in the context of socio-technical regime transformation remains in its infancy. This thesis represents one small step towards providing some insight into institutional change processes to support a broader transition effort. To further extend the scholarly and practical contributions of this thesis, there are a range of theoretical and empirical questions that could be addressed through future research.

9.4.1   Theoretical Steps

Further theoretical work is essential to assist the development of a more detailed and well-rounded picture of institutional change processes in the context of a sustainability transition.

The development of a set of institutional change indicators would be a useful contribution in this regard, enabling the identification of institutional change processes as they are unfolding, rather than retrospectively. This in turn could be a valuable first step in providing timely opportunities for shaping and guiding institutional change processes.

Further theoretical research is also required to more specifically examine the interactions between actors and institutions during different transition phases and in different regime contexts. For example, how do niche versus regime actors engage with the prevailing institutional frameworks? Do they engage in different strategies to influence and initiate change? Do actors engage with institutional frameworks different in the early pre-development and take-off transition phases as compared to the later acceleration and stabilisation phases? Examination of such questions is critical to better understand the contests and tensions between actors with different agendas, interests and responsibilities, and the implications for institutional transformation.

Additionally, the relative power of individual actors can also have a significant impact on how institutional change processes unfold. Future research in this area should more directly engage with questions of power and the effect on institutional change processes and outcomes more broadly. These more nuanced insights may help inform the development of conceptual frameworks that more comprehensively capture the richness and complexity of institutional change while also informing strategic action to this end.

In addition, further research is required in order to understand how the institutionalisation of individual innovations contributes to an overall transition. This would involve exploration of the interactions between innovations or regime subsystems and how they compete with or empower each other as part of a system's overall dynamic. Such conceptual insights would further inform the selection of strategic initiatives for facilitating system transitions.

Further empirical work and theoretical development is also needed to refine the Institutional Change Framework. This could include research on how to the identify the mechanisms of change as they are in use, which would help provide cities and actors with a more reliable means of identifying and refining institutional change strategies. Examination of the mechanisms of institutional change and their relationship with broader transition dynamics could also provide valuable insight. In addition, exploration of traditional approaches to institutional change within the city could also be of interest, and the extent to which that informs the institutional change approach in the context of transformative change.

Ultimately, further theoretical exploration will be critical to generating insights that can inform the development of strategic interventions to guide institutional change processes in a way that supports regime transformation.

9.4.2   Empirical Steps

Many more detailed empirical cases of institutional change in the context of broader system transformation are needed to provide a rich and reliable evidence base for the development of theoretical frameworks that can inform the development of strategic interventions to guide institutional change processes.

As noted above, empirical testing and validation of the framework is required, and would in particular be assisted by application in sectors beyond that of urban water servicing. Of particular empirical interest is whether the institutional change mechanisms and processes are similar across different fields.

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