Participatory Adaptive Integrated Urban Water Management – the Tensions

by Bao Anh Nong

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Doctor of Philosophy

under the supervision of Professor Pierre Mukheibir (Principal) and Associate Professor Simon Fane (Co-Supervisor)

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Certificate of original authorship

I, Bao Anh Nong declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy in the Institute for Sustainable Futures at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Table of Contents

List of figures

List of tables

Abbreviations

AM: Adaptive Management

AP: Adaptive Planning

APP: Adaptive Pathway Planning

CF: Cynefin Framework

DAPP: Dynamic Adaptive Policy Pathways

DELWP: Department of Environment, Land, Water and Planning (Victoria)

GWP: Global Water Partnership

IAP2: International Association for Public Participation

IPART: NSW Independent Pricing and Regulatory Tribunal

IUWM: Integrated Urban Water Management

IWCM: Integrated Water Cycle Management

IWM: Integrated Water Management

IWRM: Integrated Water Resources Management

LHWSP: Lower Hunter Water Security Plan

MCDA: Multi-Criteria Decision Analysis

MWP: Metropolitan Water Plan

NSW DPIE: New South Wales Department Planning, Industry and Environment

PP: Public Participatory

ROA: Real Option Analysis

SSM: Soft Systems Methodology

ST: System Thinking

SUWM: Sustainable Urban Water Management

SWITCH: Sustainable Water Management Improves Tomorrow's Cities' Health

TWCM: Total Water Cycle Management

UNCED: United Nations Conference on Environment and Development

WPP: Water Partnership Program

WSC: Water Sensitive Cities

WSUD: water sensitive urban design

YVW: Yarra Valley Water

Abstract

Urban water management is now experiencing significant growth in complexity and uncertainty. This trend is expected to continue as emerging pressures will likely be exacerbated in the future. Furthermore, the way we currently manage our water in the city is no longer appropriate to respond to this ever-growing uncertainty and complexity of the human-urban water system. A shift to an *Adaptive, integrated and participatory approach* is advocated.

In this thesis I seek to inform the transition to a more sustainable paradigm for urban water planning and management, which exhibits characteristics and qualities from public participatory (PP), integrated urban water management (IUWM), and adaptive management (AM) approaches. To that end, the research explores the challenges and issues of complexity and uncertainty in current water planning processes. The potential tools and methods to deal with such problems are discussed from different perspectives.

A nested exploratory case study methodology with multiple cases was utilised to conduct the research in South Eastern Australia seaboard metropolitan areas. The methods include semi-structured interviews, literature review and document analyses.

The literature reviewing process identified the lack of documented cases that exhibit principles of the three approaches and the lack of analysis on how they should be adopted in conjunction. The interviews confirmed that the three approaches are perceived as highly interconnected and have the potential to complement others. Further, the findings indicated critical features of the three approaches in practice and identified four major challenges. Furthermore, uncertainty and complexity emerged as critical concerns that were further explored.

The Cynefin framework was adopted to investigate the roots causes of the emerging complexity and uncertainty and the potential methods and tools for future planning and management. The study revealed that there is a lack of methods or tools that can operate within the complex domain.

The key recommendations from this research are 1) that the methods and associated tools should be applied and coordinated together in a framework guided by a combined approach to better address complex problems; 2) more attention should be paid to develop the techniques and practices for designing and implementing pilots and learning experiments; and 3) it is necessary to provide capacity-building assistance on integrating IUWM and AP.

This research demonstrated that to adequately plan for sustainable and resilient urban water servicing, the water sector needs to find a consistent and coherent way to simultaneously incorporate adaptive, integrated, and participatory approaches, especially when dealing with complexity.

1 Chapter 1 - Introduction

1.1 Urban water planning and management – complex problems under uncertainty

1.1.1 Problem statement

Urban water planning and management is now experiencing significant growth in complexity and uncertainty in the assumptions about the future. In brief, complexity is a way of perceiving the world as a complex system which is characterised by several characteristics:

i) there are a large number of elements that interact in a non-linear manner
ii) insignificant changes can induce severe consequence
iii) 'the whole is greater than the sum of its part', and solutions can only be emerged from the circumstances rather than imposed
iv) the system's elements evolve with others and the surrounding environment over time
v) the system constantly changes, and the behaviours cannot be predicted. (Snowden & Boone, 2007).

Various aspects of urban water systems, such as socio-economic, legislation and regulation, and natural conditions (Cosgrove & Loucks, 2015), continuously interact and evolve in the context of climate change. Hence, the associated decision-making in the planning and managing of such systems is considered complex (Floyd et al., 2014; Fratini et al., 2012). Further, the concept of uncertainty refers to either i) an ontological situation where there are aspects of the system that are inherently unpredictable (unpredictability) or ii) an epistemic situation where there is a lack of information or data, credibility of available data, theoretical understanding (incomplete knowledge), or iii) ambiguity where there are multiple ways/perspectives (sometimes conflict) of understanding or interpreting the system (Brugnach et al., 2008, 2009).

The growth of complexity and uncertainty is expected to continue as emerging pressures are likely to exacerbate existing issues (Bichai et al., 2018; Burn et al., 2012; Ferguson, Brown, Frantzeskaki, et al., 2013; Keath & Brown, 2008; Maheepala et al., 2010; Mukheibir, Howe, et al., 2014). Furthermore, the way we currently manage our water systems and services is no longer appropriate to respond to this ever-growing uncertainty and complexity of urban water systems (Mukheibir & Mitchell, 2014; Nieuwenhuis et al., 2021; Wallington et al., 2012). The credibility of an expert-led deterministic approach to urban water management that relies on rainfall prediction based on around 110 years or so of historical data has been questioned in light of various unexpected events (more detail can be found in section 3.1 and throughout chapter 6).

The challenges associated with ensuring safe and improving reliable water services in cities are many. On the one hand, there are challenges that relate to the 'socio-physical' and governance dimensions of water systems. The term 'socio-physical' refers to the aging of current infrastructure (Bichai et al., 2018), which leads to the need for further refurbishing investment (Mukheibir & Currie, 2016); and growth in demand caused by population growth and rapid urbanisation (Koop & van Leeuwen, 2017). As one of the main future stressors, rapid urbanisation, population growth and industrialisation intensify the impacts of global warming on urban water systems. Besides the associated growth in water demand, the expansion of urban areas and increased industrialisation negatively impacts the quantity and quality of water resources due to the alteration and destruction of existing habitats (UNEP 2007). The governance dimension emphasises the dominance of top-down approaches to urban water management where government agencies, who rely on the expertise and knowledge of engineers, are the ones who make all decisions (Keath & Brown, 2008), as illustrated in Australia, where resources are still being invested in technical solutions such as upsizing, upgrading or building new infrastructure. Less attention is paid to soft measures such as demand management, diversification of water sources or fit-for-purpose water reuse and recycling (Mukheibir & Currie 2016). Also, the entrenched risk-averse culture associated with this governance approach is associated with resistance to new ways of responding and adapting to complex, unpredictable problems (Marsalek, Rochfort & Savic 2001; Wong, 2006). Moreover, the lack of mechanisms for public participation in the decision-making process is hampering the ability to gain more knowledge, benefit from local experience and creative ideas, and make use of opportunities for resolving conflicts.

On the other hand, the pressure is amplified further by the impacts of climate change. Climate change and climate variability are global problems that have led to the uneven distribution of seasonal precipitation throughout the year, which in urban contexts is associated with more intense and more frequent floods, storm surges, and prolonged droughts (Keath & Brown 2008; (Mukheibir et al., 2013); (Trenberth et al., 2014). These effects are particularly severe in Australia, which is the driest populated continent on earth. Metropolitan areas such as Sydney and Melbourne rely on surface water from rainfall; thus, changing precipitation patterns has led to the depletion of resources (Burn et al., 2012). Cities in the south-east of the continent have experienced the Millennium Drought and severe heatwaves, during which the existing infrastructure could not provide security of water and ensure cool and green cities (Cai et al., 2014; Grant et al., 2013; Loughnan et al., 2013). Protracted drought is not the only concern, however, since current drainage systems cannot keep up with the intense rainfall, leading to severe flash flooding. Recent examples have occurred in Melbourne (2011), Queensland (December 2010-January 2011; 2017), New South Wales (2015), and most recently, across the eastern seaboard in 2022. Also, climate change impacts water quantity and quality due to changes in sediment loads, evaporation rates and salinity (IPCC 2014), resulting in public health issues (Delpla et al., 2009). Additionally, population growth and migration in metropolitan areas make cities more vulnerable to the aforementioned extreme events.

1.1.2 A research direction focused by emerging issues

In response to the growing complexity and uncertainty of the abovementioned issues, the traditional management paradigms have been found to be incapable in adequately dealing with these problems. There is now a common awareness and increasing interest among researchers and practitioners' in the need for new approaches to making management and investment decisions (Halbe et al., 2013; Mitchell, 2006; Mukheibir, Howe, et al., 2014; Pahl-Wostl, 2007a).

It is a common view that for both basin-scale and urban water systems to implement sustainable solutions, the governance and management factors have just as much influence as the technical aspects on the emerging issues. Given the rapid technological advancement in the past decades, it is suggested from the literature that more attention should be invested in the management dimensions consisting of governance and institutional factors (Cosgrove & Loucks, 2015; Pahl-Wostl et al., 2006). Among others, the governance and institutional setting that is hindering the uptake of water recycling in NSW might be a typical example. Wastewater treatment technology has been developed and well-established in Australia; however, the current governance and regulatory framework have not been successful in making the benefits of recycled water schemes (RWS) realised. There are multi-facets to the problem, such as risk-averse regulators pushing the limit to overtreat wastewater for public safety, which drove up the cost of RWS significantly (Mukheibir & Mitchell, 2018). Moreover, the way the regulatory framework was set up to measure the cost and benefits of RWS does not reflect the social and environmental benefits nor the readiness for future trends and shocks, to name a few (Frontier Economics, 2018). Thus, RWS might be perceived as a less attractive option financially and sustainably.

A review of the literature revealed a consistent trend towards recommending two main paradigms. One is the transition to an *integrated and participatory approach* at the basin scale (see (J. Allan, 2005; 1994; Gleick, 2000; Pinkham, 1999)), and in the urban context (see (Burn et al., 2012; Ferguson, Brown, Frantzeskaki, et al., 2013;

Maheepala et al., 2010; Makropoulos et al., 2008; Mitchell, 2006; Sharma et al., 2010; US Water Alliance, 2017; Wong & Brown, 2009). The other is the shift to an a*daptive, integrated and participatory approach* at the basin scale (see US National Research Council 2004; NeWater project from 2005 – 2009 (various publications), and in the urban setting (see SWITCH project from 2006 – 2011 (various publications); (Bettini et al., 2015; Farrelly & Brown, 2011; Mukheibir, Boyle, et al., 2014). Overall, the implication is that Sustainable Urban Water Management as a goal and a process itself needs to consider all Adaptive Management, Integrated Urban Water Management as well as Participatory approach dimensions to deal with the complexity and uncertainty faced successfully.

In the current Australian urban water context, it is evident that despite the significant improvements offered by the "new" paradigm in theory (Farrelly & Brown, 2011; Mukheibir & Mitchell, 2011, 2014; Wong & Brown, 2009), the top-down mode of management remains more or less the same (Marlow et al., 2013; Roy et al., 2008). Moreover, efforts to transition to "integrated" systems focus mostly on developing sustainable technologies for decentralised and distributed options for greywater and stormwater recycling (Furlong et al., 2015). The practice of *engaging stakeholders and the wider public* in planning and management has been discussed, and implementation can be found in several documents. However, it has seldom been implemented in a systematic manner that allows follow-up engagement in the later phases. Moreover, the consideration of *uncertainty* is still being neglected. This trend is unsatisfactory because the issues associated with urban water are primarily related to the governance factors mentioned above (and as further outlined in sections 3.1 and 3.2). It should also be noted that the challenges that prevent the theory from being put into practice are closely related to Governance and political considerations rather than technical issues. Efforts to identify and analyse the institutional, political and social factors that act as barriers to implementing new approaches have already been undertaken in the urban water management domain (Bichai & Smeets, 2013; R. Brown & Farrelly, 2009; Mukheibir, Howe, et al., 2014; Werbeloff & Brown, 2011).

Considering all the challenges the water system must face and the issues when introducing approaches in combination, my research seeks to assist and inform the Australian water sector about the transformation toward a novel sustainable approach. The approach proposes incorporating the principles of Adaptive Management (AM), Integrated Urban Water Management Frameworks (IUWM), and a Public Participatory (PP) approach. To that end, the challenges and issues that might arise along the transformational journey will be investigated, especially in the context of growing complexity and uncertainty.

Moreover, my research aims to examine the challenges and issues of complexity and uncertainty in metropolitan areas on the South-Eastern Australian seaboard. The 2017-2020 unexpectedly extreme heat and dryness that led up to the worst bushfire on NSW State record challenged the readiness and resilience of the urban water system in many places along the South-Eastern coast. It showed that our capacity to predict future climate conditions was limited and deep uncertainty (the unknown unknown) is likely to increase over time. Analysis of paleoclimate records suggested that there might be a far worse drought in the future (Ho et al., 2015). The study can potentially improve planning and management practices in the context of growing complexity and uncertainty, especially climate change-related ones, since the recent severe drought threatened the water security and resilience of the urban water system. To that end, the research sets out to achieve these outcomes:

- The empirical analysis of the current urban water planning and management landscape in major cities along the South-Eastern seaboard (see sections 3.1 and 3.2).
- An analysis of emerging issues for urban water planning and management due to complexity and uncertainty in adopting the three approaches together through the lens of the Cynefin framework (see sections 6.2 and 6.3)
- Providing analysis of and discussions on potential future solutions to deal with complex issues in urban water planning and management by conducting empirical exploration through different perspectives (see chapter 7).

- Showcasing different uses of the Cynefin framework in guiding and facilitating an empirical exploration of both a set of issues in a study area (sections 6.2 and 6.3) and future methods/tool for its analysis and planning (section 7.8).

1.1.3 Overall aim of the research

The overall aim and more specific objectives had first been derived from the gaps found in the literature and were later adjusted and adapted based on the initial research outcomes.

The initial literature review in Chapter 2 will highlight the need to merge the three approaches (AM, IUWM and PP) so that the strategies are flexible and robust enough to cope with unpredictable climate patterns, surprises from population growth rates, and the uncertain dynamics of socio-economic, socio-political, and socio-institutional aspects of urban water systems. However, it will be demonstrated that there is no framework explicitly combines these approaches. Moreover, the lack of evidence showing the extent to which those approaches might be combined illustrates the gap in practical analysis. Furthermore, while the analysis of challenges from adopting the individual approach and, in some cases, challenges that arise from pairing approaches are documented, the analysis of root causes for the complexity that arises when delivering these frameworks in combination has *not been analysed* in the published literature to date.

My research does not aim to solve all the issues mentioned above but instead, to investigate and acknowledge that the way we currently manage our water in the city is no longer appropriate for the challenge of responding to the ever-growing uncertainty associated with the complex urban water system. Then, based on collective knowledge, an examination of planning and management methods and tools, which have the potential to improve urban water system resilience, will be carried out.

The thesis offers integrated and contextualised knowledge to support the transition of the current urban water planning and management paradigm in the study area into an emerging sustainable one. To that end, the research provides insight into the challenges and issues that the urban water sector in metropolitan areas along the South-Eastern Australian seaboard must face when adopting the three approaches within their unique contexts. Further, the thesis also provides an improved understanding of the tools and methods potentially valuable for supporting decision-making in complex situations under uncertainty. The research is carried out in an exploratory manner to understand how professionals in the sector perceived the combined approach and the issues associated with them. In doing so, it distils from their wealth of past experiences. Therefore, the findings provide professional communities, water utilities, policymakers, and academics with a new and holistic perspective on the existing problems and the methods to potentially overcome those to maintain reliable water services under deep uncertainty. An in-depth introduction to the methodological approach used in this research is presented in section 4.1.

1.2 Research questions and methodology

1.2.1 Introducing research questions

The overall aim can be summed up in an overarching research question: *How can urban water service planning and management simultaneously incorporate adaptive, integrated, and participatory approaches when dealing with complexity in the Australian context?*

In order to achieve that aim, the study was designed to investigate four sub-questions in an exploratory manner by adopting a nested case study together with a grounded theory approaches to utilise literature review, document analysis and semi-structured interviews as a qualitative data collection technique.

As mentioned above, even though the three approaches, which are the focus of this study, were frequently cited in the literature as being most effective in combination, the lack of empirical evidence led to the formulation of the first research questions:

To what extent are there examples in which all the three approaches have been combined?

Seeking Illustrative cases that exhibit elements of the three approaches to a certain extent is the critical component of the question. While examples of the combined approach on the ground are limited, there are traces of it emerging in metropolitan areas of the South-Eastern seaboard of Australia. Such cases, for the most part, appeared in documents without having the implementation process documented yet, or with incomplete reporting of the actual practice. The recent 2021 Lower Hunter Water Plan (NSW DPIE, 2021b) is an excellent example of how the combination of three approaches manifests within the planning framework but is yet to be implemented.

In response to the lack of any analysis that explicitly investigates the three approaches together, research question 2 proposes:

What tensions and broader challenges are evident when planning water services using the three approaches?

This question addresses the second gap by explicitly examining the *empirical evidence* of the tensions and broader challenges. With that objective in mind, the data collection process is designed to elicit participants' practical experience and insights from urban water planning and management practitioners. During the attempt to answer this question, findings from document analysis, data collection and analysis indicated that the current practices have been struggling to deal with the complexity and uncertainty that would accompany the adoption of sustainable practices (within the frameworks of IUWM, PP, and AM). Layers of cascading issues in the current planning context contribute to the complexity that participants indicated was, at times, challenging to comprehend. As the findings presented in this thesis confirm, decision-making might resort to 'secure' options that hold more certainty, such as business-as-usual or infrastructural solutions.

The notion led to the change in research focus, resulting in the reframing of research question 3. Initially, research question 3 would have focused solely on investigating and constructing solutions from the participants' collective knowledge to respond to challenges and issues identified and analysed previously (research question 2). However, the high level of complexity and uncertainty associated with the issues in enacting new/innovative practices initiate another research trajectory of pursuing more fundamental problems related to that 'complexity' and 'uncertainty'. Hence, research question 3 asks:

What are the underlining causes of the tensions and challenges?

A new lens of complexity theory is adopted to further explore the complexity and uncertainty that were referred to in question 2. In this case, the research method employed was the Cynefin framework (CF), a sense-making tool that utilises the concepts and principles of its domains to describe events and the associated contexts. To be more specific, the research uses CF's four domains (namely simple, complicated, complex, and chaotic) as a guide and a theoretical standpoint to reflect on the literature review and structure the data collection and analysis of this stage. The study also shifts to focus on Sydney metropolitan area due to several reasons that can be found in detail in section 4.1.2. The findings comprise an analysis of and discussions on the urban water planning response through the CF lens and six key topics of the root causes and emerging issues.

Further, CF is used to make sense of the emerging issues due to complexity and uncertainty and provide a structure for the participants to reflect on their experience and opinions about the tools and methods that could be capable of dealing with future complex problems. For that reason, research question 4 is formed as follows.

Are the current available tools appropriate for dealing with complex problems?

In response to the interviewees revealing challenges associated with complexity and uncertainty in combining the three approaches in their contexts, the research utilised CF to foster discussions with the interviewees on the possible solutions to deal with emerging complex problems. The discussions focused on the available tools and methods for urban water planning and management that could help solve issues in the different operating contexts of CF, and that could facilitate or accommodate combining the three approaches. To that end, potential tools/methods proposed by the interviewees are critically reviewed, analysed, and discussed in this thesis from different perspectives to uncover their efficacy.

1.2.2 Research methodology and plan

An embedded exploratory case study approach with grounded theory analysis methods was used to guide this qualitative research process. The methodology can be described as analysing multiple units within a case where the participants' perspectives are extracted and analysed in-depth to understand its contexts. Urban water management practices in South Eastern Australia seaboard metropolitan areas were considered as the high-level case study, emphasising metropolitan areas in Queensland, New South Wales, and Victoria.

Initially, to answer the proposed questions, the research had been designed in three consecutive steps/stages with associated data collecting and analysing methods/techniques: semi-structured interview, literature review and document analysis, deliberative workshops, and coding of qualitative data (see figure 1.1). However, due to the impact of COVID-19 and the changes in research focus, adjustments have been made regarding the methods used to collect data.

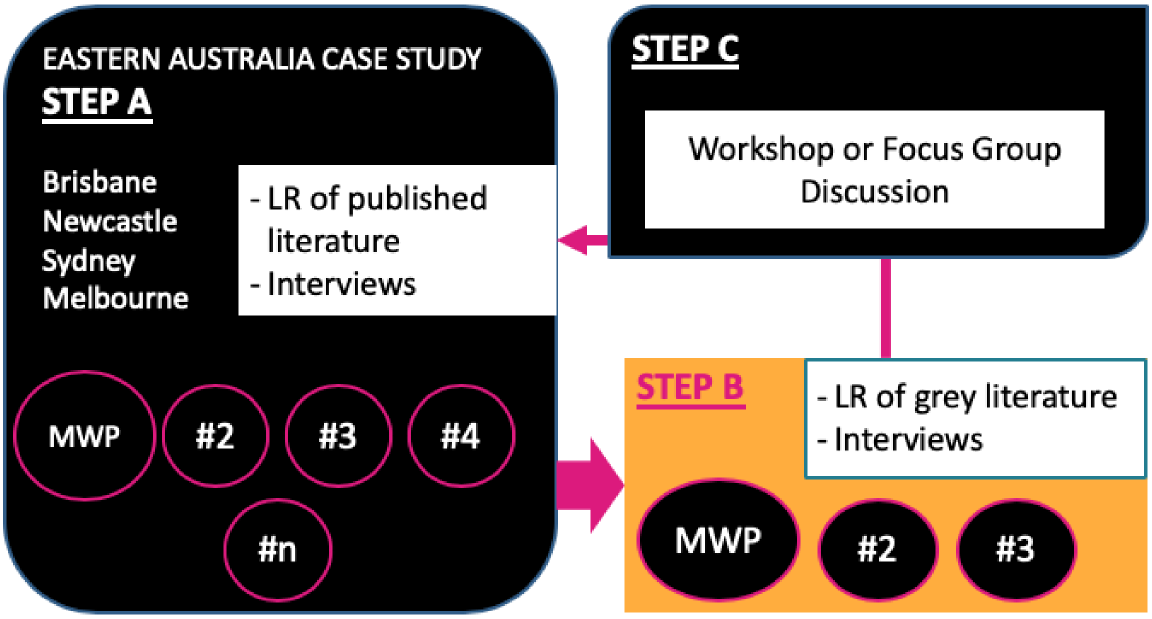


Figure 1. 1: The Proposed data collection process

In the beginning, step A was to elicit perspectives and knowledge from urban water professionals on the extent to which the three approaches combine in practice and to identify specific sub-case studies in major cities. Literature review analysis and semi-structured interviews were chosen to collect qualitative data. After analysing data and screening the case studies, analysis of grey literature and in-depth semi-structured interviews were employed in step B to investigate the emerging tensions/challenges qualitatively. Finally, a deliberative workshop or focus group facilitated by the Cynefin framework was proposed as the primary method to explore options and to 'socially construct' potential strategies to address those identified issues.

Nevertheless, the social distancing policies and multiple multi-month lockdown periods issued by the Australian Government in response to the COVID-19 pandemic presented significant challenges to data collection. Physical contact was forbidden at the point when invitations to the deliberative workshop (step C) had already been sent out to professionals across the urban water industry. Thus, given the limitation of time and resources available for the PhD project, it was necessary to find alternative methods for step C. As a result, the research was delayed while seeking online platforms as a substitute means of communication for the workshop. However, there were many technical difficulties and uncertainty with regard to available online conferencing software such as Zoom and Teams since it was at the beginning of the lockdown, and they had not been widely used and well-understood at the time. Hence, the researcher decided to move forward with online semi-structured interviews as the primary data collection method due to its ability to sustain in-depth discussions and the logistical conveniences in coordinating interviewees.

Finally, after incorporating the changes in research focus and impacts of COVID-19, the data collection process essentially includes two rounds of semi-structured interviews to gather qualitative data on the perspectives of urban water professionals in the study areas. The first round consists of eleven semi-structured interviews with senior urban water professionals working in Metropolitan areas on the South East Australian seaboard (outlined further in section 4.2.2). The first round aimed to extract participants' knowledge and hands-on experience on the extent to which the three approaches of interest have been employed in practice, and then explore the challenges around those combining processes. In the second round, five in-depth semi-structured interviews were conducted with experts working in the urban water sector in Sydney to explore the root causes for the incomprehensible complexity and uncertainty (based on findings from the first round). Furthermore, this round also seeks potential tools and methods to address those issues.

1.3 Thesis structure

The thesis is organised into eight chapters:

The first chapter introduced the general motivation and context for the research, defined the research problem, clarified the aim, explained the objectives and research questions, described how the research design can address the problem and how COVID-19 affects the research progress presented the contribution of this research project.

In Chapter 2, an overview of the three focused approaches (Adaptive management, Integrated Urban Water Management, and Public participation) and their applications are introduced and critiqued. The outcomes from the high-level literature review form basis and overall context for the more focused review in the next chapter.

In chapter 3, the applications of the three approaches and their shortcomings in urban settings, especially in Australia, are critically analysed. The current and future trends of urban water planning and management practices are also discussed. The outcomes from this chapter contribute partly to the answer to research question 1.

Chapter 4 introduces the methodological design, tools, and techniques for answering the research questions. As adopting an exploratory research approach, this chapter describes how the research activities progress and evolve in response to the findings in the previous step. Moreover, this chapter provides the rationale behind the selection of nested case study methodology, metropolitan areas in the South-Eastern Australian seaboard as the study area, the changes in research focus, research questions and data collection methods, and the data analysis techniques.

In chapter 5, participants' perceptions of the three approaches, the different framings for data analysis, and the themes of challenges in employing and implementing the combined approach are presented and discussed. The findings found in this chapter helped to address research questions 1 and 2.

Chapter 6 marks a shift in the study regarding both research focus and research methods. This chapter describes how the lens of complexity theory, the Cynefin framework, is introduced to guide the semi-structured interviews and data analysis to unpack issues related to complexity and uncertainty. Findings from this chapter include an overall image of urban water planning and management context to date, analysis based on features of different domains in CF and the list of six emerging issues/root causes of complexity. Chapter 6 provides the answer to research question 3.

In chapter 7, possible solutions for future complex issues are discussed from different perspectives. Based on literature reviews, documents analysis, and interviewees' opinions on how the tools measure up against the identified issues from chapters 5 and 6 in different levels of complexity (via the lenses of the Cynefin framework) and through the perspective of a combined approach (IUWM, AM and PP). The outcome of the critical analysis provides synthesis discussions on potential tools that cover research question 4.

Chapter 8 summarises all the findings and explains how they answer the research questions. Further, discussions and recommendations on the proposed way forward for the urban water sector are articulated in response to the overall research question.

2 Chapter 2 – literature on IUWM, AM and PP approaches

2.1 Introduction

Commentators have explicitly and implicitly called for a combined approach between integrated, adaptive, and participatory planning approaches to address the growing complexity and uncertainty currently found in the urban water sector (Bichai & Flamini, 2018; Mukheibir, Howe, et al., 2015). Water resources management literature at the river basin scale has partially examined this new sustainable urban water management paradigm. However, there is no clear consensus on the definition, the research scope or the implementation agendas in the urban context. The author considers that it is helpful to first gain insights on the three approaches individually in different contexts (different cities and types of projects) to understand how they could potentially work in conjunction. Further, this information can inform the interpretation of the adaptive management approach since it has not yet been extensively developed in urban water sector and, ultimately, the combined approach in this study's chosen context. The synthesised knowledge and information on the three approaches are helpful for both the data collection process and the formulation of the research outcomes.

To accommodate multiple environmental, social and economic objectives, the Integrated Urban Water Management (IUWM) approach was formulated to simultaneously coordinate water supply, wastewater, and stormwater management with the consideration of energy, land use, and urban planning. The approach has been applied with varying degrees of success in range of contexts in Australia, which will be explored further in section 2.2.

Community engagement, which is a manifestation of the public participation (PP), has been attracting more and more attention in recent years. A participatory approach calls for the inclusion of useful perspectives and values of stakeholders, the public, individuals, and organisations in the decision-making process to improve decisions and policies. There are several ways to investigate the level of engagement and how that would affect the outcomes. Some consider one-way communication as passive consultation and two-way communication as active engagement. Others took a step further and unpacked different levels of involvement by considering the impacts of participants' perspectives and values on the decision ((figure 2.8 from (IAP2, 2014)) or reinvented the 'wheel' by considering the directions of information flows within different contexts ((figure 2.9 from (Reed et al., 2017)). Overall, the aspiration is to use those tools to develop management strategies with the right level and timing of community engagement.

Adaptive management (AM) has been developed for nearly four decades based on the doctrine that the understanding of the system to support decision-making can be constantly improved via learning through iterative monitoring, evaluating, and adapting (Pahl-Wostl, 2007b; Walters, 2007; Williams & Brown, 2014). Hence, the system would be more resilient to unexpected events. AM approach has been the primary tool to address environmental management and ecological conservation uncertainties. However, as uncertainty and complexity keep growing, the literature showed that AM approach has recently gained popularity in urban water planning and management (as outlined in section 3.2.3).

The overall approach to literature review

The study employed a snowball approach to develop the literature review process and explore potential gaps.

The documents were searched firstly in scientific databases (Web of Science, Scopus, and Google Scholar) for the application of an integrated approach at the basin scale, as well as in the urban context, and the challenges and issues associated with the implementation process. Therefore, some of the initial search terms included IUWM, IWRM, sustainable water resources management, sustainable urban water management, integrated/sustainable/ decentralised/natural solutions or interventions, integrated decision support system/decision-making process, lessons/issues with implementing IWRM/IUWM, Governance/institutional arrangement for IUWM, etc.

Then, the review showed the trend of combining approaches; thus, the process broadened to tracking citations from those documents and exploring other concepts such as adaptive management, participatory approach, WSUD, etc.

This thesis argues that there is a need to combine the three approaches to increase urban water resilience in the face of complexity and uncertainty (see Figure 2.1). Hence, this chapter aims to investigate the definitions, rationales, and methods of IUWM, AM and PP and gauge their practical effectiveness. The research approach in the thesis uses qualitative data obtained through a literature review and targeted interviews with this chapter together with Chapter three being the key literature review chapters.

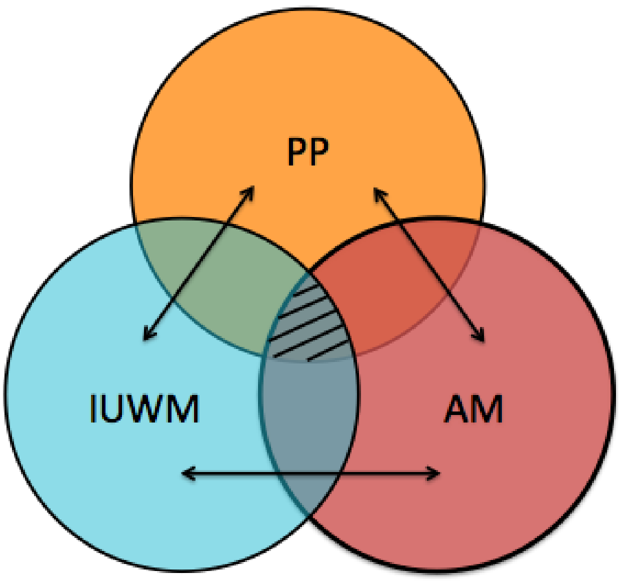


Figure 2. 1: Illustration of the approach which underpins this study

2.2 Integrated urban water management

2.2.1 What is IUWM?

Integrated Urban Water Management (IUWM) has been explored and adopted by both the research community and authorities. Thus, the author believes that understanding its origin, the associated concepts, the motivations and what the approach entails is essential. This section provides an overview of IUWM and its applications in both international and Australian contexts.

IUWM is reported to have originated from the Urban Water Resources Research Council of the American Society of Civil Engineering in the early 1970s. This Council advocated the application of the concept of a water balance to urban water issues and highlighted the need for a more holistic and integrated approach to operating water supply, sanitation and drainage systems (Geldof, 1995; Grigg, 1999; Mitchell, 2006). Throughout the literature, a number of terms can be found which are similar to IUWM, including *integrated water cycle planning and management* (Coombes & Kuczera, 2002; Department of the Environment, 2015), *integrated urban water resources management* (Bahri, 2012; Maheepala et al., 2010), and *Total Water Management* (Jeffcoat et al., 2009). The term is now closely linked with *water sensitive urban design and water sensitive cities* (Fletcher et al., 2015; Wong, 2006; Wong & Brown, 2009).

IUWM means different things to different people. Disciplinary background and experience are the main determinants of how they observe the associated issues, and this leads to the differences in their initial framing (Pahl-Wostl et al., 2011). For example, to reduce water demand, engineers might pay more attention to available technologies than they would to understand the values and perspectives of the stakeholders. However, the essential elements of IUWM remain intact as a management paradigm for managing all urban streams, including water supply, stormwater and wastewater, together with the consideration of the interdependencies between these components with other sectors such as energy, land-use planning, urban planning. IUWM places the planning and management of urban water within basin-wide water plans (Burn et al., 2012; Makropoulos et al., 2008; Mukheibir, Howe, et al., 2014). Its aims are to: minimise impacts on the environment via explicit consideration of liveability and ecosystem protection (Ferguson, Brown, Frantzeskaki, et al., 2013; Mitchell, 2006), maximise the contribution to economic development (Global Water Partnership 2012; Burn et al. 2012), and enhance social wellbeing, equity and the participation of stakeholders and the wider public (Fletcher et al., 2015; Maheepala et al., 2010). IUWM incorporates existing water supply and sanitation management within an urban water management framework and considers the whole water cycle within the scope of the river basin.

It is believed that the fundamental elements of IUWM were inherited from the broader concept called Integrated Water Resources Management (IWRM) (Fletcher et al., 2015; Maheepala et al., 2010). While originating from the analytical work of the Harvard Water Program and others in the 1960s (Lenton & Muller, 2009), IWRM was most comprehensively described in Agenda 21 of the Earth Summit, informed by the four Dublin Principles which were compiled at the Summit preparatory conferences for UNCED in 1992 (Savenije & van der Zaag, 2008). Despite being on the global research agenda for a long time, the definition of IWRM has never been unambiguous (Jeffrey & Gearey, 2006). The most frequently quoted definition of IWRM is the one outlined by the Global Water Partnership (GWP): 'a process which promotes the co-ordinated 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' ((Global Water Partnership (GWP) & International Network of Basin Organization, 2009).

The critical differences between IUWM and IWRM lie in their spatial scopes and their sectors of application. IWRM focuses on all parts of the water cycle within a river basin which might include multiple urban areas, as well as hydroelectric and agriculture sectors. IUWM only deals with the management of water supply, wastewater, and stormwater systems in urban settings. Thus, IUWM can be considered to be a sub-set of the IWRM process (Maheepala et al. 2010). This approach also emerged from the notion that water is an integral part of the ecosystem, a natural resource, and a social and economic good (United Nation 1992). Thus, within the spatial scope of the urban unit, the IUWM framework considers all the interrelations internally and across urban water systems, urban designs, land-use management and other related sectors (Figure 2.2).

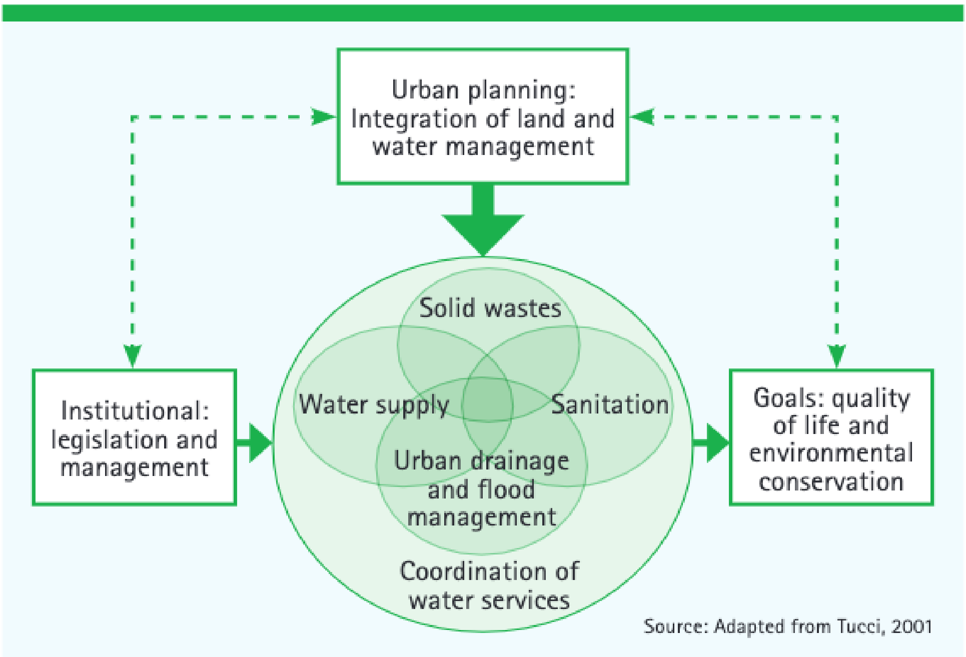


Figure 2. 2 : Illustration of IUWM components (Global Water Partnership, 2013)

2.2.2 The rationale and principles of IUWM

The ultimate aims of IUWM are 'to provide socially acceptable, economically viable and environmentally sustainable water supply, wastewater and stormwater services in urban areas by considering interdependencies between water/waste-water/stormwater, energy, urban design and the surrounding environment' (Burn, Maheepala & Sharma 2012) and 'to enable multi-functionality of urban water services to optimise the outcomes from the system' (Mitchell 2006). To that end, the key mechanism needs to be minimising the collective consequences of individual planning and management processes, and maximising collective efficiency on a practical basis (Mitchell 2006). Regarding the principles of IUWM, there is no universal standard, but those developed by Mitchell (2006) are generally followed.

From a slightly different angle, Marlow et al. (2013) suggested that IUWM and other similar concepts such as Total Water Cycle Management (Grant et al. 2010) and Water Sensitive Urban Design (Wong 2006) are the backbone of Sustainable Urban Water Management paradigm, and that all of these concepts which emphasise decentralisation are trying to develop a more ‘natural’ water cycle which increases water security via local source diversification and the efficient use of resources.

Pinkman (1999) and ICLEI (2011) (quoted in Mukheibir et al. 2014) have compared the characteristics of IUWM with the traditional approach.

Table 2. 1: Comparison of the traditional approach and integrated approach

Aspect of urban water management	***Conventional approach***	***Integrated approach***
Overall approach	Integration is by accident. Water supply, wastewater and stormwater may be managed in the same agency as a matter of historical happenstance, but physically the three systems are separated	Physical and institutional integration is by design. Linkages are made between water supply, wastewater and stormwater, as well as with other areas of urban development, through highly coordinated management.
Collaboration with stakeholders	Collaboration = public relations Other agencies and the public are approached when approval of a pre-chosen solution is required.	Collaboration = engagement Other agencies and the public search together for effective solutions.

Choice of infrastructure	Infrastructure is made of concrete, metal or plastic.	Infrastructure can also be green including soils, vegetation and other natural systems.
Management of stormwater	Stormwater is a nuisance that is moved away from urban areas as rapidly as possible.	Stormwater is a resource that can be harvested for water supply and retained to support aquifers, waterways and biodiversity.
Management of human waste	Human waste is collected, treated and disposed of to the environment.	Human waste is a resource and can be used productively for energy generation and nutrient recycling.
Management of water demand	Investment in new supply sources and infrastructure.	Other options to reduce demand, harvest rainwater and reclaim wastewater are given priority over developing new resources.
Choice of technological solutions	Complexity is neglected and standard engineering initiatives are applied to individual components of the water cycle.	Diverse solutions (technological and ecological) and new management strategies are explored that encourage coordinated decisions involving water management, urban design and landscape architecture.

2.2.3 Approaches to IUWM

In the Australian urban water sector, there are several similar noteworthy approaches including Integrated Water Cycle Management (IWCM), Total Water Cycle Management (TWCM), water sensitive urban design (WSUD), water sensitive cities (WSC) and OneWater. While sharing major similarities, these frameworks have different interpretations and have been applied at various scales as they have been developed by different organisations.

Integrated Water Cycle Management (IWCM) and Total Water Cycle Management (TWCM)

The main idea of IWCM and TWCM is very similar to that of IUWM, but the initial scale of consideration is larger. These frameworks focus on increasing the effectiveness of surface and groundwater in the integration of water supplies for different urban uses and also for irrigation; control of stormwater; diversification of water sources via wastewater recycling, greywater reuse and reclamation, fit-for-purpose water use; sustaining ecosystem services through environmental flow (Grant et al., 2013; Radcliffe, 2004)

These frameworks have been adopted by many organisations in Australia at various spatial scales. In 2004, the New South Wales (NSW) Department of Primary Industries (DPI) adopted IWCM as the overall approach to creating a nested long-term (30-year) management strategy and financial plan at the regional scale (New South Wales region) (NSW Office of Water, 2014b). During the same period, the Total Water Cycle Management framework has been employed by the Queensland Government for its South-East Queensland Regional Plan (Queensland DIP, 2009). These two frameworks can also be applied at the precinct scale (e.g. the Elizabeth Street Catchment (City of Melbourne, 2015) and Moreton Bay (Grant et al. 2013) and at the city scale (e.g. Melbourne (City West Water, 2016) and Brisbane (Brisbane City Council, 2013).

In addition to the difference in the scope compared to IUWM, the impacts of governance structures and institutional arrangements are not explicitly included in these frameworks.

Water Sensitive Urban Design (WSUD) and Water Sensitive Cities (WSC)

Water Sensitive Urban design (WSUD)

The definition of WSUD appears to be ambiguous, but a widely accepted definition used in an inter-government agreement on national water initiatives is: 'the integration of urban planning with the management, protection and conservation of the urban water cycle, that ensures urban water management is sensitive to natural hydrological and ecological processes' (National Water Commission, 2011). Basically, the urban design component refers to the planning and architectural design of urban environments, and the water sensitive component refers to the integrated management of urban water cycles (Ashley et al., 2013). Although the concept has been broadened to refer to the integration of urban design and planning into the whole urban water cycle in its widest interpretation (Lloyd, 2001; Wong, 2006), WSUD was originally considered to be a decentralised stormwater management tool which offered technologies and approaches to retain water in the urban landscape via: stormwater harvesting; fit-for-purpose reuses; and infiltration into the soil to achieve ecological, social and financial objectives (Coutts et al., 2013; Lloyd, 2001; Roy et al., 2008). The approach had been adopted and incorporated into stormwater planning and management in Western Australia (Whelans et al. 1994), Victoria (Victoria Stormwater Committee 1999) and Queensland (Brisbane City Council 1999).

Click or tap here to enter text.It is noteworthy that there are similar initiatives launched elsewhere , such as Low Impact Development (LID) in North America (USA and Canada) and New Zealand, as sustainable urban drainage systems (SUDS) or sustainable drainage systems (SUDS) in the UK (Morrison et al. 2010).

In general, LID focuses on ensuring stormwater quality, minimising the cost of stormwater management and the impacts of interventions on the surrounding environment. To that end, the approach utilises the site layout and integrated control interventions to create a 'functionally equivalent hydrologic landscape' to retain the pre-development hydrologic conditions (runoffs, infiltration, and evapotranspiration volumes) (US Environmental Protection Agency, 2000). To a certain extent, LID and WSUD share the same focus on the decentralised strategy as opposed to large-scale end-of-pipe retention systems that were common stormwater management practices in the 1990s. LID is primarily characterised by small-scale stormwater treatment systems such as bio-retention systems (pits, swales, basins or rain gardens) and green roofs that are placed close to the source of runoff (Fletcher et al., 2015). It could be argued that the subtle difference between WSUD and LID lies in the scope of their application. While WSUD considers the whole water cycle involving water supply and wastewater management, LID focuses on a small local scale with site-specific implementations.

The term SUDS was first coined by Jim Conlin of Scottish Water to describe stormwater technology in 1997; after that, a range of guidance documents, manuals, and authoritative guides was published from 2000 – 2007 in the UK. In practice, SUDS comprises a range of drainage technologies and techniques to manage stormwater (and surface water) runoff which are considered more sustainable than conventional structural solutions. SUDS was built on the concept of a sustainable drainage triangle (quantity, quality, and habitat/amenity) and follows a similar philosophy as LID, which emphasises minimal impacts on the environment(Fletcher et al., 2015).

Water sensitive cities

While WSUD is recognised as the process of moving toward sustainable urban water management, WSC is the term used to describe the 'end-game' – the arrival of this process (Brown & Farrelly 2009; (Marlow et al., 2013). Brown and Farrelly (2009) stated that WSC provided a clear goal for all attributes of a sustainable water city, and that the framework is a conceptual tool for city-scale benchmarking. The framework is characterised by a nested continuum of six transition states, in which the 'hydro social contract' of each phase influences and shapes the next one. The 'hydro social contract' is seen as involving the integration of normative values of environmental repair and protection, supply security, flood control, public health, amenity, liveability and economic sustainability, amongst others (R. Brown & Farrelly, 2007)

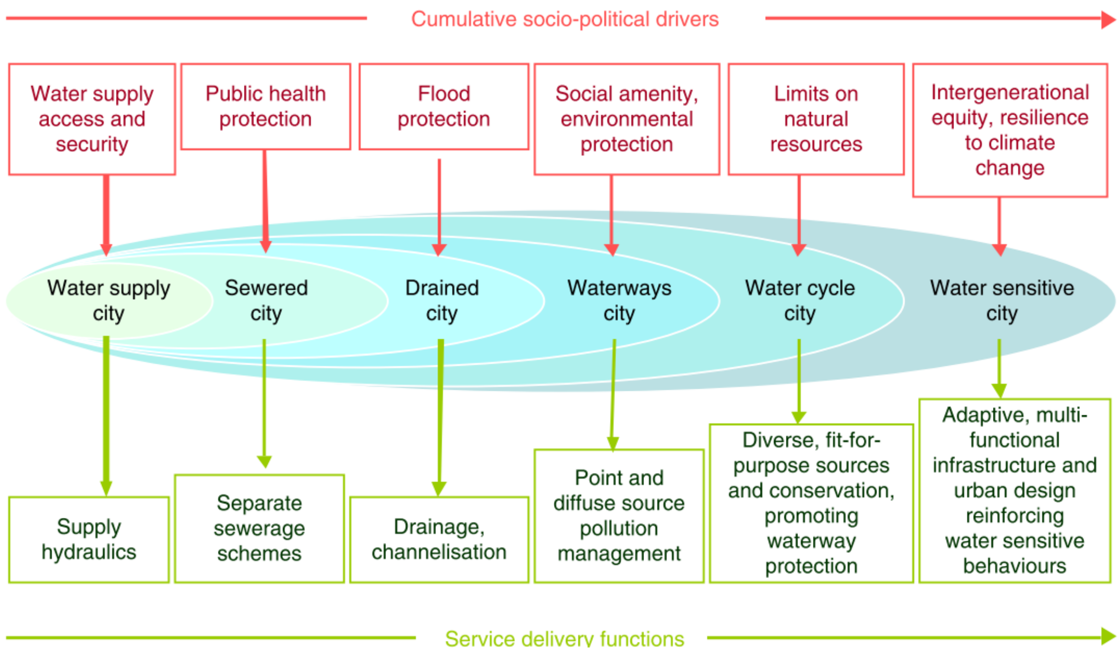


Figure 2. 3: Nested framework of the development of urban water overtime (Brown & Wong 2009)

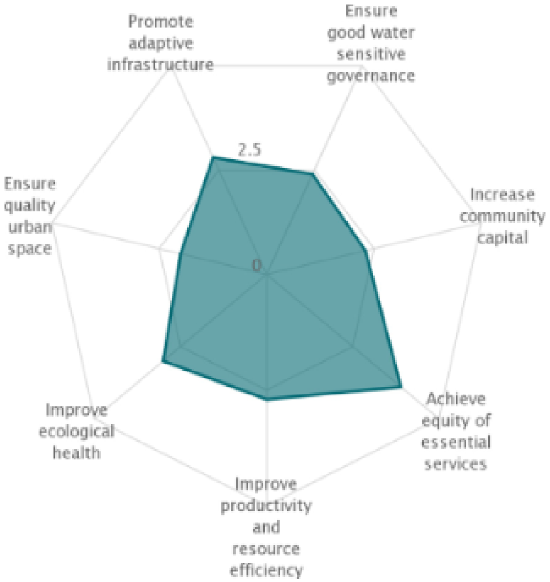
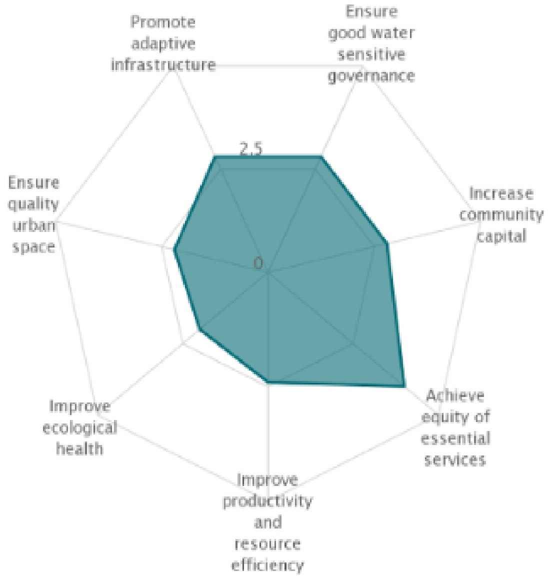
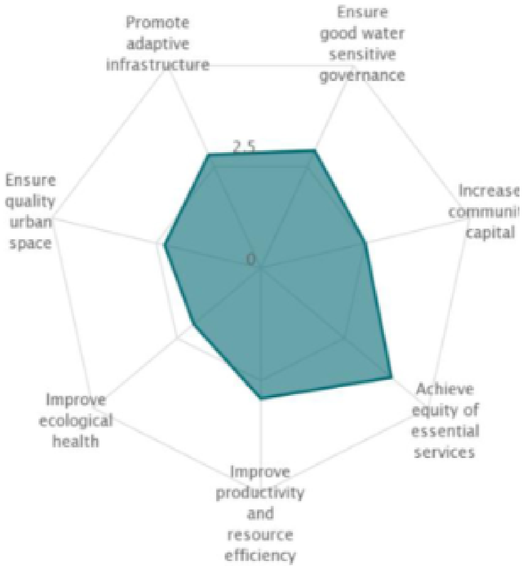
To date, the application of the framework peaked at the development of the WSC index – a qualitative tool for evaluation, which aims to 'provide a communication tool for describing key attributes of a water sensitive city; articulate a shared set of goals of a water sensitive city; provide benchmarking for a city's water-sensitive performance; measure the progress and direction of progress towards achieving water sensitive city goals; assist decision-makers prioritise actions, define responsibility and foster accountability for water-related practices' (Lloyd et al., 2016, p. 3). The water sensitive cities goals and their associated indicators are shown in Figure 2.3.

Ensure good water sensitive governance	Increase community capital	Achieve equity of essential services	Improve productivity and resource efficiency	Promote adaptive infrastructure	Improve ecological health	Ensure quality urban space
Knowledge, skills and organisational capacity	Water literacy	Equitable access to safe and secure water supply	Maximised resource recovery	Diversify self-sufficient fit-for-purpose water supply	Healthy and biodiverse habitat	Activating connected urban green and blue space
Water is key element in city planning and design	Connection with water	Equitable access to safe and reliable sanitation	Low GHG emission in water sector	Multi-functional water infrastructure	Surface water quality and flows	Urban elements functioning to mitigate heat impacts
Sound institutional arrangements and processes	Shared ownership, management and responsibility of water assets	Equitable access to flood protection	Water-related business opportunities	Integration and intelligent control	Groundwater quality and replenishment	Vegetation coverage
Public engagement, participation and transparency	Community preparedness and response to extreme events	Equitable and affordable access to amenity values of water-related assets	Low end-user potable water demand	Robust infrastructure	Protect existing areas of high ecological value	
Leadership, long-term vision and commitment	Indigenous involvement in water planning		Benefits across other sectors because of water-related services	Infrastructure and ownership at multiple scales		
Water resourcing and funding to deliver broad societal value				Adequate maintenance		
Equitable representation of perspectives						

Figure 2. 4: List of Water Sensitive Cities' characteristics/goals and indicators (Lloyd, Roberts & Beck 2016, p.5)

The WSC index has been applied in various contexts (across Australia and international) to benchmark their performance against WSC goals, to gain insights into the cities' status quo, or to track their transitioning progress toward a water sensitive city (based on urban water transition framework, figure 2.3). In a recent review, Rogers and her colleagues exhibited three Australian case studies where WSC index has been applied, and how the insights obtained from those applications informed specific management strategies in different contexts. The case studies are i) Greater Sydney at metropolitan scale (NSW), ii) City of Greater Bendigo, a regional city in Victoria, and iii) Moonee Valley City Council, a municipal council in Melbourne, Victoria. Table 2.2 summarizes the three case studies' context and WSC index results.

Table 2. 2: WSC index applied in the three case studies

	Greater Sydney	City of Greater Bendigo	Moonee Valley City Council
Context	Large coastal metropolitan area inhabited by 4.7 million people, forecast to grow to 8 million by 2050 (Greater Sydney Commission, 2018)	Regional inland city inhabited by 93,000 people, forecast to grow to over 170,000 by 2050 (Department of Environment, Land, Water and Planning, 2016).	Inner city suburbs covering 43 km^2, inhabited by 124,700 people, forecast to grow to 180,000 by 2040 (Moonee Valley City Council, 2017).
WSC Index application	July 2017 as part of the validation period. Involved 50 government and non-government participants from water, planning, environment and development sectors.	October 2017 as part of the validation period. Involved 36 participants from the local council, water utility, state government department, catchment management authority, private developers, and Indigenous community representatives.	April 2016 as part of the validation period. Participants represented a diverse range of internal stakeholders as well as external stakeholders (including representation from the local council, water utilities and state government department.
Radar results			

Note: The scores in the radar diagrams range from 0 (lowest performance, centre of the radar) to 5 (highest performance, outer edge of the radar). The midpoint value of 2.5 is indicated as a grey line in the middle of the radar to show the relative performance of a city to this midpoint score across the different goals. The shaded blue areas show the overall performance of the city—the larger the shaded area the higher water sensitive performance.

In the Greater Sydney case study, the results from the benchmarking exercises have i) led to strategic recommendations for short and medium-term issues prioritisations, ii) provided a systemic understanding of the drivers, challenges, and opportunities to move toward a WSC and iii) reinforced relationships between participants via series of workshops across the city. However, as the application scale covered a large region with different administrative areas, the participants reflected that accumulated scores might not reveal the high variations in performance index between different locations at a smaller scale (sub-city, municipal or precinct).

The city of Greater Bendigo's application has i) led to the identification of prioritised indications for strategic interventions, ii) fostered an ongoing network of WSC champion, and ii) informed decision makers to put in place a mandate for establishing changes to improve the score.

In the Moonee Valley case study, the WSC index results have led to a nine-point action plan upon which initiatives to improve the score have been guided.

While it is a fine tool which cities can use to find out where they stand at a point in time, several impediments could be improved. The 'destination' or vision determined by the framework's application and stakeholder engagement might not be the future that one community might need, or there might be changes in the future that make the vision's benefits unrealisable. Also, the qualitative process of benchmarking the city depends on the people involved. Hence the outcomes, which are shaped by the perspectives of the participants, and their views might not align. Besides, one risk of having participants who are involved in the planning and management process is that they might not want to share experiences from their failures, and this might be a distorting factor. Moreover, the nested framework might lack the flexibility need`ed to integrate various plausible unpredictable scenarios, and to reflect the different characteristics of various locations within the city (some locations might be placed in different positions in the nested framework). This notion was also pointed out by Sydney participants in the case study described above. As for the recommendations which result from the benchmarking activities, it would be more helpful if the actions for change are clearly assigned to specific people or organisations.

OneWater

OneWater is another USA-based approach which includes basically every aspect of integrated urban water management and in some cases, it can be used interchangeably with IUWM or sustainable urban water management (SUWM) (Mukheibir, Howe, et al., 2015). The approach was built upon and was a timely extension of the extensive research on Integrated Water Resources Management (IWRM) and water sensitive urban design (WSUD). It promotes the shift from solving ad hoc issues in an isolated manner to an approach that stresses the additional value of water services to urban landscapes holistically (Mukheibir, Howe, et al., 2015; US Water Alliance, 2017). One working definition that is both flexible and detailed was developed by Mukheibir and Howe (2015): 'the OneWater approach considers the urban water cycle as a single integrated system, in which all urban water flows are recognized as potential resources and the interconnectedness of water supply, groundwater, stormwater and wastewater is optimized, and their combined impact on flooding, water quality, wetlands, watercourses, estuaries and coastal waters is recognized'. The key elements of the approach were pointed out in the same document.

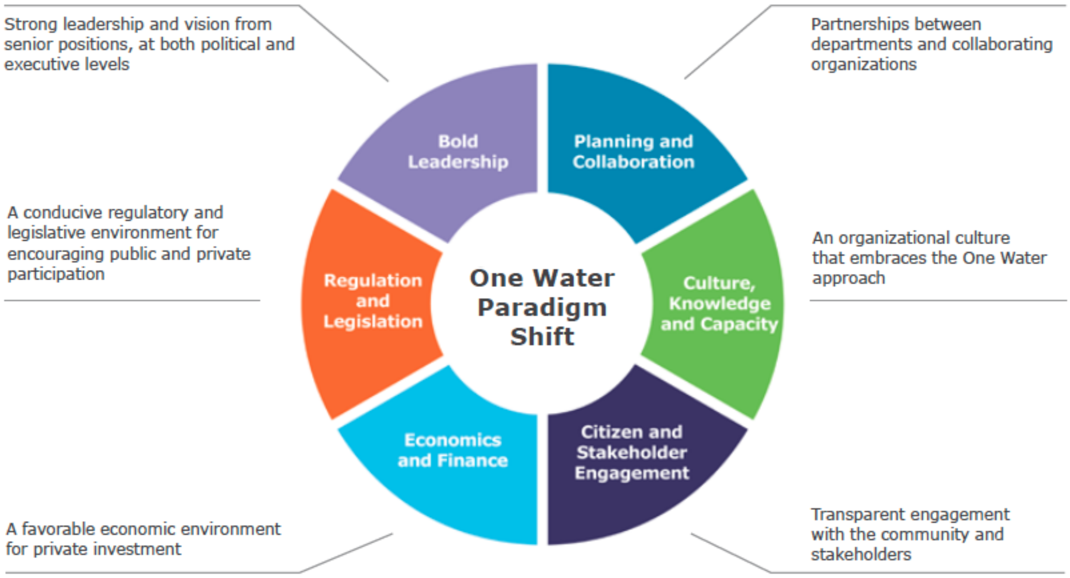


Figure 2. 5: Key elements of the OneWater paradigm (Mukheibir, Howe & Gallet 2015, p.4)

The applications of the One Water approach have been documented in various places (mainly in the USA) and for different purposes. Most notably, Mukheibir & Howe (2015) reviewed a range of case studies to emphasise how the shift toward a One Water Paradigm has been developing in six critical elements in practice (as summarised in the following table).

Table 2. 3: Examples of One water applications

Elements	Case study	Description
Bold leadership	*[Creating unified vision]* One Water for City of Los Angeles	A city-wide One Water vision helped informing the development and implementation of an integrated plan which incorporated water supply, water conservation, water recycling, runoff management and wastewater facilities planning.
	[Political leadership]	The Independent Living Victoria Ministerial Advisory Council was established in 2011 to assist Victoria

	The establishment of the Victorian state government appointed the Independent Living Victoria Ministerial Advisory Council	Government achieving its vision for Melbourne water systems as 'a smart and resilient water system that for a liveable, sustainable and productive Melbourne'. The Council provides advice on the changes needed to achieve that vision at all scales of government.
Planning and Collaboration	*[Identify the stakeholders]* Community engagement in Thorton Creek, Seattle	A group of business, community and environmental interest groups were assembled by the city to play a part in decision making process. The result shown consensus on a natural biofiltration swale which would improve creek water quality, while also promoting open space, liveability and economic development
	[Collaborate across government] Stakeholder engagement in Pinellas County Utilities, Florida	Members governments of Pinellas County entered a Regional System water Supply Contract and they adopted laws and regulations to fair coordination and distribution of water to all parties
	[Share data] Collaborating on data collection and analysis in Cincinnati	Cincinnati Metropolitan Sewer District collaborated with the county, PA and local universities to collecting data for evaluation of green infrastructure performance in reducing overflow. This collaboration resulted in approx. $200 mil saved and the establishment of an urban amenity

	[Plan regionally, act locally] Sewer-shed based planning in Pittsburgh	3 Rivers Wet Weather (3RWW) was established to coordinate integrated sewer solutions across 83 municipalities and the City of Pittsburgh. It was estimated that the collaborative approach has helped saving $60 million for ratepayers
Culture, Knowledge and Capacity	*[Understanding your organization]* The social network analysis of Melbourne water	Melbourne Water undertook social analysis to identify vulnerabilities within the organization and enabled targeted engagement, communication by influential people and quantitative metrics to measure how well One Water was embedded in their organization
	[The enabling champions] Identifying attributes of One Water Organisations (various case studies)	Philadelphia Water Commissioner started at a lower-level position as a champion for water sustainability and cultivated a group of staff referred to as “passionistas" Kentucky, Sanitation District 1’s organizational attributes enabled sustainable operations.
	[Improving capacity] Knowledge Transfer Partnerships program with Scottish Water	Incorporating New sustainable urban drainage systems (SUDS) into Scottish Water’s existing processes was mandated. As a result, a lack of professional knowledge and technical skills in design, construction and long-term management of these new systems were overcome by two Knowledge Transfer Partnerships in collaboration with Abertay University.

		Interacting workshops helped improving various skillsets and reducing resistance to change.
Citizen and Stakeholder Engagement	*[Embed engagement in planning]* Daylighting buried creek in Kalamazoo, Michigan	Five city blocks of the stream were daylighted and restored for ecological and human purposes. Concerns were raised, however, series of involving interventions such as engagement of the Downtown Development Association public outreach and education to schools, informational resources about flooding impacts and green infrastructure, charettes and meetings helped to change public opinion
	[Empower customers] Demand management measure in Albuquerque, New Mexico	Citizens of the city have been accustomed to high outdoor water use activities combining with urban sprawl led to the high withdrawal rate of the arid Albuquerque aquifer. The city engaged citizens in programs to develop strategy for education, ordinances, rebates and supply side auditing as means for empowerment. Results showed 46% and 35% reduction for residential and commercial customers, respectively.
	[Gain community support] Green infrastructure implementation in Philadelphia	The Philadelphia Water Department (PWD) takes on one of the most ambitious hybrid grey/green infrastructure projects in the U.S. The hurdle was the complexity of jurisdictional coordination of seven watersheds and with combined and separate stormwater system. PWD partnered with the State Department of Environmental Resources and the EPA to assure the community about the

		program with serious legal strength to back it up.
	[Multi-disciplinary engagement] Charrette process in Pittsburgh	The City of Pittsburgh and Pittsburgh Water and Sewer Authority (PWSA) turned outward to researchers, architects, engineers and environmental non-profits for help with their green infrastructure planning as solution for stormwater and wastewater issues. Three charettes were used to understand legal, institutional and financial issues which led to the creation of stormwater utility, PWSA leading green infrastructure and a comprehensive education and engagement campaign targeted at residents and the development community.
Economics and Finance	*[Seek dedicated funding]* Solutions for flash floods in Austin	The Watershed Protection Department (WPD) works in collaboration with Austin Water, the Office of Sustainability, Austin Resource Recovery and the Planning Department to come up with a drainage fee applied to residential customers based on the number of storeys in their dwellings and commercial properties based on impervious surface, with offsets for on-site actions, to ensure a stable revenue stream.
	[Look for synergies] Resource recovery and energy generation in Oakland	East Bay Municipal Utility District (EBMUD) aims to reduce its energy use. Thus, it partnered with Recology to add food waste to its digesters and received revenue from accepting this food waste. In 2012, EBMUD became the first treatment plant to be a net producer of energy – producing 120% of its own needs.
	[Ensure equitable revenue streams]	The city has two stormwater parcel fees: i)Stormwater User Fee is a flat fee each yearthe ii) Clean Beaches & Ocean

	Stormwater property taxes in santa monica	Parcel Tax is tied to the Consumer Price Index and adjusted accordingly. Revenues from these fees support the city's watershed management program which required to comply with federal and state Clean Water Act regulations.
	[See the bigger picture] Triple bottom line accounting in seattle	Seattle Public Utilities (SPU) used a 'Triple Bottom Line' approach to demonstrate to regulators that financial, social and environmental benefits of an integrated plan outweigh the costs. The plan included implementing stormwater projects and delaying some combined sewer overflow projects, would significantly benefit water quality.
Regulation and Legislation	*[Use redevelopment as a catalyst]* Solaire building in New York	The greening of Battery Park City started in 1999 when the Battery Park City Authority, a New York State public-benefit corporation, published its own green building guidelines, requiring every residence and commercial property in the area to meet strict sustainability criteria. The Authority has tightened its guidelines overtime. Now all water, including toilet (or black water), must be recycled for toilet flushing, air-conditioning, irrigation and central laundry. Developers must file annual reports that account for their energy and water savings.
	[Quantify wider benefits] 2030 district planning in Seattle	Seattle aimed to create a high-performance and sustainable building district in downtown Seattle. Permitting was extremely time-consuming with state regulations prohibiting the use of energy/water efficient innovation due to the lack of knowledge on long-term effectiveness. To overcome this, the city implemented

		a Streamlined Permitting Process to cut times by 25%.
	[Harmonize across scales] Optimizing consent decrees in Northern Kentucky	Regionally, Northern Kentucky Sanitation District 1 (SD1) worked with planning agencies to take an integrated approach to stormwater and wastewater management, including overcoming barriers in local ordinances. Statewide, SD1's partnerships led to passage of a Kentucky House Bill (504) requiring regulators to consider affordability, green infrastructure and effectiveness when enforcing the Clean Water Act. At the Federal level, SD1 is collaborating with the US Conference of Mayors to address policy concerns with the US Environmental Protection Agency.
	[Streamline the permitting process] Recycled water in San Francisco	In 2012, San Francisco (SF) developed a program to streamline the permitting process for the installation of non-potable water systems. This process overcomes a gap in the CA Plumbing Code and lack of guidelines at a state level, and ensures appropriate health and construction guidelines for safe and reliable use of these systems. Codifying the roles and actions of SF Public Utilities Commission, Public Health and Building Inspection led to quick development of the guidelines. To encourage uptake, developers can access a non-potable water calculator, a developer's guidebook, technical assistance and funding assistance in the form of grants

US Water Alliance (2016) compiled a range of successful case study that were organised into six 'arenas for action' (Figure 2.6).

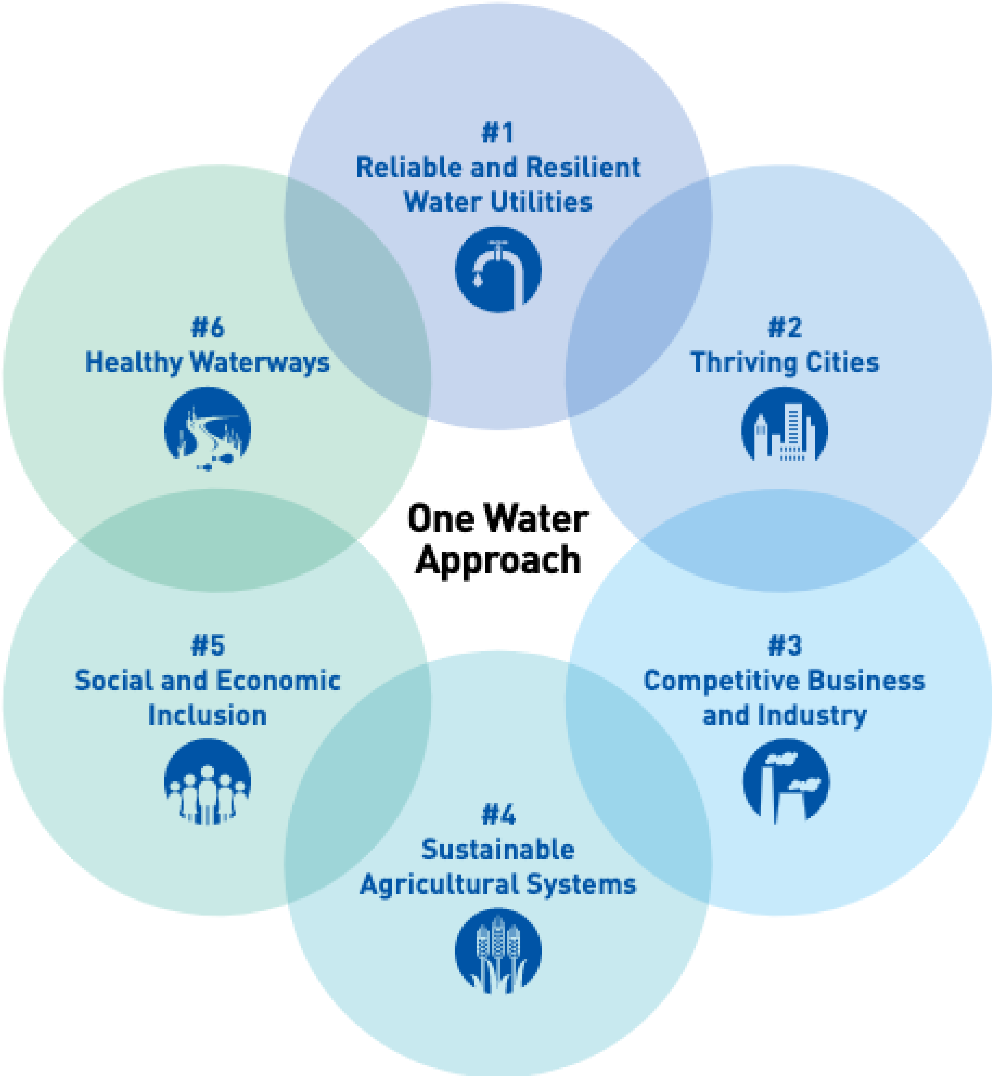


Figure 2. 6: One Water – Arenas for Actions (US Water Alliance, 2016)

The list of cases and their associated strategies is shown in the following table.

Table 2. 4: One Water case studies in the US and the associated arenas for actions (US Water Alliance, 2016)

Arenas for Action	Strategies	Case Studies
#1 Reliable and Resilient Water Utilities	Diversifying and stretching water supplies	Santa Clara Valley Water District Deploys Water Reuse on a Massive Scale
	Utilizing green infrastructure to manage flooding and revitalize neighborhoods	Philadelphia's Green City, Clean Waters: A Model for Green Infrastructure
	Transforming wastewater into a resource	DC Water Leads Our Nation's Capital to a More Resilient Future
	Forging new business models	Louisville: Sharing Services, Finding Efficiencies
#2 Thriving Cities	Integrated planning across the water cycle	One Water Los Angeles Exemplifies an Integrated Approach to Planning
	Utilizing onsite water systems	Emory WaterHub® Shows Students that Recycling is Not Just for Trash
	Adopting a "dig once" approach	Spokane Looks Above and Below Ground to Leverage Infrastructure Investments
	Deploying advanced technologies to improve decision-making	Harnessing the Power of Data to Tackle Water Main Breaks in Syracuse
	Managing water to foster climate resilience	Rebuilding for Resilience in New Orleans
#3 Competitive Business and Industry	Fully integrating water stewardship into company strategy	Coca-Cola Launches 500 Projects to Manage Water Sustainably
	Deploying water efficiency, stormwater management, and water reuse at industrial facilities	Dow Tackles Water Efficiency at its Largest Chemical Manufacturing Complex
	Developing upstream and downstream partnerships in priority watersheds	Change the Course Replenishes more than 225 Million Gallons of Water
#4 Sustainable Agricultural Systems	Using on-farm strategies to reduce water consumption and manage nutrients	Salinas Valley: Recycled Water Saves the Agricultural Sector
	Creating partnerships among upstream and downstream communities	Cedar Rapids: Multi-Pronged Coalition for Change
	Using watershed-scale planning and monitoring	Madison, Wisconsin uses Adaptive Management to Target Phosphorous Runoff
#5 Social and Economic Inclusion	Building a water safety net	Detroit Water and Sewerage Department Offers Low-Income Customers Rate Assistance
	Leveraging water investments to generate community benefits	A Good Neighbor: The San Francisco Public Utilities Commission's Community Benefits Program
	Fostering community resilience in the face of a changing climate	Ironbound: Empowering Newark Residents to Revitalize Their River
	Enhancing community capacity to engage in water planning and governance	Community Water Center Helps San Joaquin Valley Residents Build Their Water Knowledge
#6 Healthy Waterways	Maximizing natural infrastructure for healthy ecosystems	Working Together to Deploy Natural Infrastructure in Saginaw Bay Watershed
	Managing groundwater for the future	Tucson Replenishes Aquifer by Diversifying Supply
	Protecting forests to protect water	Chesapeake Bay Uses Forest Buffers to Boost Water Quality
	Utilizing citizen science for ecosystem monitoring and watershed restoration	Chattahoochee Riverkeepers Empower Citizens on Local Water Quality Monitoring

The development of the OneWater paradigm is not particularly new, and its aim is not to overshadow IWRM. Rather, it is an effort to improve the applicability of

IWRM and WSUD at the strategic and tactic levels via re-specifying the elements and processes involved, and by identifying the challenges faced by today's generation.

2.2.4 The applications of the approach

Overall, while IUWM as a concept has been articulated, the processes are not clearly defined, and thus, its implementation has been carried out in a reactive manner, one where the IUWM planning and management processes and their associated projects are tailored to *specific contexts* in order to solve *ad hoc issues* (issues which are dealt with whenever they emerge without being planned for in the long-term) (Guthrie, Silva, et al., 2017; Mukheibir, Howe, et al., 2015). In the author's opinion, the case of multiple newly built eastern states' desalination plants that were either put on standby or closed before being used (the Brisbane Advanced Water Treatment Plants) offered insightful lessons on reactive responses. Further, after the end of the millennium drought, 'national policy priorities have turned elsewhere' and 'intergovernmental and statutory institutional structures have been abolished' (Radcliffe, 2015). The interventions and how they have been withdrawn revealed a reactive management pattern. The term 'reactive manner' is referred to as the opposite of long-term, proactive planning that focuses on acknowledging uncertainty and increasing resilience via flexible and robust strategies. Further discussion on how the reactive mode of management is not suitable to deal with complex issues can be found in section 6.2.4.

In Australia, non-potable wastewater and stormwater recycling and reuse projects have been seen to be the primary manifestation of the IUWM approach to infrastructure planning (Furlong, 2016; Productivity Commission, 2020). In their review, the Productivity Commission (2020) highlighted that the Government realised the benefits of reducing potable water use besides significant system augmentation during the last decade and materialised this vision by issuing mandates and providing subsidies for projects that demonstrated a few aspects of integration. Those IUWM projects include: i) stormwater reuse for irrigation (parks, gardens, and sporting fields), ii) wastewater recycling for toilet flush or laundry or household irrigation, iii) wastewater recycling and stormwater harvesting for irrigation of parklands and golf courses and/or agriculture, iv) stormwater reuse for drinking water supply, and v) investing in green infrastructure to remove gross pollutants, to reduce peaks flow and provide wetland habitat (Productivity Commission, 2020). The integration of water supply, wastewater and stormwater in centralised, decentralised and hybrid systems is gaining much attention (Furlong, Gan, et al., 2016; Makropoulos & Butler, 2010; Sapkota et al., 2015). However, those projects have been implemented without a consistent and robust integrated water service planning approach to guarantee that they showed value for money (Productivity Commission, 2020).

As highlighted by Hering et al. (2015), high-level management policies are not always success in solving water issues that arise from local conditions if they are not informed by the local and regional people and institutions. Hence, the practice of contextualisation is particularly appropriate. One example is how the Building Sustainable Index (BASIX) program in NSW might have led to more financial risk for recycled water schemes (Watson et al., 2017b). The BASIX program essentially set a 40% consumption reduction target for all new homes (compared to similar-sized homes) via water-efficient fixtures and internal connection to the alternate water supply. The issue is that BASIX is an outcome-based program, so it is not mandating how the target should be met. Therefore, the financial risk is that new dwellers might choose to go with other options such as rainwater tanks instead of connecting to recycled water schemes that have already been built if it is found to be more cost-effective.

However, even incorporating the contextual conditions and local community into management processes to tackle ad hoc issues alone, as is the practice of Australian water utilities, may not be enough. The aspiration is that the management regime should also include a number of other characteristics, such as long-term, proactive planning; collaboration between organisations and departments vertically and horizontally; integration of water consideration into urban planning processes; and the inclusion of both centralised and decentralised planning and infrastructure (Mukheibir, Howe, et al., 2014).

IUWM has been theoretically and practically studied and promoted by a number of influential organisations and projects in various part of the globe. Prominent examples include the Global Water Partnership, the SWITCH project, and the Water Partnership Program (by the World Bank). The *Global Water Partnership* (GWP), which is one of the largest global action networks with 3000 partner organisations in 183 developed and developing countries, aims to provide knowledge and build capacity for enhancing water management at all levels through coordination between participants. Through collaborative research and capacity building between its partners, the GWP became a pioneer organisation that compiled and analysed the theoretical backgrounds, motivations, opportunities, challenges and functions of IUWM (see Bahri 2012). IUWM projects carried out by GWP that focus on encouraging innovative urban water management practices can be found mostly in developing countries in Africa, Asia and Latin America. The latest effort focuses on developing an urban water hub within the framework of the IUWM Program for Africa in cooperation with the Africa Water Facility of the African Development Bank (GWP 2017).

The next example was the *SWITCH project (Sustainable Water Management Improves Tomorrow's Cities' Health)* which was an action research project funded by the European Union with the budget of more than 20 million euros. A cross-disciplinary team of 33 partners implemented the project from around the world to facilitate a paradigm shift toward sustainability in urban water management from 2006 to 2011 (Howe et al., 2011). The project set out to address three identified fundamental issues with urban water management: i) the limited uptake of available research findings, ii) the fragmentation of institutional arrangements, and iii) the complexity of urban water problems which required integrated solutions (Butterworth & McIntyre, 2011). To that end, four key objectives were identified including: a) improving the scientific basis for IUWM in demonstration cities though fundamental research, b) experimenting with innovations and technologies via demonstration activities, c) supporting multi-level institutional platforms and stakeholder engagement, and d) improving decision support processes, better policies and realising evidence-based IUWM via long term planning. The project focused on establishing collaborative research and sharing knowledge platforms called 'learning alliances' connecting networks of academic and urban planning fields, water utilities and consultants. The primary aim of the research alliances was to facilitate the implementation of research and pilots to solve local problems in various demonstration cities and then to integrate those activities city-wide to upscale the implementation of integrated solutions. The learning alliances consisted of different nested multi-level platforms (local, city, national and global levels). The project worked directly with stakeholders in twelve cities in Africa, Asia, Europe and South-America to accelerate and foster up-scaling and the adoption of sustainable and innovative solutions (from demonstration activities) to water issues (Furlong, Gan, et al., 2016; Steen & Howe, 2009). In general, the outcome of the project is a ‘strategic planning approach’ highlighting the impacts of global changes, joint visions and the development of a strategy which was distilled through the development of various tailored ‘experimental’ strategic plans in a number of cities (see Howe et al. 2011). The focus and outcomes of the project are summarised in the following table.

Table 2. 5: Summary of SWITCH projects

No.	City	Focus	Outcomes
1	Lima, Peru	Scaling up wastewater reuse in extreme water scarce areas	1. Development of Learning alliances at: - National Level for policy issues - Local level for demonstration projects and research 2. National policy guidelines promoting safe wastewater reuse in the country 3. Establishing an eco-productive park for wastewater reuse (restriction for growing food) and play area for a local community
2	Cali, Colombia	Research and Stakeholder engagement for sustainable, innovative urban planning (urban drainage, river health and city expansion)	1. Generating ideas, outputs and advice from SWITCH dialogue 2. Informing formal planning processes and public policy advocacy 3. Identifying and supporting 'champions' in various organisations who have become ambassadors for SWITCH ideas 4. Reduction in short-term planning and infrastructural solutions in wastewater management. 5. A growing consideration for alternatives in new developments.
3	Rio Bogota, Colombia	Preventing pollution from small tanneries upstream of the Bogota river	1. Establishing platform for engaging an association of the tanners, the environmental regulator, local government, an NGO, a university and the Chamber of Commerce → supporting conflict resolution, capacity and dialogue 2. Assisting the tanneries in implement cleaner production principles → reducing half of the

			pollution and increasing productivity. 3. Expanding the adopting of alternatives to a wider catchment area 4. Changing the regulators' punitive, legalistic approach to wastewater
4	Belo Horizonte, Brazil	Changing the approach to urban drainage to be more natural and environmental friendly in order to minimise flood risks and improve river corridor habitat	1. Establishing a partnership between the municipality and the University 2. Establishing learning alliance between schools and communities around demonstration sites (at the local level), and between planning and services institutions at the city scale. 3. Institutions committing to up-scaling rainwater harvesting 4. Participatory budgeting committees have begun to implement sustainable solutions.
5	Accra, Ghana	Research on materialising strategy and facilitating debates on IUWM	1. Applying the RIDA framework to collect, synthesise and analyse secondary data on elements of the urban water cycle 2. Informing city strategic planning 3. Assisting the development of a World Bank-supported project and the Metropolitan Assemblies' development plan. 4. Demonstrations on safe wastewater urban irrigation, on how urine can be collected and reused.
6	Alexandria, Egypt	Development of an IUWM plan and demonstration on water supply for urban slum communities	1. Nine studies (by learning alliance) on a. Assessment of current and future water supply b. Strategies to reduce unaccounted water

			2. Engaging City Government, water and sanitation utilities, an urban slum community, and a research institute with the research 3. The findings informed the city's IUWM and the water company's master plan
7	Birmingham, UK	- Climate change impacts on flooding - Implication of rising groundwater level (as industrial demand declined)	1. Engaging the city council, the water company, the Environment Agency, the regulatory authority, consumer bodies and a professional association. 2. Research on the effect of green roof on future flood risk attracted attention from planners 3. Influencing the use of sustainable alternatives in the redevelopment plans for a major site in the city centre
8	Zaragoza, Spain	Reducing water consumption	Establishing a solid stakeholder engagement platform to successfully adopt and scale up 'sectionalisation' (dividing the water supply network into a limited number of sectors). 'Sectionalisation' is a vital strategy to improve the efficiency of water supply management via effective bursts and leaks detection and is included in the municipal by-laws.
9	Hamburg, Germany	Improving planning of on the river island of Wilhemsburg	- Engaging a broad range of stakeholders from the island in the development of a water management plan - The engagement program did not yield positive outcomes. o The benefits of demonstration activities had not been realised. o The SWITCH approach had been criticised for being too theoretical.

10	Lodz, Poland	Rivers restoration by developing and including 'blue-green network' (attaching green areas to river systems) into city planning	1. A demonstration project successfully recovered one river corridor. 2. Learning alliance within the city institutions will inform further activities for continuing and scaling up the approach. 3. The blue-green network has been recognised as part of the city's planning strategy.
11	Tel Aviv, Isarel	Research on soil aquifer treatment technologies to assist wastewater reuse	1. Developing research agenda on micro-pollutant risks in treated wastewater. 2. Raising awareness of the city planning authorities about water issues through engagement processes led to its inclusion in the city's strategic plan.
12	Beijing, China	Investigating the impact of increasing water scarcity for urban farming induced by the growth of urban water consumption.	1. Establishing collaboration between research institutes, Government officials, and farmer cooperatives to find potential solutions 2. A demonstration project illustrated the usefulness of roofwater harvesting as an alternative source of water for urban farming 3. Policies advice on shifting to higher value crops and promoting Agro-tourism.

Another illustrative case is the *Water Partnership Program* (WPP), a multi-donor trust fund that was administered by the World Bank and funded by the governments of the Netherlands, the United Kingdom and Denmark. It involved technical aid and analytical effort in project preparation and implementation across all water subsectors (Closas et al., 2012). The aim of the program was to facilitate and implement IUWM initiatives and pilot studies in Latin America and the Caribbean (LCR), Europe and Central Asia (ECA), and sub-Saharan Africa.

Further, those funded case studies created a knowledge base to assist various actors in exploring and developing the concept of IUWM by highlighting the associated *challenges* and *opportunities*. The program was carried out from 2009 to 2012, with 214 activities in 62 countries with an investment of $19.6 million (WPP 2012).

In LCR, case studies in the city of Sao Paulo, Brazil and Bogota, Colombia, highlighted good IUWM practices. In Sao Paulo, the 2007 State Complementary Law was an innovative law issued to overcome silos in urban water management by incorporating cross-municipal coordination between the State government, the municipalities, and the utilities into urban water management. As a result, the Macro-Metropolis Plan was improved; and the Federal growth and development plans (loans and grants) supported IUWM initiatives across different sectors, involving multiple actors and at various scales. In Bogota, stakeholder engagement among central and local governments, municipal authorities, the regional environmental agency and the public water utility was funded and established to plan for wastewater management issues and changes in legislation. Thus, the strategic plan to improve Bogota river health and environment issued by the Centre Government included the construction of small wastewater treatment plants, ecological restoration projects, flood control, and enhancing wastewater management in the city.

In ECA, the IUWM strategy for the Greater Baku area stood out as a successful example. The economic viability of infrastructural options for water supply, economic evaluation of water services (with community engagement), and the CBA of interventions were analysed to inform decision-making for 2010-2025 addressing water supply and wastewater management issues.

In Sub-Saharan Africa, the IUWM project included several components. Firstly, a background study described the capacity of 31 cities (through the constructed IUWM index) and the challenges they faced concerning IUWM. Secondly, findings from a study of IUWM knowledge, attitudes and practices (KAP) carried out in 13 municipalities, and 24 water operators in 28 countries showed that aspects of IUWM were desirable in planning. However, the need for more investment, technical and capacity building and knowledge sharing were also highlighted. Finally, pilot studies and research on the IUWM approach to diversifying water supply were implemented in four cities. In Nairobi, Kenya, the outcomes of the research project pointed to the importance of implementing diverse, flexible and adaptive IUWM systems (sequencing integrated solutions in the medium and long term) as future uncertainty about water supply, growth, and availability under the impacts of climate change is high. In Mbale, Uganda, a water supply diversification portfolio consisting of surface water, groundwater and greywater reuse was advised for new urban clusters. The decentralised wastewater systems (DEWATS) and soil-aquifer treatment (SAT) were adopted to increase community acceptance of treated grey water reuse through groundwater recharge. In Arua, Uganda, urban water issues were unauthorised abstract and pollution from upstream settlements, incapable water supply system, unreliable wastewater treatment plan due to river turbidity and the lack of reliable energy source, and groundwater contaminant due to poor management of septic tanks. To address those problems, a decentralised water treatment approach for stormwater and greywater reuse was implemented at the urban cluster level. In the case of Douala, Cameroon, findings suggested that stakeholder and community engagement and capacity building for local organisations play a vital role in sustaining the IUWM process and overcoming political and economic barriers to IUWM solutions.

In 2017, an Integrated Water Management framework for Victoria, Australia (DELWP, 2017) was developed to guide and support organisations in achieving the objectives which were strategically formulated in 'water for Victoria' by the State Government (DELWP, 2016). Victoria State Government is a firm supporter of an integrated approach in urban water sector. So, by recognising the issues and opportunities, DELWP came up with a framework which focuses on creating a collaborative platform for water planners and urban planners at all levels, local governments, and the community to jointly identify and prioritise options and opportunities for integrated solutions. The framework basically provided a structure for a collaborative approach which specify steps of a planning process and roles of involved organisations (figure 2.5). Group of leaders who represent organisations with core water cycle responsibilities will participate in IWM forums to identify, prioritise and coordinate place-based IWM plans (figure 2.6). The IWM plan working groups comprised of IWM partners will be in charge of carrying out and progressing IWM plans. The document does not only provide structure for a collaborative approach, but also include a number of guidelines and tools to support collaboration process such as:

- IWM collaborative mapping tool,
- Preliminary project assessment guidelines
- Guidelines for IWM planning and analysis
- Economic evaluation and cost allocation framework
- Externality valuation
- Green-blue infrastructure guidelines
- Urban forest guidelines.

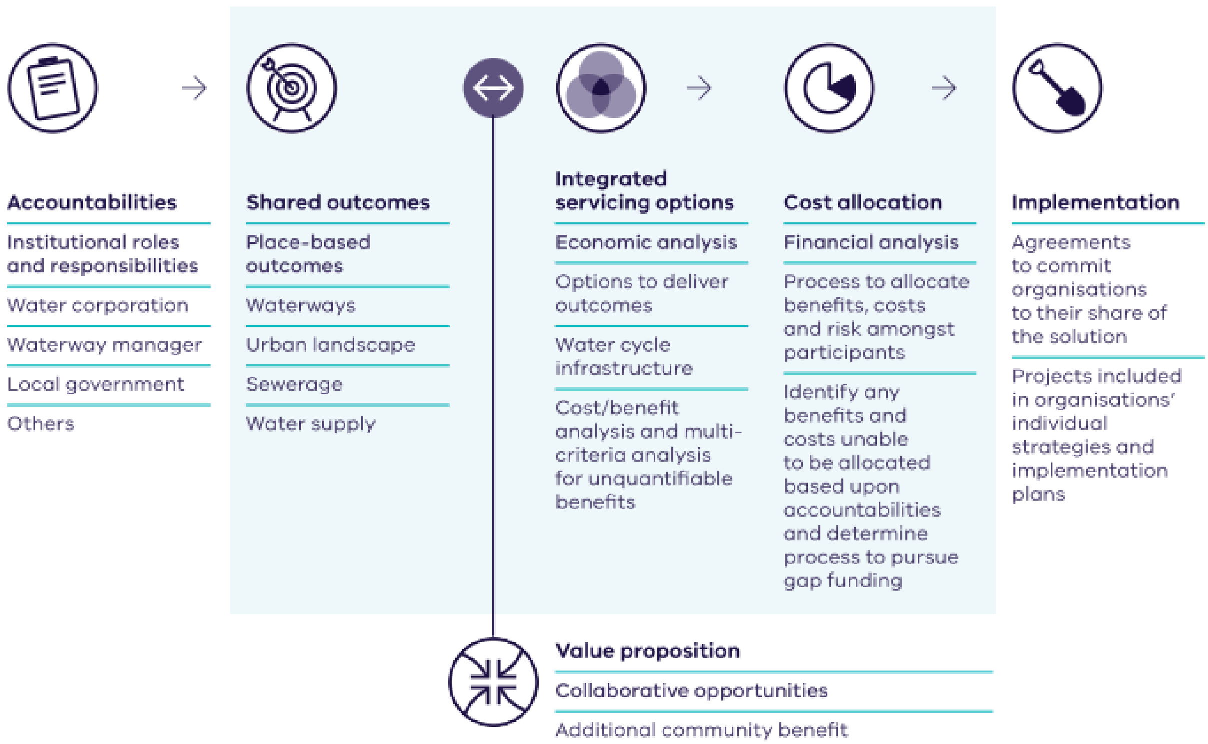


Figure 2. 7: IWM planning process

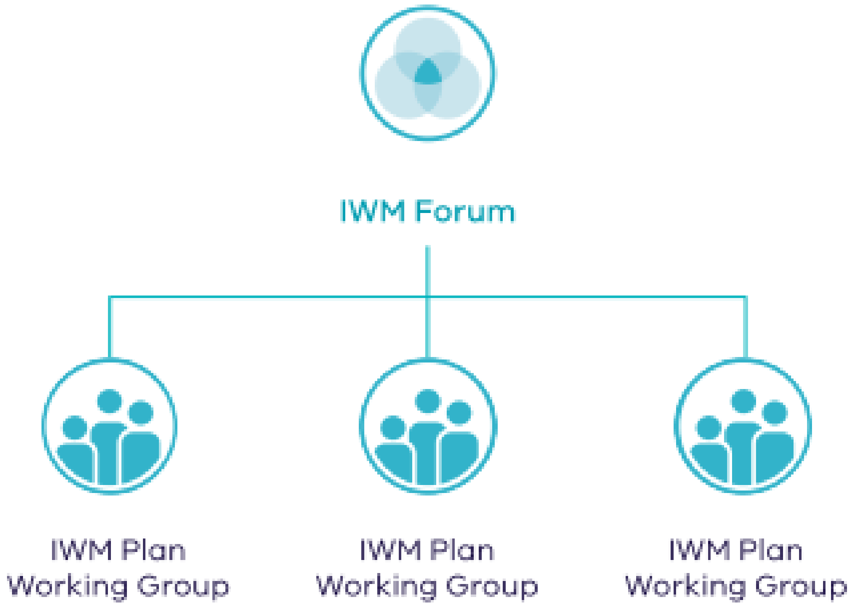


Figure 2. 8: IWM planning Governance Structure

It can be observed from this application in Victoria that the definition of the IUWM concept and what it comprises is ambiguous; and there has been no concrete example of a large-scale implementation of IUWM so far since they were either focusing on individual water services at a large-scale or integrating multiple services at a suburb or new development areas (Furlong & Silva, 2016). Nevertheless, the framework still commands the serious attention of academic and practitioner communities to further explore and develop with the belief that IUWM will be a potential solution for water-related issues in the future.

In Australia, efforts to apply IUWM have mainly focused on incorporating wastewater recycling, stormwater reuse (treatment and harvesting) into planning for cities as alternative water sources and responses to environmental concerns (Ferguson, Brown, Frantzeskaki, et al., 2013; Wong et al., 2013). Identification of challenges and barriers to the adoption of an IUWM approach can be found in more detail in section 3.3.

2.3 Participatory approach

Today, hardly any environmental research, decision-making and management is conducted without a certain degree of stakeholder involvement. This could be attributed to the fact that stakeholder involvement has been embedded in national and international policies (Jakeman et al., 2006; Mysiak et al., 2010; Reed, 2008; Voinov & Bousquet, 2010). It is believed that participatory process can help improve the effectiveness and efficiency of environmental decisions and fulfil the social objectives of conflict resolution; increasing compliance with public policies; trust building; and social learning among stakeholders (Beierle & Cayford, 2002; Dietz & Stern, 2009; Koontz & Newig, 2014; Reed, 2008; Vente et al., 2016). Furthermore, the significance of stakeholder and community engagement in either an integrated or an adaptive approach has been realised in various research (Bahri, 2012; Colloff et al., 2017; Moellenkamp et al., 2010; Mukheibir, Howe, et al., 2014; Walters, 2007).

However, it is not clear whether these aspirations are being realised in practice. This is due in part to the focus of participatory research being on process aspects and social outcomes such as the changes in the public's viewpoints or formation of new networks, rather than environmental outcomes and resource impacts such as water quality enhancement and ecological conservation (Bierle & Cayford 2002; Hogl et al., 2012; Koontz & Thomas, 2006). Thus, this sub-section aims to present both the theoretical basis and the practical implications of the concept in natural resources management and water resources management domains to create a knowledge foundation for stakeholder and community engagement in urban water sector.

2.3.1 What is Participatory Approach?

Various terms and approaches that have been coined to describe and explain the Participatory approach concept make it problematic to define. There are many cross-sectoral terms associated with the concept throughout the literature such as collaboration, stakeholder engagement, public participation, stakeholder involvement, and deliberative process (Carr, 2015). In addition, there are also various approaches that have been developed, including: participatory action research (PAR); Rapid Rural Appraisal (RRA); Participatory Rural Appraisal (PRA); Participatory Assessment, Monitoring and Evaluation (PAME); Participatory Research (PR); Participatory and Integrated Policy (PIP) (Cambell & Salagrama, 2001; Pretty, 1995). Therefore, it would be unrealistic to attempt to settle on one definition (Chambers, 1992; Pretty 1995; Carr 2015). Instead, one should look into some elements that are associated with the process that guide the conceptualisations in seminal works.

These elements include *level of participation, direction of information flow,* and *the nature (aims)* of the implementation process (Reed, 2008; Rowe & Frewer, 2000). For example, Rowe and Frewer (2000) refined the concepts and pointed out the differences in nature of public communication (officials inform the public about decisions to gain acceptance) and participation (exploring public's perspectives and values to improve decisions).

Reed et al. (2017) argued that the participatory approach was a mechanism for involving 'public or stakeholder groups, individuals, and organizations in making decision that affect them, whether passively via consultation or actively via two-way engagement, where publics are defined as groups of people who are not affected by or able to affect decisions but who engage with the issues to which decisions pertain through discussion and stakeholders are defined as those who are affected by or can affect a decision (after Freeman 1984)' (Beierle & Cayford, 2002; Reed et al., 2017).

The shift 'from top-down to bottom-up, from centralized standardization to local diversity, and from blueprint to learning process' (Chambers 1992) originated from the dissatisfaction with how decision-makers, who are detached from the location and specific contextual conditions, do not have the capacity and legitimacy to manage systems in a sustainable manner. Instead, the approach used should focus on the inclusion of the various perspectives, understandings, values, and interests of local communities.

2.3.2 Approaches to stakeholders and public participation

Participatory approaches have a long history, with applications in different contexts involving a wide range of social, ideological, political, methodological interpretations that are often associated with contested terms. Therefore, it is useful to consider different typologies in order to understand the methods and contexts associated with different interpretations (A. Lawrence, 2006; Reed, 2008). In this section, the most influential and up-to-date typologies are discussed.

Arnstein's work on the 'ladder of participation' (1969) is considered the first effort to classify types of participation according to how much influence stakeholders and the wider public have in decision-making. Arnstein's study influenced later variations of the participation spectrum introduced by Bigg (1989); Pretty (1995); Gaventa and Cornwall (2001); Mostert (2007); IAP2 (2014). It is argued by these authors that the more deliberative and cooperative modes of participation deliver more desirable outcomes (Arnstein 1969; Pretty 1995; Reed et al. 2017). However, authors such as Richards et al. (2007) and Vella et al. (2015) argued that the appropriate degree of involvement heavily depends on the *purpose of the process*, the *circumstances* and how *influential* stakeholders are over decisions

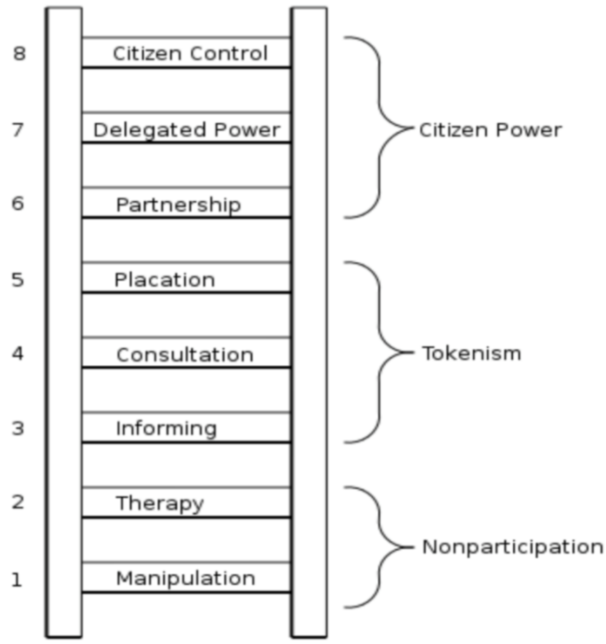


Figure 2. 9: Ladder of participation (Arnstein, 1969)

The most widely used variation of Arnstein's 'ladder' is the 'public participation spectrum' published by the International Association for Public Participation (IAP2) in 2006 and updated in 2014 (Figure 2.10). This ladder describes different levels of participation based on the purposes of the process and the promises made to the public. It differs from the original 'ladder' by implying that higher levels of participation are not necessarily better (Koontz and Newig 2014). Instead, the authors argue that the focus should be on which level best fits conditions such *as the willingness of the participants* (to take part in the higher levels), *different stages of the project* or the *nature of a particular decision-making process* (Sarno 2013; Stuart 2017). In addition, the selection of the degree of engagement and the directions of information flows should be *flexible* and should be re-*negotiated* if problems arise (Hardy, 2015; Videira et al., 2006). The spectrum has been used to guide engagement practices in various integrated urban water programs in New South Wales, Victoria and Queensland according to interviewees N1, N2, V2, and Q1 .

IAP2'S PUBLIC PARTICIPATION SPECTRUM

iap2 international association for public participation

The IAP2 Federation has developed the Spectrum to help groups define the public's role in any public participation process. The IAP2 Spectrum is quickly becoming an international standard.

INCREASING IMPACT ON THE DECISION →

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

Figure 2. 10: Public participation spectrum (IAP2 2014)

While the 'the ladder' has been accepted and used by many organisations, some scholars consider it to be out of date and too-linear (Collins & Ison, 2009; Reed, 2008). Recently, Reed et al. (2017) reinforced this argument by assembling evidence of the failure of high level (even top rung) participation practices. Plus, they pointed out a potentially confusing aspect of 'the ladder' which is 'trying to describe what is possible while trying to recommend ideal types based on what should work in theory' (Reed et al., 2017, p. 3).

Reed et al. (2017) introduced a new generalised typology, which was inspired by the wheel of participation (Davidson 1998). Their typology is based on four broad types of participation which do not have pre-determined values. Their wheel includes an outer ring of agency (who initiated and led the process) and an inner ring of mode of participation (from one-way communication to co-production) that can be spun in both directions for a particular context and purpose (Reed et al 2017). This new typology for stakeholder and public participation is worth mentioning in the review as it might be of valuable for future studies in urban water context.

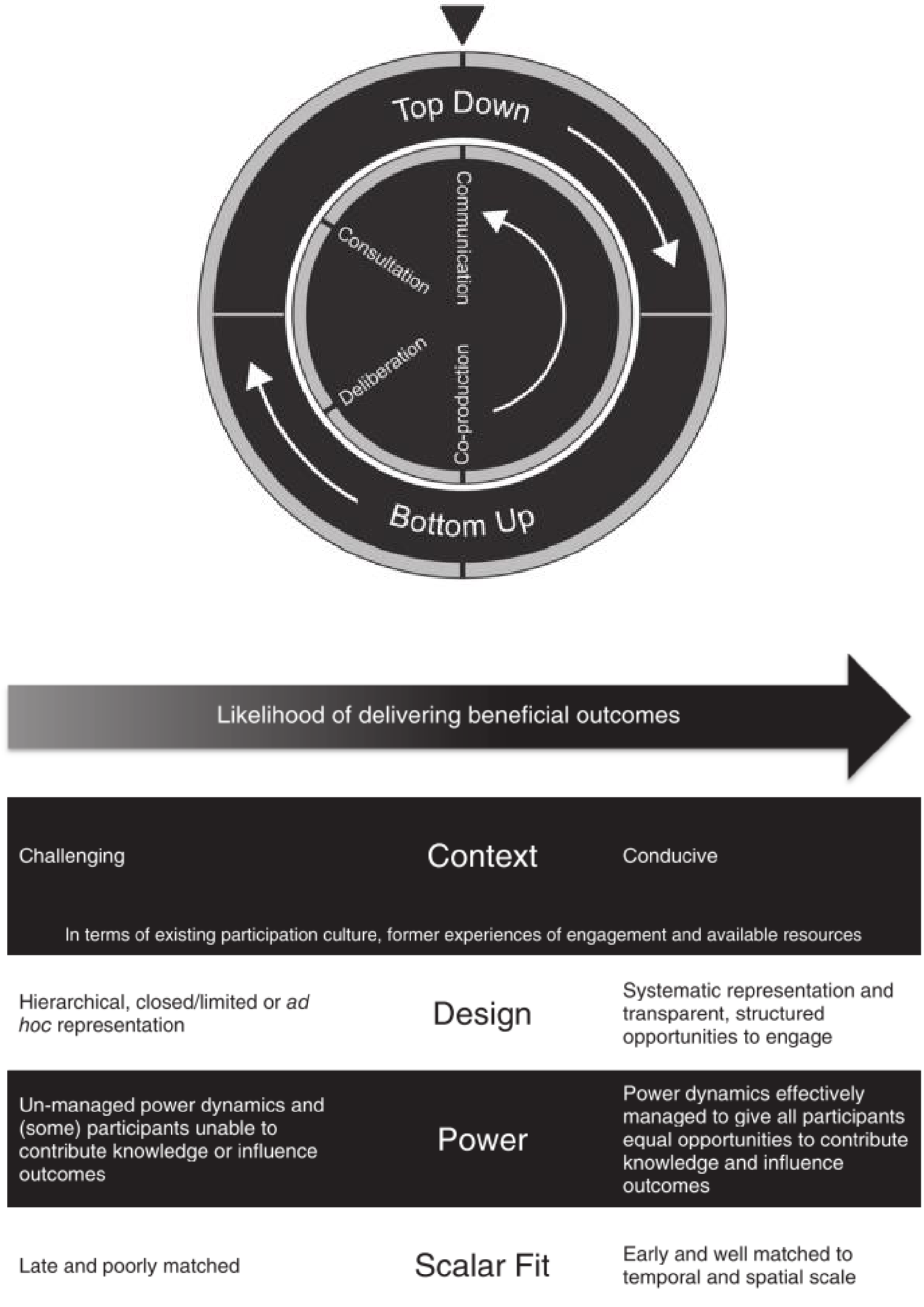


Figure 2. 11: The new version of Wheel and the theory of participation (Reed et al., 2017, pp. 4, 8)

2.3.3 The applications of the participatory approach

This subsection focuses on critically reviewing previous to carry out participatory approaches in natural resources management and water management. It also identifies the existing limitations that might be helpful to consider when implementing in the urban water sector. Thus, the review focuses on literature and documents evaluating public and stakeholder engagement efforts.

Literature on this subject is ample but scattered. It examines diverse aspects of the issues involved, leading to various, sometimes contested, findings. As a result, rather than describe various single cases, it will be helpful to consolidate and analyse these studies as comparative case studies or grounded theory studies based on the conceptualisation illustrated in Figure 2.12. This subsection describes the overall picture and conceptualisation, followed by a process evaluation and then an outcomes evaluation.

2.3.3.1 The overall picture and the conceptualisation

In general, the focus of research is gradually turning from how to best adopt and implement the process in theory into systematically studying and evaluating the effectiveness as well as the efficacy of the implementation (Hogl et al., 2012; Mauerhofer, 2016; Reed, 2008; Rowe & Frewer, 2004; Videira et al., 2006).

Although studies have provided data on the influence of the context on outcomes, and advances in how to assess the achievement of *process outputs* (such as agreements, plans, decisions and alternatives) and *social outcomes* (such as learning, trust and acceptance), it is strongly believed that there is a gap in knowledge about how these factors influence actual *environmental* changes which were usually the overall goals of the programs (Beierle and Cayford 2002; Koontz and Thomas 2006; (von Korff et al., 2012); Hogl et al. 2012; Vente et al. 2016; Reed et al. 2017). Newig et al.'s (2013) conceptualisation (figure 2.11) was utilized to guide literature review on those dimensions.

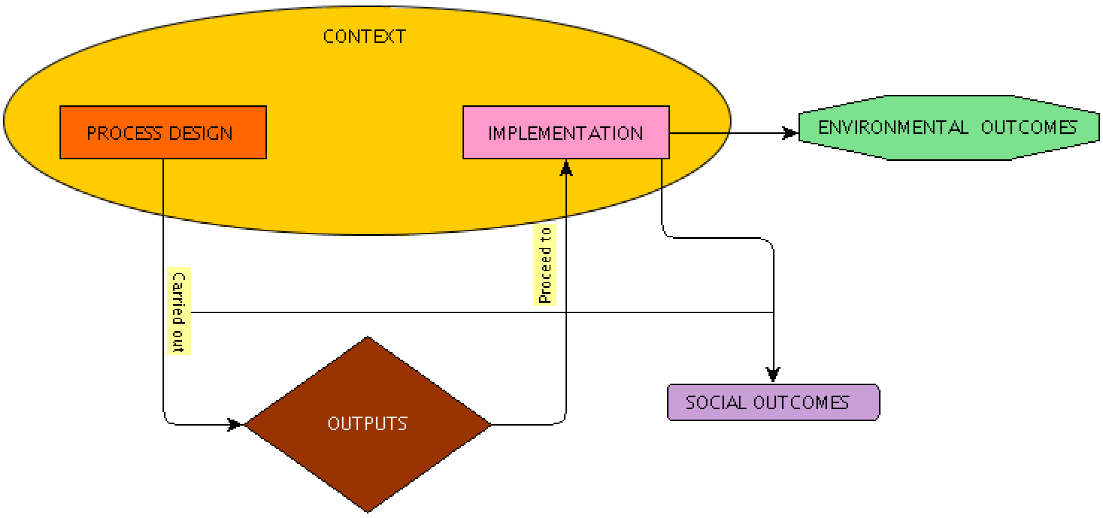


Figure 2. 12: Conceptualization of participatory efforts (influenced by Newig et al. 2013)

Interactions between the *context, process, and outcomes* are emphasised through *outputs* (the tangible products from the participatory process like plans or agreements) and *implementation* (the process of carrying out the decisions made in the participatory process). The social outcomes are intangible products such as changes in stakeholders' viewpoints or the establishment of the new networks of agents. *Environmental outcomes* are usually the overall goal of the decision-making process such as improving waterways' water quality, modifying stream flows or ecological conservations. Further analysis of each element within the conceptualisation will be discussed in the following sections.

2.3.3.2 Process evaluation

Most literature on evaluating participatory approaches focuses on assessing different *process* aspects of public and stakeholder participation in environmental management. In particular, two prevalent themes, including studying how contextual conditions affect participatory processes and the evaluation of participatory processes design, were highlighted in both the theoretical and practical literature (Ansell & Gash, 2008; Brooks et al., 2013; Carpini et al., 2004; Ingram, 2013; Koontz & Newig, 2014; Koontz & Thomas, 2006; Newig & Fritsch, 2009; Reed et al., 2017; Vente et al., 2016). In the water management domain, authors have focused on how the process should be designed and in what context (Korff et al., 2010; Leach & Sabatier, 2005; Videira et al., 2006). For example, Korff et al. (2010) compared and then combined five process design guidelines from five previous studies to produce a widely applicable yet comprehensive guide with seven principles, three main phases and a set of steps and sub-steps for each phase. Thus, to recognise the effectiveness and efficiency of the participatory approach, it is crucial to understand the role of context conditions and how well the process design has performed up to now.

The role of contextual conditions in understanding issues and identifying the purposes of participatory efforts

The importance of 'local realities' in understanding the issues and identifying purposes of participatory efforts has been highlighted in a number of studies (Blackstock et al., 2007; Bryson et al., 2013; Drazkiewicz et al., 2015; Foxon et al., 2008; Gurney et al., 2016; Koontz, 2005; Sterling et al., 2017; Videira et al., 2006). A better understanding of local conditions can improve the process design that informs deeper insights on the issues and the dynamics of the projects (Bryson et al., 2013; Drazkiewicz et al., 2015; Ingram, 2013). Further, the choice of participatory method is influenced by the context as the same method will not necessarily produce the same results in different circumstances (Rowe & Frewer 2000, 2004; Midgley et al., 2013). Moreover, the level of impact on policies is connected to local conditions rather than any internal group factors (Koontz 2005) and the local context is one of the most important aspects to be considered when one wants to evaluate the process and outcomes of participatory efforts (Brooks et al., 2013; Sterling et al. 2017). The vital role that 'local reality' plays in planning and management has also been found in urban water context (see section 2.2.4)

The context can be described as the various parameters of the socio-economic, cultural and institutional dimensions in which the engagement exercises take place (table 2.6).

Table 2. 6: Compilation of contextual parameters in a participatory program

Planning dimension	Socio-economic dimension	Cultural dimension	Institutional dimension
Type of environmental problem (Beierle & Cayford, 2002; Vente et al., 2016)	Social networks (Vente et al., 2016)	Pre-existing relationships (among participant) (Beierle & Cayford, 2002; Ostrom, 2011; Webler & Tuler, 2006)	Leading agency and its level of government (Beierle & Cayford, 2002)
Target system elements (Beierle & Konisky, 2000; Hassenforder et al., 2015)	Trust between stakeholder groups (Vente et al., 2016)	Other past/present intervention attempts (Dietz, 2005; Midgley et al., 2013)	Existing policy, legal and institutional framework (Brooks et al., 2013; Sterling et al., 2017; Vente et al., 2016)
	Characteristic of the market (Brooks et al., 2013; Sterling et al., 2017)	Participants' understanding of target system elements (Hassenforder et al., 2015)	Political rights (Brooks et al., 2013; Sterling et al., 2017)
	Presence of a charismatic individual or group (Brooks et al., 2013; Sterling et al., 2017)		

To sum up, despite the contested views about the impact of the local conditions on the outcomes of a participatory approach, literature emphasized the crucial role they have in the design and implementation of participatory programmes.

Process designs

Process design is among the most influential factors in the outcomes, and most literature assessed aspects of the process when it comes to evaluating how successful the participatory programs were, rather than the impacts of outputs (Koontz & Thomas, 2006; Rowe & Frewer, 2000; Sterling et al., 2017; Vente et al., 2016).

The attributes of process dimensions, which are found explicitly or implicitly in the literature, can be grouped into *levels of engagement, methods/mechanisms of participation,* and *stakeholder selection/analysis*. Characteristics of each attribute can be used to define the others. *Firstly*, the level of engagement has already been discussed in the typologies of participation section above. *Secondly*, the traditional methods (*public hearings, public comments, public surveys, negotiated rule-making* and *citizen review panels* (Fiorino, 1990; Laird, 1993)) or more contemporary one (*consensus conferences, citizens' juries, citizen/public advisory committees,* and *focus groups* (Rowe & Frewer, 2000, 2004)) are usually deemed crucial. More recently, *mediated modelling* or *participatory modelling* has been introduced, which is a new system dynamics-based scheme of research highlighting the interactive learning process via computational simulation or mental model to increase levels of shared understanding and consensus (Basco-Carrera et al., 2017; Langsdale et al., 2013; van den Belt & Dietz, 2004; Voinov et al., 2016; Voinov & Bousquet, 2010). *Finally*, the stakeholder analysis (SA) is a preliminary step in the participatory process to identify the relevant actors, evaluate their interests, analyse their differences, and investigate the inter-relationships (Reed et al., 2009; Sabina & Stanghellini, 2010).

The evaluation frameworks

Frameworks to evaluate public participatory processes varies as they depended on those authors' perspectives on success.

From the *normative perspective*, Leach (2006) offered a framework consisting of seven criteria to measure the democratic merits of the participatory water management process, namely, *inclusiveness, representativeness, impartiality, transparency, deliberativeness, lawfulness, and empowerment*. Based on an analysis of 76 case studies, the criterion of *deliberativeness* was found to be the most frequently delivered democratic attribute, while *representativeness* was the weakest. Representativeness relates to whether all interest groups had a voice in the process or had sufficient incentives, means, and skills to participate. Birnbaum et al., (2015) focus on the evaluation of *perceived legitimacy* of environmental policies via parameters including 'deliberative qualities', 'democratic qualities' and 'instrumental-substantive' sources of legitimacy. Their conclusion was that outcomes' legitimacy depends more on how the decisions support participants' 'pre-political preferences about the preferred content of the policy' over deliberative qualities.

From a more *pragmatic* view, the literature concerns more about the tangible aspects of the process (Beierle & Cayford, 2002; Brooks et al., 2013; Hassenforder et al., 2015; Sterling et al., 2017; Vente et al., 2016).

Beierle and Cayford (2002) came up with the *participatory mechanism* (selection of participants, type of participants, type of output, seek consensus*), the intensity of participation process,* and *the variables of the process features* (responsiveness of the lead agency; motivation of participants; quality of deliberations and degree of public control). The findings indicated that more intensive processes are more likely to achieve social goals. Hassenforder et al. (2015) gathered fourteen instrumental criteria from the literature, and each criterion came with a set of parameters for evaluation. Recently, based on the 'scheme for the comparative analysis of public environmental decision- making' (SCAPE) framework (Newig et al., 2013), Vente et al. (2016) proposed 19 evaluation criteria which came with 15 measurable parameters to evaluate the process design of some 24 cases. Sterling et al. (2017) adapted critical project criteria developed by (Brooks et al., 2013), considering the types and actions of engagement qualitatively and quantitatively. They highlighted the significance of several factors to the success of the process, such as the *right balance and timing of engagement* (focus on 'key' stakeholder and involve them into the process as early as possible), *the appropriate types and methods of participation, strong leaders, rights and governance*.

Rowe and Frewer's framework (2000) draw on both *normative* and *pragmatic* perspectives to suggest two types of criteria to evaluate attributes regarding methods and techniques. They are *acceptance criteria* which consider attributes that make methods acceptable to the wider public, and *process criteria* which concern the effectiveness of features of the process. The authors aim to provide an optimal benchmark to compare and measure different methods in the manner that reflects and acknowledges democratic ideals, enhancing trust in agencies, and transparency in governance (Rowe & Frewer, 2000).

Overall, although more effort needs to be paid to monitoring the data for evaluation, most of the literature suggests that more intensive process design will yield good results (Beierle & Cayford 2002; Newig & Frisch 2009; Sterling et al. 2017).

2.3.3.3 The outcomes of participatory approach implementations

As mentioned in section 2.3.3.1, the issue is the missing connections from *process outputs* to the *social outcomes* and *environmental outcomes* (Koontz & Thomas 2005). It is likely that while the distance between *outputs* and social *outcomes* is bridged by the *process design* and its *execution*, the connection between the participatory *process* and *environmental outcomes* is much more complex as the process of *implementing* decisions has not yet been well analysed in the literature.

Outputs are usually defined in *formal agreements*. They are either plans, policies, legislation regulations, and proposals for public officials to review or *innovations* such as strategies, alternatives, and ideas and other items generated by participatory efforts later on (Connick & Innes, 2003; Lamers et al., 2010; Leach et al., 2002; Newig & Fritsch, 2009; Susskind et al., 2010).

Tangible *outcomes* such as an agreement (in conflicted situations) and strategies (to overcome stalemate) are usually used to measure the success of the process in terms of *social outcomes* (Innes & Booher, 1999).

The achievement of *environmental outcomes* depend solely on whether the *outputs* are implemented or not (figure 2.12). A comparative analysis of 76 watershed partnerships carried out by Leach (2006) found out that in *one third of the cases* there was at least *one* project being implemented. As *reaching agreement* and *funding* are two main factors affecting the implementation process (Leach & Sabatier, 2005), the tangible policy impacts may gradually appear after four or more years (Leach et al., 2002). Mandarano (2008) also found that *funding* and having adequate *resources* play a crucial role in implementation. Furthermore, *networks* such as interpersonal, inter-organisational and political networks were highlighted as important factors to support the recommendations, coordinated actions and to create capacity to address the problem of member turnover (Koontz & Newig, 2014; Margerum, 2008).

The social outcomes evaluation

The social outcomes which are usually termed interchangeably as intangible products (Innes and Booher 1999) or intermediary outcomes (Carr et al., 2012) are defined as the effects of the participatory process on changing social conditions (Gruber, 2010; Putnam, 1995) or as the 'social capital, political capital, intellectual capital' (Mandarano, 2008b, p. 457). Some concrete examples of social outcomes can include: *transformations* of stakeholders' perspectives via social learning which fosters shared understanding and changes in their attitudes, behaviours and actions; *new personal and professional networks* leading to changes in the dynamic of the conversation; establishing new participants networks; widely acceptable, practical and implementable decisions; building up trust in institutions and among stakeholders; and resolving conflict among competing interests (Beierle and Cayford 2002; Connick and Innes 2003; Pretty 2003; Leach 2006; Newig and Frisch 2009).

Beierle and Cayford (2002) studied the social outcomes of participatory processes by scoring five different social goals: how many cases and to what degree public values were incorporated in the decision; to what extent the substantive quality of decisions was improved by creative problem solving, innovative ideas or new information; the extent to which conflicts were resolved at the end of the process; the degree to which mistrust of institutions was resolved; and how much the public learnt about the issues to actively engage in the decision-making process. The main identified tension was the *balance between meeting social goals* and *failing to engage the wider public*. Leach (2006) also reported tension coming from the marginal parties whose values and perspectives was not well-understood (Leach & Sabatier, 2005; Leach 2006).

Innes and Booher's framework (1999) is another example of using social outcomes as evaluation tools in water policy making. In the framework, nine main criteria were developed at three levels (Figure 2.13). *First order effects* related to developing of social, political and intellectual capital, agreements, and innovative ideas and strategies; *second order effects* which arise in the first or second year of implementation, including new partnerships and collaborative activities, coordinative actions and learnings; and *third order effects* which are usually the enhancement of first- and second-order effects. The results of the study support the claims that participatory processes can resolve conflicts of interests among various stakeholders and shape decision-making practices.

First Order Effects	**Second Order Effects**	**Third Order Effects**
• Social Capital: Trust, Relationships	• New Partnerships	• New Collaborations
• Intellectual Capital: Mutual Understanding, Shared Problem Frames, Agreed Upon Data	• Coordination and Joint Action	• More Coevolution, Less Destructive Conflict
• Political Capital: Ability to Work Together for Agreed Ends	• Joint Learning Extends Into the Community	• Results on the Ground: Adaptation of Cities, Regions, Resources, Services
• High-Quality Agreements	• Implementation of Agreements	• New Institutions
• Innovative Strategies	• Changes in Practices	• New Norms and Heuristics
	• Changes in Perceptions	• New Discourses

Figure 2. 13: Three level effect of evaluation tool by Innes and Booher (1999, p.419)

Newig and Frisch (2009) found that public participation tends to foster social goals, such as *better acceptance rate, higher compliance and faster implementation*; *conflict resolution* and *trust building,* rather environment goals.

The environmental outcomes

Participatory efforts in NRM often aim to achieve environmental goals. Participatory projects/programmes that deal with soil erosion, forest fires, restoration, water quality improvement and pollution control, biodiversity conservation, and other environmental/ecosystem-oriented goals can be found in review papers such as Brooks et al., (2013), Koontz & Newig, (2014), Koontz & Thomas, (2006); Vente et al., (2016); Sterling et al., (2017). However, there is very little evidence of the achievement of environmental outcomes *due to participatory processes* (Newig 2012). Some of the reasons are difficulties in *measuring changes in environmental conditions,* the long time period between the implementation of outputs and environmental changes, and the lack of methods to disentangle the contributions of public participation and other factors (Koontz and Thomas 2006).

There have been several studies of: the evaluation of the effectiveness of participation on environmental improvements (Schweik & Thomas 2002; Mandarano 2008); environmental outcome evaluation frameworks (Koontz and Thomas 2006); the factors influencing implementation (Drazkiewicz et al., 2015); perceptions of implementation which are picked up from other streams of theory such as policy implementation; and collaborative implementation (Koont 2005; Koontz & Newig 2014). However, in most cases, environmental improvements as the results of policy changes, plans, or agreement were qualitatively evaluated by expert opinions via surveys, questionnaires, and structured and unstructured interviews combined with a review of the literatures and relevant documents, (Koontz & Newig 2014; Drazkiewicz et al. 2015) rather quantitative monitoring procedures or pre-determined evaluation parameters or aspects.

Conclusion

Literature on the participatory approach indicated that the benefits of public participation had been realised in both normative and instrumental viewpoints. Moreover, the research focus has gradually turned to systematically studying and evaluating the effectiveness and efficacy of the implementation. It insinuated a transformation from single-loop learning (learn to do things better) to double-loop learning, where the nature and values of the practices have been evaluated.

This section drew on the conceptualisation of public participation (figure 2.12) to break down and critically analyse the approach into several components, including contextual conditions, process design, the outputs and their implementation, and social and environmental outcomes. Some of the key implications or lessons that can be learnt to improve the effectiveness of public participation programmes are:

- Understanding contextual conditions in the study area are critical in identifying the issues, defining the programmes' objectives, and assisting process design and implementation.

- Context variables were usually generated to investigate Governance, institutional arrangement, and the socio-economic and cultural dimensions in which public engagement occurs.

- The process designs, which generally comprised of analysing the level of engagement, methods of participation, and stakeholders' analysis, have been perceived as the most crucial aspect contributing to the success of community engagement exercises.

- There are various frameworks developed to evaluate public participation programmes. They varied due to different views on the success that were influenced by the perspectives that the authors chose to draw on (normative and pragmatic perspectives).

- Outputs (such as plans, policies, proposals, strategies, alternatives, etc.) must be implemented so that environmental outcomes can come to life.

- Public participation tends to foster social goals rather than environmental goals, including *better acceptance* leading to *higher compliance and faster implementation*, *conflict resolution* and *trust-building*.

- There was little evidence showing participatory process leads to better environmental conditions due to difficulties in measuring environmental changes over a long time and separating the contribution of community engagement from other factors

2.4 Adaptive management

2.4.1 What is Adaptive Management?

The notion that adaptive management (AM) is a focus on a structured process of 'learning by doing' (Walters, 1997) is consistent throughout the literature. The underlying philosophy emphases the lack of knowledge about natural systems, leading to limitations in predicting outcomes of management alternatives. However, decisions must still be made regardless of these uncertainties (Chaffin & Gunderson, 2016; Lee, 1999; Pahl-Wostl, 2007a; Walters, 1986). The concept emerged in the 1970s as 'adaptive environmental assessment and management (AEAM)' describing a way to improve ecosystem management decisions in the face of complexity and uncertainty by continuously probing the responses of the system with interventions over time to adapt to changes and disruptions (Holling et al., 1978). The approach also arose in response to the frustration in endless efforts to make predictions through incorporating scientific knowledge into computational modelling (Walter, 1997). Since then, the concept has continued to evolve and has been hailed as one promising approach to addressing contemporary and future issues (Lee, 1999; Pahl-Wostl & Hare, 2004; Walters, 1986; Williams & Brown, 2014), and it is perceived as essential for the sustainability of natural systems (Allan & Stankey, 2009; Pahl-Wostl, 2009). However, it was not until 1990s that the application of the concept was widely translated into practice and attracted attention from resource managers as well as scientific communities around the world (Scarlett, 2013).

After about four decades of maturing, with an incredible growth in the literature (Allen et al., 2011; Hasselman, 2016; Mcfadden et al., 2011; Rist et al., 2012; Westgate et al., 2013), the definition of adaptive management was advanced to the level that different authors are generally in agreement. It is observed that the principal feature of *learning from the outcomes* of implementing well-designed experiments *to produce new information* (McLain & Lee, 1996) and the process *of adapting that new knowledge* into the next management cycle to reduce uncertainty lie at the heart of this iterative learning-based process (Williams, 2011a). Hence, monitoring procedures play a crucial role in gathering new information from the results of experimentation. However, institutions/organisations need to have the will and capacity to change in response to these new understandings (Pahl-Wostl 2007). As the systems are ever-changing, actions need to be done in an iterative manner to provide successful management and achieve social objectives over time (C. Allen & Garmestani, 2015; McLain & Lee, 1996). Holling (1978) and Walters (1986) emphasised the importance of stakeholder inclusion from the early stages throughout the process to reduce potential conflicts as well as enhance the knowledge base.

It is noteworthy that emerging from the literature, other terms related to AM also appeared prominently including adaptive co-management (ACM) and adaptive governance (AG). ACM focuses on the capacity of local groups to be 'self-organised' to shape and adapt to social and environmental changes within a location related to specific issues as participants are empowered to make joint decisions with authorities or their own decisions (Armitage, 2008; Carlsson & Berkes, 2005; Folke et al., 2005; Hasselman, 2016; Olsson et al., 2004; Plummer et al., 2012). AG was introduced mainly in the domains of resilience, social-ecological systems, and environmental governance (Chaffin et al., 2014). AG is identified as: the requirement for AM implementation (Gunderson & Light, 2006; Huitema et al., 2009), a method to explore social dimensions (e.g. conflicts among stakeholders) and adapt it along with ecological knowledge to solve dynamic ecosystems issues (Folke et al. 2005).

2.4.2 Principles and frameworks of adaptive management

It has been identified that at least three levels of social and institutional learning can occur throughout the process of implementing AM, namely incremental learning (single loop learning) which is the lowest level, episodic learning (double loop learning), and transformational learning (triple loop learning) which is the highest degree of learning (Gunderson & Holling, 2002). Therefore, in this section, the characteristics of different AM frameworks are discussed in association with the concepts of single loop, double loop and triple-loop learning (Hargrove, 2008; Pahl-Wostl, 2009).

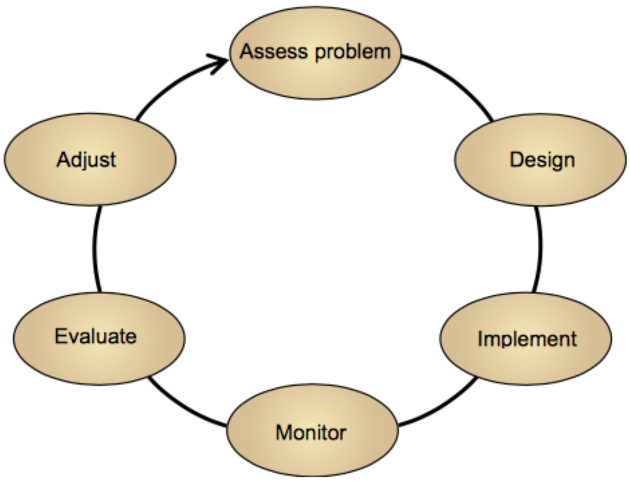


Figure 2. 14: Adaptive management cycle (Williams, Szaro & Shapio 2009, p.4)

Adapted from the works of Holling (1978) and Walters (1986), the operational adaptive management cycle was generated and modified for more than three decades (Duxbury & Dickinson, 2007; Fulton, 2010; Nyberg et al., 1999; Rist et al., 2013; Stankey et al., 2005; Williams et al., 2009) (Figure 2.14). Single-loop learning can be described as the process of answering the question ‘Are we doing things right?’ or ‘How should we do it?’ (Flood & Romm, 1996; van den Belt & Blake, 2015).

This learning mode assumes that the underlying understandings of the system, its dynamics and the interventions are 'correct' for achieving desirable outcomes, and hence, the new knowledge should only be learnt to change or improve the implementation of specific interventions, the instrumental changes (Argyris 1977; Flood & Romm 1996; Armitage et al, 2008; Pahl-Wostl 2009).

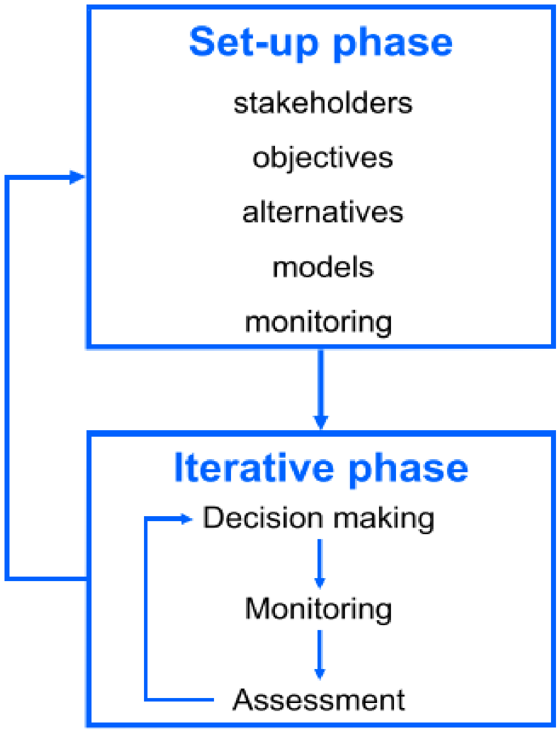


Figure 2. 15: Two-phase learning in adaptive management (Williams 2011, p.1348)

In 2007, William et al. conceptualised the adaptive management cycle from a decision theory perspective to develop a structured decision-making framework. The framework provides a 'picture' of the system through the interactions of the elements in *deliberative (set-up)* phase; and the operational process in the *iterative* phase (figure 2.15). The importance of the early engagement of stakeholders is explicitly expressed in the first phase and this is consistent with other prominent authors' ideas (C. Allen & Garmestani, 2015; Pahl-Wostl, 2007a). The *iterative phase* describes the process of subjecting the established system to experiments for learning purposes. The framework provides a typical example of applying 'double-loop' learning (Williams, 2011a). While there is a single loop in the iterative phase where new knowledge helps improving the choice of options, double loop learning that appears through interactions between the two phases highlights the reassessment of the overall assumptions in different perspectives on outcomes and instruments (Argyris 1976; Flood & Romm 1996; Van den Belt & Blake 2015). The reflection process repeatly raises the question of whether the understanding about the system in each timeslice of consideration is accurate or not, leading to the realisation that assumptions about one or more element in the iterative phase may not hold over time. Therefore, this reflection process might foster transformation or sometimes, reformation of objectives, models and hypotheses, or of the parameters to be monitored.

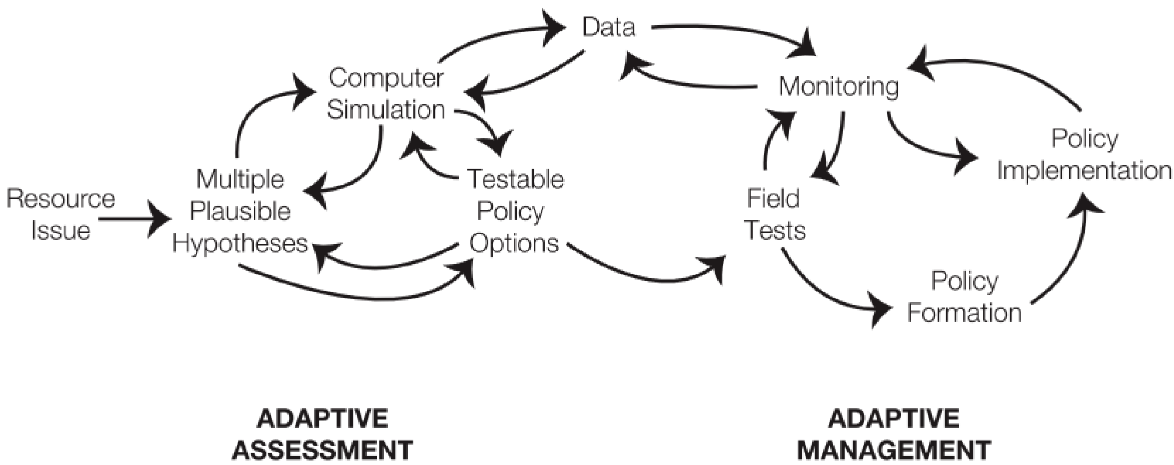


Figure 2. 16: Conceptual model of Adaptive Environmental Assessment and Management (Holling 1981)

This original conceptual model from Holling (1981) shows that the combination of two main interactive and ongoing processes, *adaptive assessment* and *adaptive management*, makes up a learning process that is able to deal with the uncertainties and complexities of the system (Holling et al., 1978; Walters, 1986). In the assessment phase, computer simulation models are used to generate sets of hypotheses and hypothetically test them with potential management interventions (policy options) to provide prior knowledge about the current state of the system and what responses to the interventions might look like. In the management process, experiments (treatments) are used to 'field test' the 'real' feedback of the system with the interventions. Features are detected via the ongoing procedure of monitoring sets of parameters in order to calibrate prior knowledge, then, ideally, individuals 'learn' to adapt part of or the whole cycle from the 'evaluation' phase. Besides its emphasis on the single and double loops, the conceptualisation also implicitly illustrates the ability to undergo transformational (triple loop) learning via a process of reflection on every structural element, which can be determined as the system's underlying 'beliefs' and 'values' (Pahl-Wostl 2009; Biggs et al 2011). The question 'How do we decide what is right?' is answered by critically reflecting on the way we 'learn' instead of selectively searching for process information to confirm one belief (Henly-shepard et al., 2014).

2.4.3 Approaches to adaptive management

In the literature, there are active (experimental) and passive (non-experimental) forms of adaptive management (Schreiber et al., 2004; Walters & Holling, 1990; Williams, 2011b). The differences between active and passive forms of adaptive management lie in the way uncertainty is recognised and treated (Williams 2011). While learning is explicitly part of the objective of minimising uncertainty in the case of active approaches, in the passive approach the focus is on resource objectives while learning is a by-product (Walters 1986). As a result, the pace of learning in an active approach is higher as experiments (different optimal actions) with multiple hypotheses are purposefully tested to form a basis for the assessment of particular management actions to achieve desiable outcome.s On the other hand, the passive approach places 'historically informed best practices' (Allan 2007) at the centre of decision-making to formulate 'best guess' hypotheses. Monitoring data is then used to adjust model variables in response to new information (Gregory, Ohlson, et al., 2006; Walters & Hilborn, 1978).

Walter and Holling (1990) acknowledged two drawbacks of the passive approach: the inability to reveal the rational causal relationships between natural components and the failure to identify opportunities to improve system performance when both the chosen 'correct' model and the missing 'wrong' model anticipate the same response pattern in which the 'system is managed as though the wrong model were correct' (Walters & Holling, 1990, p. 2061). Furthermore, the passive approach is supposed to be a significantly slower instrument for learning (Gregory, Ohlson, et al., 2006). However, depending on how learning is used to improve management, a passive approach could be appropriate when experiments are designed to only enhance knowledge about just some aspects of a situation (Westgate et al., 2013) or when desirable outcomes could be reached by simply collecting further information (Walters, 1986). Overall, due to its lower cost and high level of readiness for implementation, passive AM can be useful in certain contexts (McCarthy & Possingham, 2007; Mcdonald-madden et al., 2011).

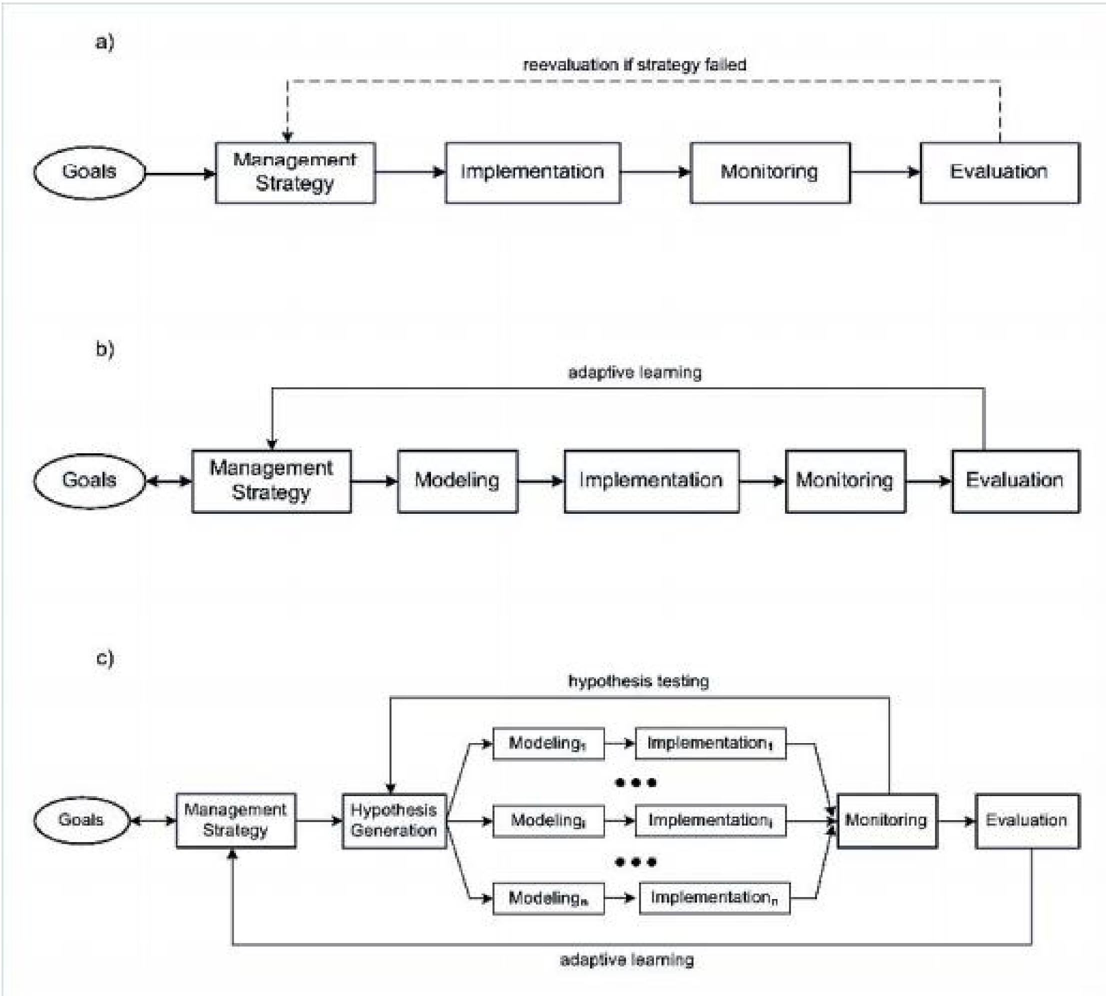


Figure 2. 17: Simplified conceptual framework of (a) traditional management; (b) passive adaptive management; and (c) active adaptive management (Linkov et al., 2006, p. 1080)

2.4.4 The application of the framework

The implementation of AM has been mostly in the domain of ecosystem restoration and conservation in ecology (Westgate et al., 2013). Despite the enthusiasm of the research community due to the benefits the approach promised, well documented successful cases of adaptive management implementation remain limited (Allen et al., 2011; Gregory, Ohlson, et al., 2006). To examine the viability of AM, in this section, a general overview of its application over time will be summarised, and then, the barriers to success are identified and discussed.

2.4.4.1 Adaptive management in practice

This subsection aims to discover how the adaptive management concept has been applied so far, how successful it has been and what the 'pathology' and challenges are. This is done by reviewing previous work in natural resource management and ecological conservation from the initial period up to now. Due to the limited documented evidence of the benefits of implementing an Adaptive management approach in urban water, the lessons and identified barriers in other domains are helpful to learn from.

The advantages of the AM approach have been widely recognised, as it has been adopted in the official agendas of many government agencies in the United States and Canada. In the early 1980s, the concepts of AM were endorsed by a number of institutions such as the Adaptive Environment Assessment Team of the U.S Fish and Wildlife Service's Western Energy and Land Use team, the US Department of the Interior, the Great Lakes Fishery Commission, the Bureau of Land Management, the US Forest Service, the Ontario Ministry of Natural Resources, Fisheries and Ocean Canada, and the British Columbia Hydro and British Columbia Forest Service (Murray et al. 2015). In Canada, adaptive environmental assessment processes were even introduced in the Canadian Environmental Assessment Act in 2003 and are featured in the Canadian Environmental

Assessment Agency reviews and court decisions (Murray et al. 2005). However, despite being adopted by many institutions, most researchers and practitioners testified that by not explicitly requiring monitoring and not accommodating iterative mechanisms, the current legal framework is impeding the implementation of adaptive management (Gunderson et al., 2017).

Adaptive management implementation and how well it plays out in real world settings

Over the last four decades, there have been many efforts to examine the use of adaptive management in solving natural resources issues through reviewing previous attempts. Some of the prominent works include Lee and McLain (1996) who analysed three early, somewhat unsuccessful case studies in the natural resource management domain: the review by Walter (1997; 2007) about his personal experiences as one of the pioneers in the field and the overall review of barriers preventing successful AM implementation; and quantitative systemic reviews by (Mcfadden et al., 2011; Rist et al., 2012; Westgate et al., 2013).

In their review paper, Lee and McLain (1996) showed three reasons for failure. The *first* one is an exclusive focus on scientific knowledge while neglecting the 'unquantifiable objectives' of socio-institutional factors. The *second* 'pitfall' is the lack of public participation and collaboration between stakeholders. The *third* is the lack of methods and processes to facilitate consensus building and shared understanding among stakeholders, leading to the deepening of existing conflicts.

Walters (1997) spoke from his 20 years of experience about how little AM has successfully solved problems. In his review, only seven out of 25 riparian and coastal ecosystems management projects resulted in experiments and only two of these experiments had well-planned statistical designs. The other exercises either failed to identify alternatives or 'vanished with no visible product' or became stuck in endless model refinement processes. Several reasons have been identified for the belief that complicated modelling exercises can replace experimentation. They include: the belief that experiments are unnecessarily expensive or ecologically risky; the intention to maintain self-interest in management bureaucracies; and value conflicts between stakeholders. Plus, reviewed projects left opened the question of how large the scale for applying the AM approach should be. Also, in his later publication in 2007, Walters concluded that there have been around 100 cases of AM application, ranging from restoration of fish species to protection of the Great Barrier Reef, that have failed to either implement the experimental plan or overcome the problems related to monitoring programs.

In their quantitative literature , some critical findings can be drawn out regarding different approaches to *evaluating the degree of success* (Mcfadden et al., 2011; Rist et al., 2012; Westgate et al., 2013).

The variety in temporal scope and the domains covered by the literature is noteworthy. Mcfadden, Hiller and Tyre (2011) examined literature from 2000 to 2009 in the field of wildlife management and ecological conservation. Mcfadden, Hiller and Tyre (2011) and Rist, Campbell & Frost (2012) considered documents from 2008 to 2009 about natural resources management, while Westgate, Likens & Lindenmayer (2013) did a broad structured review from 1978 to 2011 in the fields of ecology, fisheries, and biodiversity conservation. Despite this variety, there is no conflict in their conclusions. Although the study aim is similar in these documents, their methods of analysis varied. Mcfadden, Hiller and Tyre (2011) made a comparative analysis based on an approach following hierarchy categories containing 'mention', 'theory', 'suggest', 'framework', and 'implement'. The other two documents focus more on identifying the rarity of AM when it comes to literature on implementation. The portrayal of AM elements is used as the criterion to rate the degree of success.

The findings indicated that AM projects described in the literature are very rare, which is consistent with the widely-held opinions of Stankey et al. (2005), Walters (2007), William et al. (2009) and (C. Allen et al., 2011). Moreover, in these rare cases, AM projects have been found to be unable to meet their high expectations. From these publications, it is observed that only 14%, 8%, and 5% of the papers documented the implementation of AM approach in (Mcfadden et al., 2011; Rist et al., 2012; Westgate et al., 2013), respectively. Further, among the 8% (15 papers) describing AM applications from Rist, Campell & Frost (2012), less than five attributes were covered in each paper on average, and only nine studies claimed to have been successful in completing one full management cycle. In addition, there is no trace of adapting options in response to monitoring data yet (Rist et al. 2012). In the paper of Westgate, Likens & Lindenmayer (2013), only 13 out of 54 projects provided quantitative data showing how the results from management interventions were 'leant' and only in five projects did changes occur based on the results from monitoring and evaluation processes. These findings clearly show how little knowledge and data we have to validate the promises this theory brings. However, Mcfadden, Hiller and Tyre (2011) suggested that there was a trend away from theoretical development to realising the application of the AM approach to addressing future complexity and uncertainty. Moreover, the reason why there are few published works about the implementation of AM might be the timeframe of operating implementation processes (Mcfadden et al., 2011).

Guidelines or structured documents about the methods used to implement the AM approach so far, especially in urban water sector have been limited. However, there are a few candidates for methods that can support an adaptive approach to planning and decision-making that have recently emerged. The one that has recently been attracting the most attention from organisations around Australia is an adaptive pathway planning approach.

Adaptive pathways planning approach

In general, adaptive pathways planning (APP), sometimes called 'adaptation pathways', is a practical and analytical approach to planning. It explicitly and actively monitors and responds to future uncertainty and changes (Brotchie & Williams, 2017). The approach provides elaborated principles and steps to guide water professionals to identify, sequence, and adaptively implement decisions over time. Lin et al. (2017) compiled this list of important issues that need to be investigated when taking an APP approach:

> Scenarios of climate, policy, population, and socioeconomic change; ongoing monitoring and learning about the possible changes in the key controlling variables of the system (e.g., sea levels, storm, flood, or fire events); uncertainties in the timing, location, extent, and magnitude of the changes; expected performance of the adaptation interventions under changing conditions and thresholds-of-potential concerns when interventions can no longer perform effectively; and 'trigger points' at which the existing path needs to be re-evaluated and new options and pathways developed. (Lin et al., 2017)

The analytical tool embodies several components or 'transient scenarios' in which:

- a full range of plausible futures and the associated uncertainties and their development over time are explored;
- different sequences of various combinations of options (pathways) can be considered as potential adjustment of plans corresponding to future changes
- a rigorous and transparent monitoring system connects to the decision-making process (Bloemen et al., 2017; Marjolijn Haasnoot et al., 2013).

While the essence of the adaptive pathways approach has remained unchanged, its application has varied, most prominently in coastal flood risk planning and management under climate change impacts such as:

- the Thames Estuary 2100 project in the United Kingdom (Reeder & Ranger, 2010);
- the Dutch Delta Plan in the Netherlands (Jeuken et al., 2015);
- flood risk management in the Hutt River region in New Zealand (J. Lawrence & Haasnoot, 2017);
- the Coastal Adaptation Pathways Program in Australia (Lin et al., 2017);

or in the urban water planning context:

- urban water supply and demand planning in London (Kingsborough et al., 2016a).
- Integrated wastewater system (Sadr et al., 2020)

Key strengths of the approach lie in the time aspects introduced to the planning. While the adaptation tipping point helps determine when the current strategy is no longer able to meet the objectives, and a new one is needed, importantly, the thinking behind the triggers specifies the lead time in implementing actions before reaching the tipping point (Kwadijk et al., 2010; Kwakkel et al., 2015). The outcomes are the preferred pathways chosen to achieve strategic objectives as the future unfolds. To that end, elements of future strategies are kept robust and flexible, with monitored signposts to inform triggers so that alternative options can be employed or delayed or pathways switched (Brotchie & Williams, 2017).

Among others, the 'values-rules-knowledge' (VRK) framework (Gorddard et al., 2016) is a prominent heuristic decision-supporting tool that is commonly employed as a perspective or a basis to help developing adaptation pathways in Australia (Colloff et al., 2017; Gorddard & Dunlop, 2018; Prober et al., 2017). VRK perspective/framework is a relatively new tool to identify enabling or constraining factors of the 'decision context' that expressly incorporate the social dimension. To that end, the framework focuses on interactions between societal values (goals and objectives influenced by stakeholders' values and preferences), societal rules (rules-in-use such as social norms and rules-in-forms such as laws, regulations and Governance), and knowledge (scientific knowledge about the problems in considerations). VRK was primarily adopted in coastal climate adaptation initiatives (Colloff et al., 2017; Gorddard et al., 2016) and in climate adaptation pathways for woodland landscapes (Prober et al., 2017). So far no document adequately describes the application of VRK in detail, or provides guidance on how exactly to incorporate the perspective with other approaches.

Overall, in the author's opinion, the APP approach is a methodology developed based on the 'traditional' AM principles and has the potential to be feasible in an urban water management context. So far, publications on its implementation have been insufficient to make a compelling argument on how successful it is compared to AM approach.

How Australian organisations have been taken up adaptive pathways planning approach in the planning processes and strategy development will be discussed further in section 3.2.

2.4.4.2 The challenges and barriers of implementing adaptive management

Besides the above documents which reflect the efficacy of AM concepts in multi-disciplinary viewpoints, there were studies which focus on identifying the challenges of developing and implementing AM concepts in real-life settings from a theoretical perspective as well as on the practical implications from AM projects (C. Allen et al., 2011; Chaffin et al., 2016; Gregory, Failing, et al., 2006; Gunderson, 1999; Levine, 2004; McLain & Lee, 1996; Medema & Jeffrey, 2005; Rist et al., 2012; Scarlett, 2013; Walters, 1997, 2007). Such a lengthy accumulation of barriers from more than four decades of development and implementation can be summarised in the following table:

Table 2. 7: Challenges of adopting adaptive management approach

Process	**Barriers / Causes of failure**
Planning and decision-making	Decision-makers fail to understand the need for adaptive management
	Decision-makers are risk averse, reluctant to invest in long-term management, trade-off between the present and future value of management experimentation

	A focus on planning and discussion with a laissez faire approach treated as an option (action procrastination)
	Insufficient attention to building shared understanding and joint decision-making among diverse interest groups
	Tendency of scientists to overstate their ability to measure complex functional relationships experimentally
	Conflict and self-serving behaviour impede leadership, communication and joint action
Implementation	Difficulty of conducting experiments
	Implementation and monitoring are expensive, funding for the monitoring required to successfully compare the outcomes of different management options is inadequate
	Learning is not used to modify policy and management; costs and delays associated with gathering information and learning
	Institutional fragmentation where multiple organisations have overlapping management responsibilities
	Lack of leadership and trust
	Lack of stakeholder engagement
Monitoring and evaluation	Scientists fail to recognise the full range of management options; belief by management agencies that a single best policy confers credibility; surprises are suppressed
	Management goals become subordinate to research interests, valuing actions more than social learning.

In their comparative case studies analysis, Kochskämper et al. (2021) investigated five adaptive management projects on water quality enhancement to identify factors influencing learning, environmental improvement, and the successful delivery of a project. The findings from this empirical study indicated that the management of both ecological uncertainties (how interventions can improve water quality) and social uncertainties (how parties will respond to interventions) could enable double-loop learning, which stimulates innovations (Kochskämper et al., 2021). Also, it helped in measuring how successful the outcomes of adaptive management processes are. Furthermore, to reduce ecological uncertainties, knowledge obtained from the experts, or the integration of different knowledge types (via stakeholders and public engagement) contributed equally to assessing options performance and environmental improvement. Moreover, stakeholders' participation played a vital role in increasing the acceptance rate for experiments and reducing social uncertainty via trust-building and shared understandings.

Although Table 2.7 summarises current state of knowledge regarding the lessons from the implementation of AM concepts, the literature is located mainly in the ecological domain without any insights in the field of urban water research. Therefore, the barriers can potentially only be translated into urban water area in equivalent terms and in a predictive manner.

2.5 Towards a combined approach.

This chapter has presented the merits and some drawbacks of the three approaches as presented in the literature. Hence, this section will provide a summary of key findings and the possible areas to explore for the next chapter.

Academics and practitioners believe that further investigation and development of IUWM is a critical step forward to achieving social, environmental, and economic objectives in the urban water context. The current practice of IUWM in Australia, has demonstrated some progress in this regard, since plans for incorporating wastewater recycling, stormwater reuse, and desalination plants into the water supply and demand planning and drought response strategy as alternative water sources and responses to environmental concerns, have been published.

A review of public participation literature conducted broadly in natural resources management, and water resources management illustrated several implications or lessons that the urban water sector can utilise to improve community engagement programs. They were mainly related to how the context variables and process design components contributed to the overall success of a public participation program. Moreover, as it appears community engagement tends to help achieve social goals rather than environmental goals, there is a need for a comprehensive evaluation framework to investigate and assess its practices.

Even though the literature on the application of Adaptive management in natural resources management or ecological conservations illustrated very few successful cases, the approach is still an aspiration for dealing with unavoidable future uncertainty. Although AM is not standard practice in the urban water sector, recently, in response to unexpected extreme events, it has appeared in various urban water utilities' strategies (more detail in chapter 3) mainly in the form of an adaptive pathway planning approach.

The notion of combining integrated and adaptive approaches is not new, as it can be found in water resource management literature (Bichai & Flamini, 2018; Butler et al., 2016; Fritsch, 2017; Gain et al., 2013; Geldof, 1995; Mukheibir, Howe, et al., 2015; Pahl-Wostl et al., 2011; Rouillard et al., 2013). These authors have illustrated that Integrated Water Resources Management (IWRM) should be comprehended as the goal and overall strategy, and adaptive management should be seen as the process of implementing this strategy and accomplishing its goals as conditions change. To be more specific, IWRM, which is a framework that broadens the planning and management goal and scope through integration and coordination across scales and sectors, does not pay attention to uncertainties and the learning process to reduce those uncertainties. As a result, the nature of learning to deal with the uncertainty of AM approach is a necessary complement (Akamani, 2016; Halbe et al., 2013; Medema & Jeffrey, 2005; Pahl-Wostl, 2007b).

In response to some recent catastrophic events (more detail in section 3.1), the Australian urban water sector is also trying to move toward combining *integrated, adaptive, and public participation* approaches for both theorists and practitioners (Melbourne Water et al., 2017; Mukheibir & Mitchell, 2014; NSW DPIE, 2021b, 2021a). However, there is a lack of cases and analysis to support the transformation. As a result, it led to the formation of research questions 1 & 2 to investigate how the three approaches could come together and what problems would come across. Analysis and discussions in chapter 3 will shed light on these questions.

RQ1: *To what extent are there examples where all the three approaches have been combined*?

RQ2: *What tensions and broader challenges are evident when planning water services using the three approaches*?

3 Chapter 3 –The three approaches combined in practice

From analysing the three approaches strengths and challenges in the previous chapter, a combined approach has been considered favourable to deal with the increasing complexity and future uncertainties. This chapter aims to focus specifically on the urban water sector in Australia to seek insights of the extent that the three approaches were combined and what tensions and issues could present challenges for the sector to move toward a sustainable paradigm.

This chapter sets out the problems that the urban water sector has had to faced recently and the overall trend of planning and management practice in section 3.1. Then, in section 3.2, the background of the transition to a combined approach and some typical examples are analysed and explained. The outcomes answered research question one in part. Afterwards, section 3.3 discusses the tensions of combining the three approaches from a theoretical perspective. Subsequently, the impediments to employing the combined approach are investigated in section 3.4. Finally, section 3.5 provides a summary and conclusion remarks.

3.1 The current situation

In the Australian urban water context, the general practice is to exploit the idea of IUWM by integrating urban streams (supply, drainage, and stormwater) and other sectors such as energy and urban planning. The aspiration is to include stakeholders and the wider public in planning and management process (in such cases as the 2020 Draft Lower Hunter Water Security Plan or 2017 Yarra Valley Water's citizen jury) and encouraging decentralised and distributed innovations. IUWM projects have usually manifested in the form of wastewater and stormwater reuse and recycle planning for the purposes of diversifying water sources and protecting the environment (Mitchell 2006; Ferguson et al. 2013). However, there are two issues which arise over time. The first one is that the implementation is either challenging and does not always work out as planned or the idea of doing IUWM was so attractive that the implementation of several non-IUWM project were still being branded as IUWM (Furlong et al. 2016). A case study analysis from Melbourne pointed out that IUWM implementation has trouble overcoming several issues such as developing unambiguous definitions and methods, inadequate risk assessment, a lack of collaboration between governance levels combined with the absence of a common financial evaluation process (which induces difficulties in approval processes); and a lack of political and community preferences in planning processes. In the Melbourne case study, only three out of seven IUWM projects have been implemented, the rest faced difficulties with the process impediments pointed out earlier. Secondly, the governance of urban water is still dominated by top-down technocratic approaches, leading to the promotion of large-scale technological solutions to further expand centralised systems (Keath and Brown 2009) rather than sustainable practices (Farrelly & Brown, 2011).

Over the past five years, the unpredictable series of extreme weather events have reinforced the view that ever-growing complexity and uncertainty will always be embodied within the urban water system. The three years of unforeseen severe droughts that led up to the worst bushfire season, ‘the black summer’ of 2020, and most recently, the flooding emergency of 2022, caused significant loss and distress within economic and social components. The severe consequences can be minimized by improving adaptation local and national strategies to the inevitable increase of drought risk and committing to global climate change mitigation efforts as suggested by Abram, et al., 2021 .The author sees those events as distinctive triggers for the Australian Government, responsible organisations, and the public to rethink the way urban water had been planned for and managed in the face of uncertainty.

From January 2017 until the March 2020, severe drought hit the Murray–Darling Basin and New South Wales where it was recorded as the driest 36 months period on record. Afterwards, this long period of high temperature and low moisture fuelled the worst bushfire season recorded in the history of New South Wales, the

2019-2020 'black summer' (Australia disaster resilience Knowledge Hub, n.d). The events were induced by the combined effects of anthropogenic climate change and unusual combination of multiple drivers of climate variability (El Niño-Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) and the Southern Annular Mode (SAM)), and were perceived as out of the reasonable planning assumptions envelop (Abram, et al., 2021). Recent research had shown that the possibility of severe climate conditions and the unprecedented bushfire at that level (2017 – 2020 period) was 0.5% which was equivalent to 200 years-return events (Squire et al., 2021).

Most recently, the recorded rainfall during the early March 2022 which caused amongst the most severe floods in NSW and Queensland, were declared a national emergency by the Prime Minister. As an attempt to explain the flooding emergency, Climate Council pointed out that while La Nina and other 'combination of weather systems' influenced the extreme events, the possibility of those highly destructive and intensive events were reinforced by climate change (Climate Council, 2022). Essentially, as the 'burning of coal, oil, and gas' drive the atmosphere warmer and wetter, the chance of extreme downpours was significantly increased. While there are different explanations/concepts which were communicated by scientists in media releases such as atmospheric rivers, La Nina 'on-steroids', etc., it is a common belief that the pattern and the intensity of rainfall are changing/increasing unexpectedly and the data that we are using to analyse those extreme events (observed data for around 110 years) is not sufficient or appropriate from a statistic perspective (Readfearn, 2022).

Those unforeseeable extreme weather events highlighted the impacts of uncertainty and how important it is to account for uncertainty when doing planning. Therefore, there is a need for acknowledging that there might even be 'unknown unknowns' in the future. Thus, changes in approach to prepare urban water system for those uncertainties are necessary.

3.2 The trend of shifting to a more integrated, adaptive, and participatory approach

It has been realised in Australia's urban water sector that extreme events, such as droughts and floods, can occur outside of the planning envelope. Thus, an adaptive management approach has been selected as a critical strategy to complement the IUWM and public participatory approaches to dealing with uncertainty in major metropolitan areas. While there have not been any cases in which the implementation of a combined approach was documented, a manifestation of such a trend can be found in recent official plans and strategies documents in Melbourne and Sydney. The general expected characteristics of the combined approach are synthesised from literature review and interpreted by the author in table 3.1.

Table 3. 1: Synthesis of characteristics of participatory, adaptive and integrated urban water management approach

Aspect of urban water management	*Conventional approach*	*Integrated approach*	*Participatory Adaptive and Integrated approach*
Overall approach	Integration is by accident. Water supply, wastewater and stormwater may be managed in the same agency as a matter of historical happenstance, but physically the three systems are separated	Physical and institutional integration is by design. Linkages are made between water supply, wastewater and stormwater, as well as with other areas of urban development, through highly coordinated management.	Physical and institutional and social (values) integration is by design. Linkages are made between water supply, wastewater and stormwater, as well as with other areas of urban development, through highly coordinated management in an on-going manner (following an adaptive management cycle). Management approach utilises both experimental policy and infrastructural interventions. Long-term planning for the future with flexible and robust strategies. Incorporating elements of uncertainties in planning and decision-making process. Planning adaptively and adapting to changes whenever new information becomes available.
Collaboration with stakeholders	Collaboration = public relations Other agencies and the public are approached when approval of a pre-chosen solution is required.	Collaboration = engagement Other agencies and the public search together for effective solutions.	Highly involve stakeholders and the communities in decision-making process with appropriate level of participation (may utilise IAP2's spectrum of participation) for future strategies, options, and implementation.

Choice of infrastructure	Infrastructure is made of concrete, metal or plastic.	Infrastructure can also be green including soils, vegetation and other natural systems.	Focus on Water Sensitive Urban Design (ecosystem-based designs) and water recycled schemes (for both potable and non-potable purposes). Utilise approaches such as Real Options Analysis, Adaptive Pathway planning approach, or/and Incremental/ modulated approach for infrastructural planning
Management of stormwater	Stormwater is a nuisance that is moved away from urban areas as rapidly as possible.	Stormwater is a resource that can be harvested for water supply and retained to support aquifers, waterways and biodiversity.	Stormwater is a resource that need to be recycled or reused for either potable or non-potable purposes. Stormwater management need to be incorporated with other urban streams.
Management of human waste	Human waste is collected, treated and disposed of to the environment.	Human waste is a resource and can be used productively for energy generation and nutrient recycling.	Human waste is a resource and can be used productively for energy generation and nutrient recycling.
Management of water demand	Investment in new supply sources and infrastructure.	Other options to reduce demand, harvest rainwater and reclaim wastewater are given priority over developing new resources.	Enhance water conservations and water demand management over augmenting supply source. Focus on distributed system of water recycling and reuse for potable and non-potable purposes.
Choice of technological solutions	Complexity is neglected and standard engineering initiatives are applied to individual components of the water cycle.	Diverse solutions (technological and ecological) and new management strategies are explored that encourage coordinated decisions involving water management, urban design and landscape architecture.	All options should be considered. Emphasis on creative and innovative cross-sectoral solutions that encompass various disciplines.

Before delving into analysing documents that displayed principles of a combined approach in Australian urban water planning and management, the author believes it is necessary to discuss the terms 'adaptive management' and 'adaptive planning'. While both terms refer to an underlying philosophy of 'learning by doing', there are subtle variations that would help position the approach within the urban water context.

3.2.1 Adaptive management approach versus adaptive planning

In the author's opinion, the adaptive management approach is a conceptual framework that encompasses Adaptive planning. The adaptive management cycle (Figure 2.12) provides information on why and how to implement such processes to constantly learn about the system over time, focusing on experimentations. The emphasis is on the iterative learning processes via ongoing monitoring and periodical evaluation and on improving understanding of urban water systems sufficient to make changes as soon as that new information/knowledge is made available. The outcome of the adaptive management approach should ideally be sustainable self-organised urban water systems (at regime level) that have all the social, environmental, Governance, and Institutional arrangements dimensions readied for learning about and adapting to uncertainties (or deep uncertainties).

On the other hand, adaptive planning is both an analytical method and a process that aims to answer those 'what' questions by utilising tools, data, and technology to analyse and make informed assumptions about future conditions. The author believes that the adaptive planning approach is an interpretation of the traditional adaptive management approach with more specific actions for the urban water context. The outcome of the adaptive planning process should be a long-term adaptive plan that supposedly improves the system's responsiveness and readiness to a range of future uncertain trends and shocks by exploring flexible and robust strategies with incorporated ongoing monitoring and reviewing procedures. The adaptive plan should deal with future uncertainties better than the traditional scenario-based predictive plan since, in the authors opinion, the latter one focuses on exploring path-dependent solutions in response to the most plausible scenario.

3.2.2 Introducing adaptive pathways planning in urban water sector

Recently, the most popular tool of choice for adaptive planning among Australian urban water utilities is the adaptive pathways planning (APP) approach. The development of pathways is the focus of the method. A pathway is made of a sequence of options under different scenarios. Potential pathway adjustments can be considered based on a set of triggers (tipping point) which is the point where the current options in play can no longer be effective, and a new intervention is needed. APP has been described as the best available tool to support decision-making in water supply and sewerage systems, watershed and waterway management and flood management (Bloemen et al., 2017; Brotchie & Williams, 2017; Lin et al., 2017). However, there is little empirical evidence of the method yielding concrete, practical success, particularly in the urban context. Thus, there is still a need for further trial and research about its strength and applicability.

Two standout examples of where the adaptive pathway approach has been studied as a methodology are firstly, to assist urban water supply and demand planning in London (Kingsborough et al., 2016a) and secondly, it was proposed to be used for strategic planning of integrated urban stormwater and wastewater systems in Sadr et al. (2020). Both these case studies aimed to account for medium and long-term future planning to deal with various uncertainties via flexible adaptive strategies by emphasizing selections of no regrets or avoiding maladaptation locked-in options.

In the first instance, qualitative techniques combined with quantitative assessment was used to demonstrate how risks varies dynamically for different adaptation pathways through transient scenarios. The adaptation pathways were identified by analysing how adaptation actions of six main portfolios held up over time against risk-based thresholds in different scenarios. A risk-based approach was adopted to specify the probability of the states of the system based on various climate change and populations indicators through time. The findings highlighted the effectiveness of the adaptive pathway approach in assisting long-term decision-making for flexible strategies that deemed more capable of dealing with uncertainty.

The second example illustrated a novel approach to use adaptive pathways in strategic planning of integrated urban stormwater and wastewater systems. The performance of adaptive strategies that made up potential pathways, were assessed by a regret-based method that considered multiple performance criteria and objectives within different scenarios. The study addressed robustness by considering range of individual and hybrid strategies. The flexibility of strategies was assessed by applying regret-based method on sets of reliability, resilience, and sustainability indicators. The adaptation thresholds were determined based on multiple criteria that contribute to the state of the 'sewer flooding', 'river flooding', and 'combined sewer overflow'. The future scenario was characterised by four factors and nine parameters. The result indicated that a mixture of grey and green strategies was desirable for both short-term robustness and long-term adaptability.

Adaptive management approach and adaptive planning, especially adaptive pathways approaches, have gained more and more attention in international and Australian urban water contexts. The next section will provide an overview of how the approach has been applied to compliment IUWM and public participatory approaches to tackle future uncertainties.

3.2.3 Evidence of the combined approach in the Australian urban water context

This sub-section aims to investigate the extent to which the combined approach has been articulated. For Australia's major cities such as Sydney and Melbourne, literature and documents analysis revealed that the adaptive management approach, especially adaptive pathways planning as a methodology and a tool, has recently been embraced in strategic planning together with IUWM and community engagement for future urban water systems.

a) Sydney

From a nested Sydney case study, elements of a combined approach have been featured and portrayed differently in several key documents, such as the Metropolitan Water Plan (2017), the draft of the 2021 Greater Sydney Water Strategy, 2020 Western Sydney regional Master Plan (Re-imagining water in Western Sydney), the Greater Parramatta and Olympic Peninsula adaptive plan (2020), and the 2021 Draft Lower Hunter Water Security Plans.

The 2017 Metropolitan Water Plan (Metropolitan Water, 2017) emphasised the adaptive and participatory approach more than an IUWM one.

Adaptive management was highlighted by investigating various adaptation options for drought control, ongoing monitoring and 'adaptively managing' environmental flows in the Hawkesbury-Nepean river, and 'regularly reviewed' flow rules. The plan emphasised the vital role of ongoing monitoring, evaluation, and adjustment process (every five years) of water security and environmental flow rules in managing the water supply and demand.

In the author's opinion, the document did not focus on an integrated approach as the goal of the document was essential to secure water supply and demand with the consideration of drought response strategies and environmental flows protections. However, the aspiration to lay a foundation for an IUWM approach was demonstrated by establishing the WaterSmart Cities program as a strategy to improve the liveability and resilience of communities in Sydney. The program aims to explore opportunities for adopting integrated water cycle solutions by developing integrated strategies and plans in two pilot new developments.

The value of comprehensive community engagement was asserted throughout the documents. The 2017 plan was developed based on findings of the 2010 Metropolitan water plan review, in which extensive community and stakeholder engagement were conducted. The community engagement activities included deliberative community workshops, a one-day futures visioning workshop, annual community sentiment monitor surveys, and online focus groups. Moreover, the community's values, expectations, preferences, and priorities were incorporated into the action plans for expected outcomes such as future use of recycled water and the establishment of WaterSmart Cities programme.

The recent draft 2021 Greater Sydney Water Strategy (NSW DPIE, 2021a) outlines general strategy and aspirations in response to the 2017- 2020 severe drought by adopting a combined approach. The document acknowledged uncertainties regarding climate change impacts on water security (droughts) and dams operating at low levels during crises. Hence, it called for portfolios of creative adaptive responses and an adaptive approach to planning and decision making where strategy is designed to accommodate flexibility and robustness of short- and long-term objectives in an iterative manner. The adaptive approach is expected to include ongoing monitoring for critical changes in water demand, customer behaviours, social preferences, economic conditions, affordability, science and technology, climate change, the nature of urban form, and potential changes to standards. Further, the element of experimentation was added to the plan where a range of demonstration projects was utilised to understand integrated stormwater management solutions, reclamation of renewable gas from a wastewater treatment plant, or purified recycled wastewater.

'Re-imagining water in Western Sydney' (Sydney Water, 2020b) aims to go beyond the conventional servicing approach to adopt 'an adaptable and integrated water cycle management approach. The overall aim is to deliver the 'greatest economic value of water for 'shaping, building, greening, and cooling a new Western City'. Within this first Western Sydney Regional Master Plan, an adaptive pathway planning approach was adopted to accommodate multiple long term and short-term objectives. The Master Plan was described at a strategic level. Hence, there is a lack of specific steps. Overall, the key focus is on developing four servicing pathways with different levels of water integrations with considerations for potential triggers (decision-making point when specific intervention is no longer relevant and there is a need to switch to others).

The intentions of the plan are:

- to consider a wide range of integrated options and their economic values
- to focus on both immediate actions and long-term interventions
- to adaptively tweak the plan as new information is made available (although there is no specific interval of time or plan for reviewing and adjusting)
- to establish a specific monitoring system following the specific triggers and actions.

The document introduced an overall integrated water cycle management approach that informed the whole master plan. The approach focuses on utilising stormwater and wastewater recycling and reuse to transform the urban environment into a greener and bluer one. To be more specific, a greener and bluer urban environment means that i) integrated solutions can help ensure the quality and quantity of South Creek and Hawkesbury Nepean river ii) recycled water and stormwater can help cooling and greening space for social activities ii) integrated services that change landscape can provide more space for recreational activities (such as retention basins, wetlands for stormwater).

Further, community engagement was specified as one of the nine main priorities of the master plan. While there is no information on how the participation program and procedures are mentioned, the action plans suggested public involvement, specifically in waterways protection and recycling water for drinking purposes.

In the planning document, Sydney Water's adaptive water cycle management plan developed for Greater Parramatta and the Olympic Peninsula region (Sydney Water, 2020a) provides an integrated and adaptable vision to support decisions and policy-making in response to future uncertainty. The adaptive pathways plan was developed in the context of revitalisation and activation of the Parramatta region through infrastructure development. Circular economy concepts, integrated resource management approach, and Real options analysis were adopted to assist with developing and accessing resilient, integrated solutions by which the adaptive pathways were shaped within different scenarios.

The IUWM elements appeared to bring a step-up from the current services by including a range of alternative water sources on top of the traditional essential services (water is supplied from the dams and discharged to the wastewater treatment plant). Those are:

- Recycled water for non-drinking purposes such as cooling towers and toilet flushing
- Purified recycled water for drinking,
- Stormwater: flood management, bank naturalisation, stormwater and rainwater harvesting, water sensitive urban design (WSUD)

Public participation was mentioned only in the education and consultation regarding the acceptance of purified recycled water for drinking in this adaptive plan. Thus, the author trusts that inputs from community engagement could also be useful in developing portfolio of options especially in stormwater management options such as rainwater harvesting and WSUD since they directly related to how liveability and resilience can be built within the community.

b) Lower Hunter

The 2021 Draft Lower Hunter Water Security Plan (NSW DPIE, 2021b) might potentially be a typical example on how the three approaches can work together.

An adaptive approach was placed at the core of the Lower Hunter Water Security Plan (NSW DPIE, 2021b). The document has been developed in collaboration with customers who had just suffered droughts and floods that went beyond any projections. Thus, acknowledgement of climate emergencies and uncertainty should be cleared. While the plan aims to accommodate multiple objectives by adopting an integrated and adaptive approach, securing water supply against drought is especially emphasised. Therefore, with the priority to increase future resilience against uncertainties, planning adaptively and employing adaptive pathways modelling are among the key focuses of the strategy. The document highlighted flexibility by proposing:

- No-regret action ('soft' solutions) such as demand management, water recycling
- Incremental investment approach to avoid locked-in options
- Preparatory steps for contingency plan such as land acquisition, design and funding approvals for a desalination plant.

Although ongoing monitoring and adaptation and adaptive pathways modelling are mentioned, there have not been any details on how those processes would be developed and implemented.

c) Melbourne

An adaptive and integrated management approach was widely adopted in strategic planning documents issued by Melbourne metropolitan water retailers and Melbourne Water.

Overall, adaptation strategies comprised of innovative, flexible, and robust options and an implementation plan to carry out in an adaptive manner play vital roles in addressing future uncertainties. So, the concept is to follow a structured process in which management practices are constantly being evaluated and updated based on the latest available information gathered from an ongoing monitoring and evaluation procedure. The approach is the critical component of ‘urban water strategies’ (UWS) developed by Melbourne metropolitan retail water corporations (City West Water, South East Water and Yarra Valley Water) and Melbourne Water System Strategy (MWSS), Sewerage strategy, Healthy Waterways Strategy, flood management strategy developed by Melbourne water, the sole wholesaler (Melbourne Water et al., 2017).

Before getting into details of how organisations interpreted the ‘general’ adaptive management approach, it would be helpful to investigate the bigger picture of how the strategies and processes fit together (see Figure 3.1).

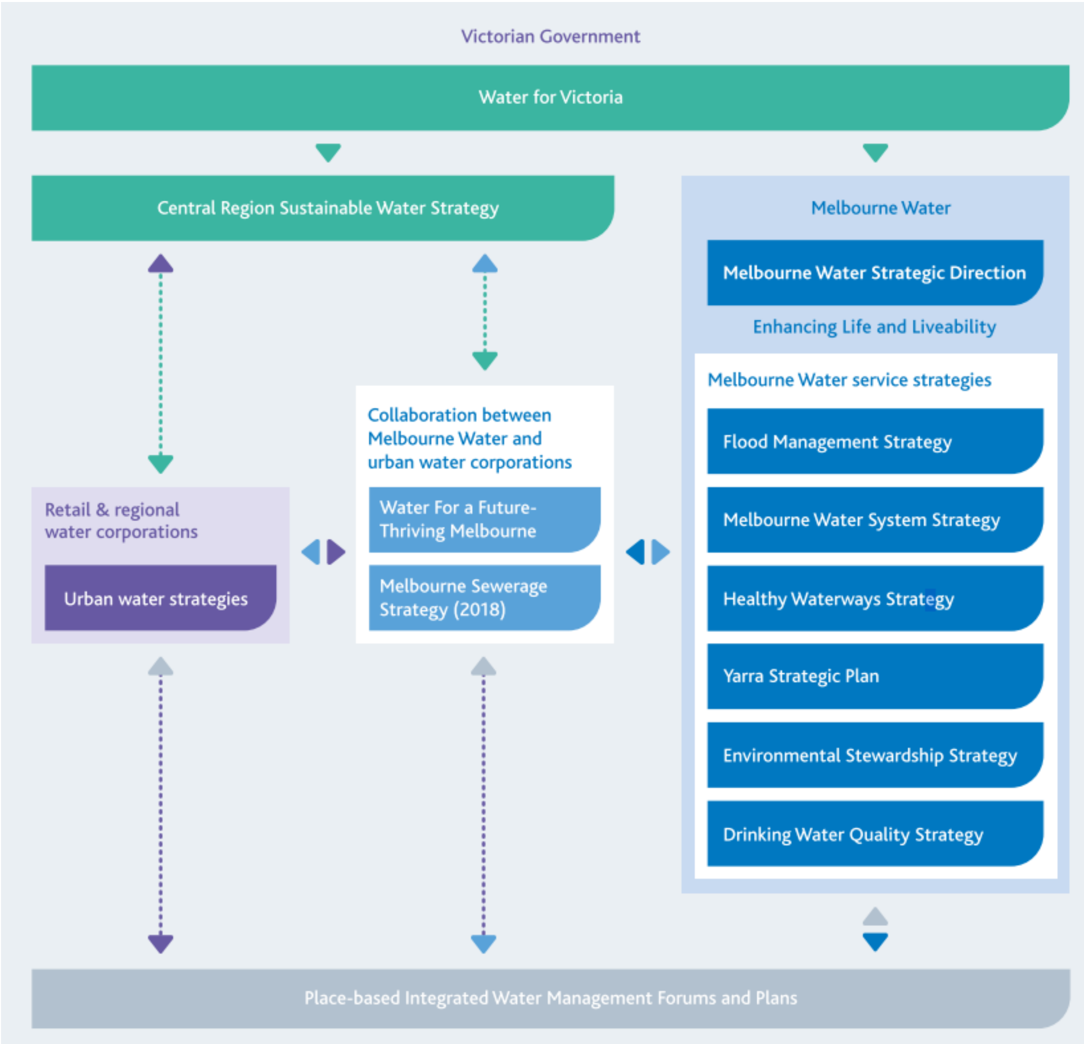


Figure 3. 1: Overview of Strategies and Plan in Melbourne (DELWP, 2017)

It all started with the commitment of the Victoria Government to ensure long term water security and sustainability to 'support a healthy environment, a prosperous economy and thriving communities. The overall goal is to meet the challenges of climate change and population growth by focusing on long term adaptive planning with innovative and efficient actions. This focus was highlighted in 'Water for Victoria' (DELWP, 2016), a statewide strategic plan for water resource management. To that end, adaptive management was adopted as a strategic approach for a 50-year-vision into the future by the next-in-line planning level, including Melbourne metropolitan urban water retailers and Melbourne Water. The approach was articulated in City West Water's, South East Water's and Yarra Valley Water's UWSs, and Melbourne Water's core service strategies before being embedded in placed-based action plans. It is noteworthy that the Melbourne Sewerage Strategy, which was developed in collaboration between Melbourne Water and those three urban water retailers, is also a core service of Melbourne Water.

Further, in 2017, the Integrated water management framework for Victoria (DELWP, 2017) was developed to guide the urban water sector to achieve the goals and objectives formulated in 'Water for Victoria' (DELWP, 2016). The framework provided a collaborative platform and standard structure for water planners at all levels, local governments, and the community to identify and prioritise options and opportunities for integrated solutions. Moreover, the document also included some guidelines and tools to support the IUWM approach. The framework was the backbone of all strategies developed for planning for the future (figure 3.1). More details on the IWM framework for Victoria can be found in section 2.2 of the previous chapter.

Melbourne metropolitan water retailers are required to develop Urban Water Strategies every five years, and Melbourne Water must formulate a Melbourne Water System Strategy. The UWSs are the plans and aspirations for securing water demand and supply balance for the next 50 years, considering climate uncertainties and population growth (Melbourne Water et al., 2017). Moreover, the UWSs also need to specify actions for the next five years. The MWSS provides a view of Melbourne's water resources governance toward 2065. In detail, the document examines the challenges and outlines solutions (an adaptive portfolio approach), including improving water supply efficiency, demand management, diversification of water sources, and optimisation of the water grid and market (Melbourne Water & Victoria State Government, 2017). Aligning with the vision from 'water for Victoria', the adaptive management plan sets out a number of short and long-term processes that will be periodically and iteratively evaluated as detailed in figure 3.2.

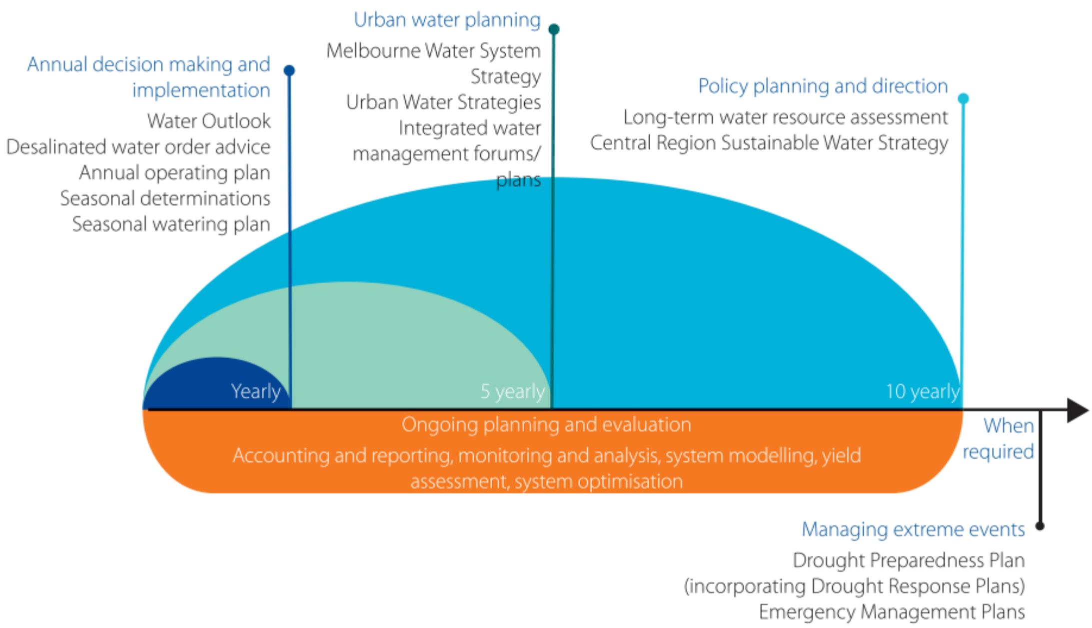


Figure 3. 2: The adaptive management plans (NSW DPIE, 2021b)

Within those 'urban water strategies' and 'Melbourne water system strategy', key responses to future uncertainties to achieve desired vision are:

- an adaptive management framework
- a diverse portfolio of supply and demand options
- making appropriate investments.

So essentially, a wide range of adaptation options ought to be considered to formulate flexible and robust strategies. Further, the strategy and plans are proposed to be implemented adaptively following an adaptive management cycle. Some components can be highlighted, such as:

- The focus on proactive and adaptive planning cycle for supply and demand management under various climate scenarios:
- Monitoring and review of triggers for the 'desalinated water order process' and 'drought preparedness plan'

- Ongoing monitoring risk to the system and continuous evaluation of actions and plans
- Utilizing adaptive pathways approach as a tool for 'flexible staged investments'.

Aligning with the goals and objectives of 'water for Victoria' and utilising the IWM framework for Victoria, some documents such as the Melbourne healthy waterway strategy (2018), the Melbourne Sewerage Strategy (2018), and the flood management strategy for Port Phillip and Westernport (2021) exhibits some characteristic of the combined approach.

In the 2018 healthy waterways strategy, the vision is enlarged to consider environmental, social, education and decision-making dimensions all together as a basis to achieve the strategy's goals. The adaptive management approach is maintained to improve the status quo through learning from implementation, and to explore uncertainties in 'temperature, changed rainfall patterns or sea level rise' (Melbourne Water, 2018a). The adaptive pathways planning approach is selected as an additional tool to assess options against uncertainties over time under different scenarios. As a result, the strategy can be flexible to modify the course of actions when needed in the future yet still robust enough to satisfy short-term objectives. Following the guidance of IWM for Victoria, the strategy placed waterways into a larger, integrated landscape and utilised community perceptions and values to set priority and action plans.

Melbourne Sewerage Strategy (2018), which was developed in collaboration between Melbourne Water and other metropolitan urban water corporations, is a part of the integral strategy adopted to deliver the sustainable objectives of Water for Victoria (2016). The vision for 2070 is to prepare 'a resilient and adaptable' sewerage system for Melbourne to deal with future uncertainties. The goals were set to optimise a range of urban water dimensions, including urban liveability, environmental protection, resource recovery, community awareness, and enabling policy and institutional arrangements. So, to achieve these goals, adaptive pathways planning was adopted as the tool to inform decision-making about future infrastructure plans (Melbourne Water, 2018b). The adaptive pathways method was proposed to use in an iterative manner by which the pathways should be monitored, evaluated, and adjusted regularly. Implementing adaptive pathways should be done in collaboration with other water corporations and Government agencies to improve understanding of the system limits, issues, interactions, options, and rules and regulations.

As Melbourne's water industry is committed to integrated water management, the sewerage strategy also picked up a system perspective to consider greenhouse gas emission reduction, sustainable waste management, and urban planning to maximise the social, environmental and economic benefits. Also, community engagement is necessary to understand social norms and contexts. All those information led to the identification and analysis of indicators for the triggers (where the current option can no longer keep the system stable), which contributed to the formulation of adaptive pathways under various scenarios.

The 2021 Flood management strategy for Port Phillip and Westernport, a ten-year strategy designed to enhance the region's flood resilience, liveability and sustainability, recognised climate change, population growth, and land-use change as major issues (Melbourne Water, 2021). While 'adaptive approaches' and 'adaptive thinking' were proposed to identify and address climate change uncertainty to support decision making on future infrastructure investment, there is no specification on how to implement and what tools would be helpful in that context.

d) City of Gold Coast (CoGC)

The Gold Coast Water Strategy 2019 – 2024 were developed based on the shared vision through an extensive collaboration process between CoGC, CRC for Water Sensitive Cities, State, research institutes and industry representative, and community groups. Inspired by the CRC WSC's urban water transition framework and the WSC index, the strategies and actions aim to achieve 'efficient, integrated, adaptive and sustainable outcomes for the community and the environment' (City of GoldCoast, 2019). The strategy followed a framework (figure 3.3) that aspired to long-term, resilient, liveable and sustainable planning consisting of environmental (our healthy waters), WSUD (water-inspired design), collaboration (partnerships for water), innovative solution components and their associated attributes.

Figure 3. 3: The city of GoldCoast water strategy framework (City of GoldCoast, 2019)

The actions plan for short to medium-term objectives and long-term goals within the framework's components indicates principles of a combined approach (IUWM, AM and PP). The long-term adaptive planning approach is adopted with potentially intensive collaborations between stakeholders, authorities, and the community, incorporating social and cultural values. The strategy accommodates a broad suite of sustainable solutions, including expanding the water recycled network, using renewable energy for water treatment plants, and exploring natural-based solutions (such as green infrastructures, stormwater harvesting, etc.) as sustainable stormwater management through experimenting (constructing and monitoring demonstration sites). Furthermore, the strategy places the integrated urban water systems at the centre of an urban planning approach, thus, connecting various sectors (land use, energy, transport, and parks infrastructure) within the plan. In the author's opinion, the application of innovative technologies, including smart metering and IoT for monitoring and evaluation of various water quality, supply and demand, leakage, etc. parameters, and the possible leeway for on-ground decentralised, community-led initiatives tie the whole vision together and set up a strong foundation for a future resilient city.

However, so far, there is little evidence of the implementation of the strategy. There is also a lack of mechanisms by which monitoring, evaluation, adaptation, as well as collaboration processes rely upon.

Overall, there has been a trend to shift the focus of urban water planning and management into a combined approach. While the AM approach was the novelty in documents, the IUWM and public participatory approaches were among the key pillars of the strategy. However, those documents are plans and strategies by which their implementations on the ground have not yet been documented. Therefore, the author was keen to investigate the practice further via in-depth interviews with senior urban water professionals. The chapter has partly answered research question one and provided insights into the extent to which the three approaches have been combined.

In the next section, the author attempted to find challenges and issues when adopting the combined approach.

3.3 Revealing the tensions between the three approaches

Literature on urban water management practice in Australia indicates several implications for adaptive management practices and the combination of the three approaches (AM, IUWM, and PP) in the urban water sector. Firstly, there is currently a lack of knowledge and empirical evidence on how the adaptive management approach could be carried out in practice the urban water context in

Australia. Whereas, IUWM and participatory processes and practices are relatively well documented in the literature. Secondly, after reviewing and synthesising the challenges and barriers to implementing the combined framework, the author recognised that while there have already been insightful works on the subject, the analysis of challenges and trade-offs in implementing the combined approach in the urban water domain has been limited.

While there is a lack of analysis of the combined of all three approaches in the urban water sector, there has been research in the binary integration of AM and Integrated Water Resources Management (Akamani, 2016; Fritsch, 2017; Halbe et al., 2013; Medema & Jeffrey, 2005; Pahl-Wostl, 2007b; Rouillard et al., 2013). Thus, from a theoretical perspective, this research intends to synthesise and interpret that information to guide the data collection process via a conceptual framework. Engle et al. (2011) tried to conceptually identify and analyse the challenges and trade-offs in implementing an adaptive and integrated water management framework based on their research in Brazil. In both AM and IWRM, a participatory approach is described as a critical component. Thus, this study has picked up the framework where Engle et al. (2011) left off to refine a suitable conceptual framework for the urban water context. The framework was used to guide the interview and facilitate the conversations with participants.

This section introduces the conceptual framework that drew on Engle et al. (2011) (see Figure 3.1) and synthesises the knowledge about the tensions of combining the three approaches from a theoretical point of view.

There are two parts to the conceptualisation from Engle et al. (2011). The first one is a 'theoretical graph' in which the characteristics and principles of the adaptive management and IWRM approaches, and the traditional modes of 'command and control' are compared. The second part is the reflection from practical experience to compare with the theoretical basis of each framework to reveal possible tensions that might arise in the adoption of the new combined framework termed 'adaptive and integrated management'. In this section, the framework consists of four potential tensions, namely 'socio-political'; 'value-based'; 'temporal'; and 'spatial boundary' are provided with examples from real-life projects. Engle et al. (2011) argued that the framework has the power to describe *negative interactions* when implementing adaptive and integrated water management and that the framework needs to be further tested but can be generalised as it also illustrates the conflicts between characteristics of these frameworks.

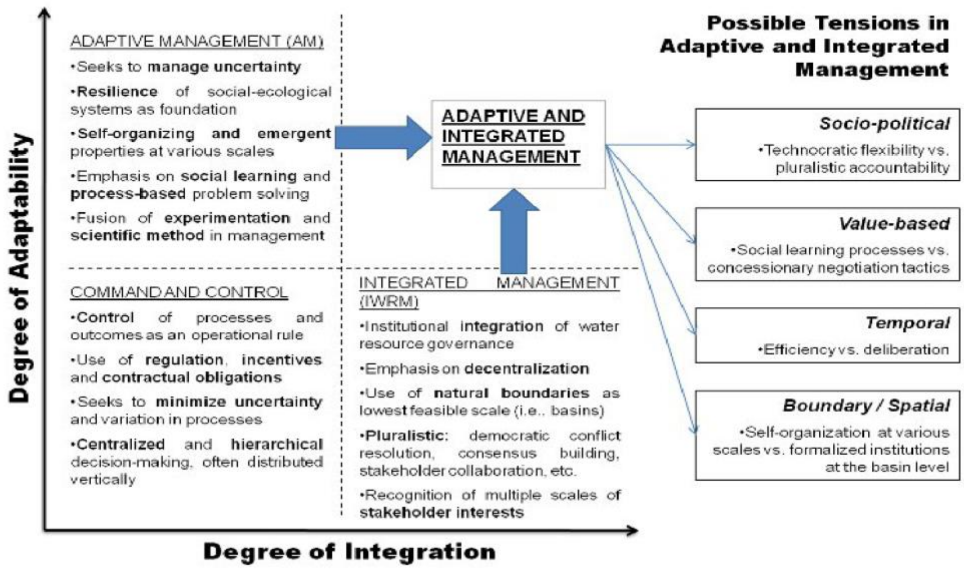


Figure 3. 4 :The conceptualization of possible tensions (Engle et al. 2011, p.5)

There are two areas where this existing framework can be expanded further. Firstly, the inclusion of stakeholders and the public in planning and management processes is highly recognised in theory. While a handful of projects show positive public participation outcomes on different scales using various methods (as reviewed by (Dean et al., 2016)), there is scarcely any systemic approach, evaluation framework, or guidance to facilitate community engagement in IUWM projects. Also, it is evident that community engagement has recently received significant institutional support, as outlined in (DELWP, 2021; NSW DPE, 2022). Thus, to highlight the importance of participatory approaches in successfully implementing the combined framework, a new continuum of 'degree of participation' is added to the graph. The degree of participation follows the level of participation from the International Association for Public Participation (IAP2 2014). The assumption is that the ‘participation’ component of AM and IUWM varies from the lowest point of ‘informing’ to the middle ground of ‘involving’ the public in two-way conversations to the ‘command and control’ mode of governance with no participation at all. That brings the new paradigm termed the Participatory Adaptive Integrated Urban Water Management (PAIUWM) to the highest end of all three axes/ continuum (Figure 3.2). Nevertheless, it is noteworthy that the adequate level of participation in this research might not be necessary at the ‘empower’ level as suggested by IAP2 (2014). Instead, this research suggests that it would be more appropriate to take a ‘flexible selection of participation’s level based on deliberative process’ as the ultimate.

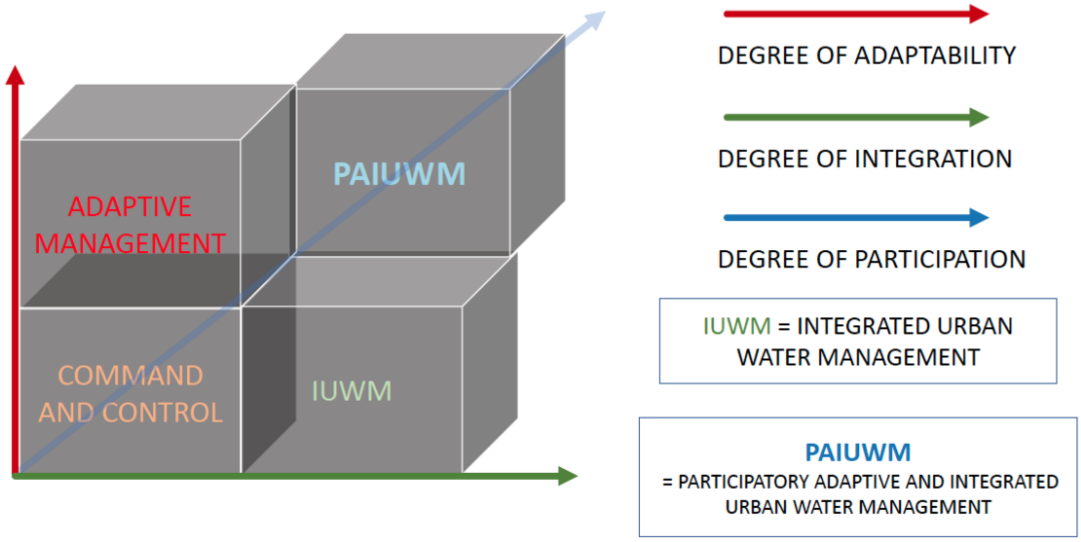


Figure 3. 5: A 3-Dimensions conceptual framework for urban water context

Secondly, regarding the challenges and tensions between AM, IUWM, and PA approaches, while it is commonly believed that they are mostly related to social-institutional factors, the technical aspects are also a significant factor mentioned countless times in the literature on all three frameworks. Technical factors include either quantitative/mathematical simulation models or qualitative mental models. Further, tensions also arise when considering the technical issues with other elements such as the ‘temporal’ and ‘spatial’ boundaries. Thus, this study contends that technical aspects should not be overlooked, and that ‘technical capacity’ should be included as the fifth element of the proposed conceptual framework (figure 3.3).

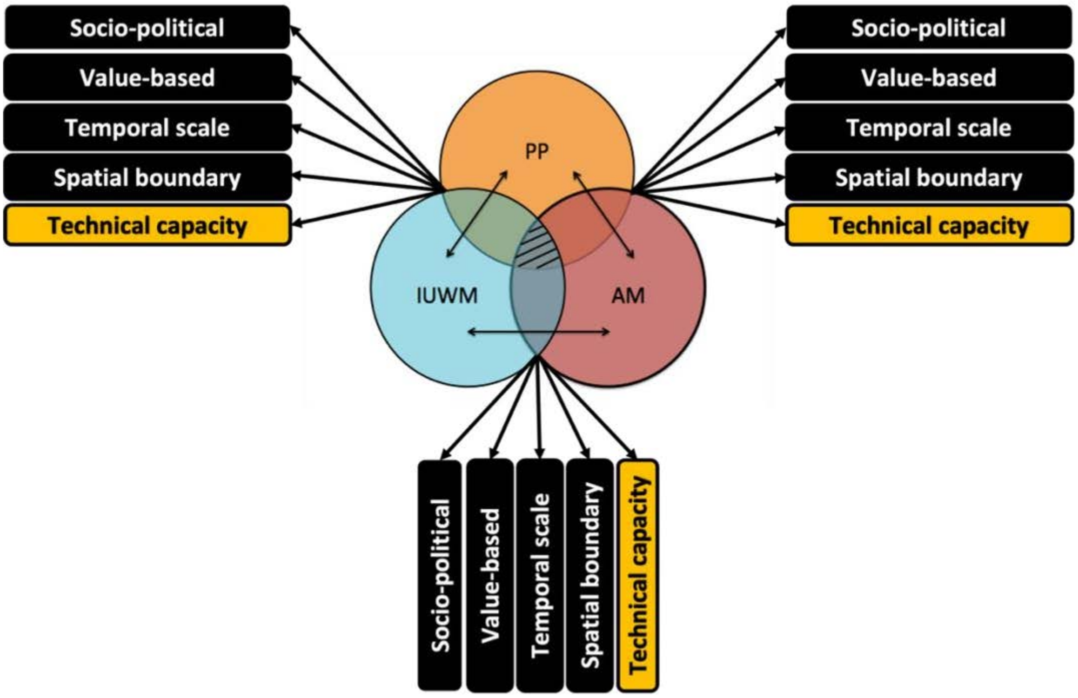


Figure 3. 6: Aspects of challenges and trade-offs

Table 3.1 summarises key trade-offs according to the five aspects of challenges (figure 3.3). Tensions were synthesised based on those identified in the literature from the international and Australian contexts. Information on the challenges and barriers of IUWM was reviewed in the urban water context. However, the tensions associated with AM and PP were translated to urban water context from environmental management, ecological restoration and conservation, risk management, and resilience theory.

Table 3. 2: The synthesis of key trade-offs when implementing the combined approach

The Frameworks	***Socio-political***	***Value-based***	***Temporal***	***Boundary/Spatial***	***Technical capacity***
AM + ***IUWM***	Both top-down, but one: Flexible governance that is willing to keep options open at different levels and scales (usually polycentric …) vs. Certain definite decisions agreed by meta-institutions through the integration of governance arrangements	Both based in systems thinking but one: Focuses on the unpredictability of science and technical realm, thus, willing to explore uncertainty to adapt through experiments and monitoring-evaluation processes (learning process; social learning process) vs. Hold the belief that the use of multi-perspectives, holistic approach with the help of science and technical expertise is enough to bring high level of certainty to make deterministic decisions in response to ad hoc issues	Ongoing, long-term planning vs. Usually one-off plan	Maybe large scale, boundaries draw on basis of ecosystems or biophysical processes vs. Commonly smaller scales boundaries drawn on land plan or governance boundaries such as precincts (sometimes catchments/ sub catchments)	Enough complexity to understand the interactions of aspects within the systems, but not making 'perfect' models and calculations (overcomplicated), so that there is room for systemic changes and adaptation. vs. Deterministic fixed black-box with high level of numerical calculations and simulations to capture intergraded systems

AM + ***PP***	One top-down and the other more bottom-up: Flexibility to make decisions (responsiveness) and readiness to implement time-sensitive options (especially in crisis events) by technocratic elites and government agencies vs. Longer and more complicated deliberative and participatory processes since groups of citizens are brought into key decision-making roles for decisions that affect their communities.	One based in complex system understanding and the other on a questioning of the legitimacy of decision-making; The values of these perspectives might pose no tensions. They may even complement each other as the PP processes are the main element to foster social/organisational learning for new knowledge to emerge, by which the monitoring and evaluation procedures as well as the implementation of adjusted decision are supported.	Long-term process of improving mechanisms to increase confidence in evaluation process and to foster learning for adjusting strategies; as well as the resources (time, money, effort, mechanisms, networks, platforms) to do so (from iterative nature of AM process) vs. Commonly short-term intense implementation of participatory/ deliberative practices	Large scale, complex and flexibility to change over time vs. Maintaining participant composition throughout the process	Methods and technology to interpret and communicate the complex models for eliciting participants' knowledge and support their understanding vs. Ability of lay people to express their views and concerns

	The trade-off between top-down and bottom-up approaches: Institutionalisation of public participation and of some AM processes such as monitoring, evaluation, iteration. vs. Weakened control power (political power) through the aforementioned process				
IUWM + **PP**	One top down and other more bottom up: Decision-making power rests with government agencies and technocratic elites vs. Democratic processes empowering community, including views of minority stakeholders	One based in holistic systems thinking and the other on a questioning of the legitimacy of decision-making: Goal of holistic investment decisions agreed by multiple parties and all major institutional stakeholders vs. Goal of legitimacy for decisions affecting communities to be based on deliberations of community members	Usually one-off projects (common)	Fixed projects boundaries vs. The changes in participation scope and scale according to options and unexpected externalities Boundaries set by limits of institutional control – land ownership such as local government area, planning precinct, growth etc. vs. Boundaries set by communities that can provide legitimacy to a decision (can be inconsistent and change throughout the process due to changes of goals or objectives of the projects)	Increasing model complexity for more rigorous and holistic system analysis vs. Wider public (lay people) capacity to understand and contribute meaningfully to the process

3.4 Challenges in adopting a combined approach in the urban water context

The transition to a sustainable urban water management paradigm centred around the three frameworks has been slow. This part provides an overview of the challenges when adopting the combined approach that can be found in the literature.

In 2020, the Productivity Commission (an Australian Government's independent research and advisory) issued a paper identifying critical impediments/barriers to implementing an Integrated Water Cycle Management (IWCM) approach in Australia's urban water sector. Ten thematic impediments were analysed in terms of policy context, service planning and delivery, and regulatory environment. While the paper focuses on IWCM, those barriers are also relevant to an adaptive management approach, in the author's opinion.

Regarding the policy context, firstly, there are disconnections between urban amenity provision planning and urban water planning. To be more specific, there is no explicit acknowledgement of the benefits that the water sector can contribute to different aspects of urban amenity. Thus, the roles and responsibilities of the water sector in urban amenity planning are unclear. Moreover, there is no formal channel for communication or collaboration between urban planning and the water sector in all States, except Western Australia. Secondly, the policy frameworks and institutional arrangements for water supply and wastewater management differ from those that govern stormwater management. The omission of stormwater management in the national water reform agenda (the focus is on enhancing water supply and wastewater management) went against the definition of IWCM, which is the integrated management of water supply, wastewater and stormwater. Moreover, while water utilities provide water supply and wastewater services, stormwater is mainly managed by local governments. The lack of review and research on integrating stormwater planning and management as a key component in IWCM called for more attention in the future. Thirdly, the Government policy bans and mandates constrain options. For example, some fit-for-purpose water supply options are imposed by policy bans preventing lower-cost options to be considered. For example, the policy bans on recycled wastewater or treated stormwater to augment potable water supply directly and indirectly. On the other hand, water reuse and recycling targets mandates can lead to 'inefficient outcomes by preventing options from being assessed on their merits'.

Regarding water services planning and delivery, there has not been a straightforward Governance arrangement for effective collaboration between stakeholders regarding IWCM. Several factors that contribute to ineffective collaboration are the lack of effective collaborative mechanisms, decision-making processes, and risk allocation between organisations. Furthermore, assessing options and their performance against different scenarios using cost-effective analysis is not always rigorous and transparent. And finally, water planning at the local and system scales is not well integrated.

Regarding the regulatory environment, environmental regulations are inflexible regarding point source and non-point source pollution control. Environmental regulations have dealt mainly with point source pollution as it was the main environmental concern. However, diffuse sources of pollution, such as stormwater runoffs, which are the more significant threat to water quality, have been inadequately regulated (Productivity Commission, 2020). More in-depth analysis of regulations (or lack thereof) to control non-point source water pollution in Australia can be found in several publications by (Graham et al., 2011; Roberts & Craig, 2014; Wahchka & Gardner, 2012). As a result, the focus of regulators on point-source wastewater prevents integrated solutions to manage impacts of both point-source and non-point-sources. The reason for this impediment is that diffuse sources control might not achieve the standards due to the lack of understanding on 'stormwater flows in the urban environment and their nutrient loads'.

3.5 Summary

In this chapter, section 3.2 described where the urban water sector has been moving towards and explained instances in which qualities and elements of the three approaches have been demonstrated. The findings partly answered research question one (*To what extent are there examples where all the three approaches have been combined*?). However, there was no evidence among the three examples present that showed the effectiveness or applicability when actually implementing the combined approach. These have all been in the planning phase. Hence, the author believes that the research question still needs further examination.

Literature showed the lack of examples and analysis of the challenges and barriers to adopting the combined approach. In sections 3.3 and 3.4, the challenges and tensions that could impede the transformation of the urban water sector were synthesised from other disciplines and translated into the urban water context. As a result, the author realised a need to further explore research question two (*What tensions and broader challenges are evident when planning water services using the three approaches?)* in practical settings.

To that end, to gain better insights into the application of the combined approach and the emerging challenges and tensions, the author has chosen to conduct in-depth semi-structured interviews with various senior urban water professionals, as described further in this thesis.

4 Chapter 4 – Methodology

4.1 Introduction

The goal of this research is to inform the urban water sector about the transition of the current planning and management paradigm into a more sustainable one which incorporates the useful elements of IUWM, AM and participatory approaches. Therefore, the research aims to address the overarching question of: '*How can urban water services planning and management simultaneously incorporate adaptive, integrated, and participatory approaches when dealing with complexity in the Australia context?* To that end, the research investigated four sub-questions by adopting an exploratory nested case study approach combined with grounded theory data analysis focused on the metropolitan areas of the South Eastern seaboard of Australia, utilising semi-structured interviews.

Table 4. 1: Summary of methodology and methods

No.	Research questions	Methods	Methodology
1	To what extent are there examples where all the three approaches have been combined?	- Literature review of published papers and documents such as plans, reports, and technical papers on the applications of and research about the elements of the three approaches within the study area. - Semi-structural interviews	Nested case study approach
2	What tensions and broader challenges are evident when planning water services using the three approaches?	- Grey literature about challenges and issues across the three approaches (to facilitate conversations in the interviews) - Semi-structural interviews	

3	What are the underlining causes of the tensions and challenges?	- Semi-structural interviews focusing on Sydney case study and guided by Cynefin Framework	
4	Are the current available tools appropriate for dealing with complex problems?	- Semi-structural interviews guided by Cynefin Framework	

This chapter provides the rationale for selecting the methodology, methods, and study areas, and describes the implementation of the research design. The structure of this chapter follows the chronological order according to which the research design was implemented.

4.1.1 Methodological considerations

The author considered the goals and objectives of the research against characteristics of narrative research, case study, and grounded theory methodologies (Creswell et al., 2007, compiled in table 4.2) to decide which methodology to choose over others.

Table 4. 2: Characteristics of different methodologies

Characteristics	**Narrative research**	**Case study**	**Grounded theory**
Type of problem	When detail story helps understand the problem	When researcher has a case bounded by time or place that can inform a problem	When no theory exists, or existing ones are inadequate
Type of research questions	Chronological, story-oriented questions about life experience of an individual and how they unfold over time	In-depth, descriptive questions about how different cases provide insights into an issue	Process questions about experience over time
Unit of analysis	One or more individuals	An event, program, activity, or more than one individual	A process, action, or interaction involving many individuals
Data collection forms	Interviews, documents	Interviews, observations, documents, artifacts	Primarily interviews

As stated in the previous section, the study's goal is to inform urban water planning and management about the challenges and issues in employing adaptive, integrated, and participatory approaches simultaneously when dealing with complexity. The combined approach has been proposed in the literature without in-depth analysis and demonstrative examples/evidence. As a result, the research aims to learn from cases and practitioners' experiences to explore barriers, issues, and potential solutions within the study area.

Considering the goals, aims, and characteristics of those narrative research, case study, and grounded theory methodologies. The author decided to choose case study and grounded theory methodologies for several reasons:

- The need to objectively investigate what works and what the issues are from different cases in practice
- Since the combined approach has not been employed in real life, the barriers and challenges need to be derived or 'grounded' from analysis of cases that exhibited principles/characteristics of adaptive, integrated, and participatory approaches based on literature, documents, and real-life experience of practitioners involved in such cases.

Narrative research is not suitable for this study since the focus is on planning and managing urban water systems rather than the subjective life experience of participants about urban water services delivery. Also, the researcher excluded ethnography research and participatory action research due to the mismatch between the type of problems and questions they are designed to solve and the purposes of the study. Ethnography research focuses on studying cultural groups in a natural setting over a long period to collect observational and interview data. Phenomenological research aims to understand and solve a particular issue within a particular community through interacting and working with the community. Since this PhD study employs an exploratory approach to understanding the issues within a sector that covers various communities, phenomenological research might not be suitable. The overall strategy was to use a qualitative case study methodology to answer the research questions. A case study approach is particularly appropriate for this research because its goal is to understand an issue from the participants' perspective through conducting an in-depth analysis of this issue within its context (Baxter & Jack, 2008; Merriam, 2009; Stake, 2006; Yin, 2018). As comprehensively defined by Creswell et al. (2007):

> 'Case study research is a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audio-visual material, and documents and reports) and reports a case description and case-based themes'

In addition, a case study approach is instrumental in this study as the boundary between the context and issue is unclear (Creswell, 2009; Flyvbjerg, 2011; Yin, 2018).

An embedded or nested exploratory case study with multiple cases combined with grounded theory methods to data analysis was used for the research. This approach can be described as an analysis of sub-units within a case (Yin 2018) where urban water management practices in the South Eastern Australia seaboard metropolitan areas are considered the high-level case study. In different metropolitan areas, planning and management practices are discrete sub-units (sub-case studies). The embedded approach increases the validity of the research through data triangulation of multiple sources, which includes a broad range of different stakeholder perspectives (Yin 2018) and the likelihood of discovering deeper meanings of the issue during the analysis process (Patton, 2002).

The initial research design consisted of three main steps. The initial research design consisted of three main steps. The first step (step A) was to gather information about how the South Eastern Australia seaboard water industry perceives the three approaches and to identify specific practical nested case studies in major urban areas. In the author's opinion, as per the nature of an integrated approach, the scope of the water industry in this study comprises all processes from all aspects of the urban water system that are required to ensure the provision of water services such as water demand-supply planning, wastewater treatment and stormwater management to residential, commercial, and industrial customers. In Australia, water utilities and local Governments are typically in charge of providing those services. The literature review and semi-structured interviews were used in this step. After screening and identifying the specific case studies, the second step was to undertake a grounded theory qualitative analysis following a tailored conceptual framework to identify the emerging tensions/challenges. Data was to be gathered by document analysis and semi-structured interviews. Finally, a deliberative workshop or facilitated focus group was suggested to explore possible strategies for avoiding or tackling the challenges/tensions. However, a few changes caused the research to evolve in different directions. Those changes are discussed in section 4.4.

4.1.2 Introducing the study area

For the first round of data collection – synthesis of broader perspectives

I chose to carry out my research in South Eastern Australia metropolitan cities for three reasons. The first reason relates to the availability of applied information on the subject. The focal point is the transition to a paradigm that exhibits the characteristics of the three approaches combined. This new area of knowledge is placed at the forefront of urban water planning and management research. While the theoretical basis can be developed regardless of location, there are only several places where this knowledge has been practiced. This study area has shown promising characteristics for applying the integrated framework identified in academic and grey literature. For example, various urban water projects in Melbourne have shown signs of IUWM and public participation. Also, the Metropolitan Water Plan for Sydney claims to embrace all three approaches; and there is plenty of evidence showing that water users and various private partners were included in decision-making processes for the Lower Hunter Water Plan in

Newcastle. The second reason is that there is more opportunity to access information via professional networks in this region than in others. Accessible data and professional networks are a considerable advantage as the recruiting process depends on the snowballing technique.

Moreover, my supervisors are experienced in the field and have connections with related individuals and organisations in those locations. Finally, unlike South or Western Australia, where a single regulated state utility provides water services in metropolitan areas, multiple utilities operate in the cities across the study area. This difference leads to more access to information and more data sources for triangulation.

Actions for this first step were focused on a high-level case study of the South Eastern Australian context with an emphasis on metropolitan areas in Queensland, New South Wales, and Victoria. As a result, the study is particularly interested in plans and projects that are potentially associated with different water utilities in Brisbane, Newcastle, Sydney, and Melbourne.

For the second round of data collection – zoom into Sydney

Why Sydney?

With the purpose of exploring the concept of complexity and uncertainty, Sydney, especially in relation to the 2017 Metropolitan Water Plan (MWP), was selected as an overarching case study in the second round of data collection due to a few reasons.

The first reason was that although a specific case that exhibited principles of the combined approaches considered in this study (PP, IUWM & AM) did not exist to the best of the author's knowledge, the Sydney case shows traits of the long-term adaptive planning (Metropolitan Water, 2017) and participatory processes (N1). In the 2017 Metropolitan Water Plan, there was not a strong emphasis on an integrated approach. However, more than a few points indicated a strong focus on adaptive elements. For example, the plan included conducting an assessment of various environmental flows from Warragamba Dam to the Hawkesbury-Nepean River as experiments to improve the river health, followed by ongoing monitoring of the river and adapting the flows for optimal outcomes (Metropolitan Water, 2017). Another example was the introduction of the WaterSmart Cities programme within the 2017 MWP which underlined experimental learning through pilot studies and demonstrations.

Also, the public participation element in Sydney was described an involving 'huge programmes' by interviewee N1. During the Millennium Drought, Sydney conducted intensive consultation programmes to inform people:

> Between 2006 – 2010 the Metropolitan water plan conducted mass marketing and educational programme worth A$2 million/year … so we provided them with the information about what the Government was doing, and what the industry was doing and asked them to play their part in defining our water restrictions and to voluntarily reduce water consumption… and that was reinforced by another A$10 mil of funding from Sydney Water for water restrictions itself (N1 2018).
>
> That combination of education and mass marketing with direct programs that people could access about the DIY water, water fit program, smart water program … helped to reduce water consumption during the time … and for a long time after that. I think it is an example of the broad public playing their part in response to a crisis… we prepare and encourage and equipped people with the right tools to play their part (N1 2018).
>
> Besides, we had a set of deliberative community engagement workshops that we ran 2006-2016, every year we ran 2 workshops (of 35 people), covering ten areas in the Sydney region. Talked about water planning, putting people in our seat for the 3-4 hours that we had them, show them the decisions we need to make, the information that we got, how would you make that decision? What

> are your values? What is your future vision for Sydney in term of water? what it can provide for? What are some of the trade-off need to be made between things like environmental flow at the time of restriction and more infrastructure (N1 2018).

While IUWM is not 'done very well in practice in Sydney' (N2 2018) and 'it was not so successful as it could has been' (Q1 2018), Sydney might have an edge compared to other cities in terms of considering long-term adaptive planning, elements of experimental learning, and evidence of a shift in public engagement from the 'inform' level to possibly the 'involve' level according to the IAP2 spectrum of public participation.

To the best of the author's knowledge, there is little published information on how the three approaches (PP, AM & IUWM) have been adopted in Queensland in recent years.

Regarding the Melbourne case study, on the other hand, it has a strong emphasis and rigorous agendas on IUWM, especially the multi-level collaboration approach among stakeholders, which was the main focus in the document, 'Integrated Water Management Framework for Victoria' (DELWP, 2017). While an adaptive (pathways) planning approach is mentioned extensively in official planning documents (Melbourne Water, 2018b, 2018a; Melbourne Water & Victoria State Government, 2017), there is little information on how the work has been done in practice. For these reasons, Sydney was considered an adequate case study.

4.2 The first round of data collection and analysis

In the first round of data collection, the qualitative techniques involved semi-structural interview, literature review, and document analysis. The perspectives of recruited senior water professionals were obtained in a series of semi-structured interviews via face-to-face meetings, phone calls and skype. Interview questions were designed with a reflection on the applications of the three approaches of interest within the study areas found in published papers and grey literature. Overall purpose was to draw on interviewees experience and knowledge related to the research questions 1 & 2. Afterward, the interview transcripts were analysed by applying qualitative data analysis methods such as provisional and grounded theory coding techniques, the essential features of the interviews were brought out as a series of insights.

4.2.1 The techniques and tools used to collect data

Qualitative data were gathered via document analysis and semi-structured interviews to answer research questions 1 & 2. Firstly, peer-reviewed articles and grey literature about conceptually combining approaches and the IUWM plans and projects containing elements of AM and participatory approach were critically reviewed. Findings from document analysis partly i) addressed how three approaches have been combined conceptually and ii) pointed out examples where elements of the combined approach were picked up in water utilities' plans and strategies (in chapter 2), as well as ii) translated some tensions and challenges from other disciplines into urban water context (in chapter 3). Secondly, insights from that information contributed to the materialisation of a proposed analytical framework (Figure 3.5), which was then applied to guide semi-structural interviews. The open-ended questions (Appendix B) were designed in an exploratory fashion, the knowledge and insights from document analysis were used to facilitate the conversations.

4.2.2 The interview processes

Prior to the recruitment process, a briefing document was prepared for participants, including information on the research's overall goal and design, purposes, and the content the interview aims to cover. This document was sent to the people who agreed to participate in the interview.

A snowballing technique was utilised during the recruiting process. The combined approach that this research is concerned with has not been employed widely and has not been well-developed. Therefore, only a relatively small number of people are currently or recently working on related projects/plans or strategies. Potential interviewees were identified as authors of published journal papers or authors/professionals who had worked on the projects that adopted or highlighted recent research on the IUWM approach, including characteristics of the adaptive and participatory approach (as outlined in Table 3.1). Moreover, participants were also targeted from professional networks. The author considered it a good idea to interview professionals from different organisations who perform different roles to ensure that diverse perspectives are represented. The interviewees were asked during the interview to suggest other people with whom they had worked.

The author believes that, albeit relatively small, the sample was sufficient to represent diverse perspectives from different aspects of urban water systems for several reasons.

Firstly, the interviewees came from various organisations and work in different positions in significant South Eastern Australian seaboard areas, including Sydney, Melbourne and Brisbane (table 4.3). The variety of interviewees allowed the researcher to investigate different facets of urban water planning and management process within the context of how the three approaches have been applied in practice.

Secondly, all interviewees have been committed to their respective organisations for a long time and held or had held leadership roles. As a result, they have plenty of experience working on various projects over the years. Thus, they are essential to provide valuable first-hand information and knowledge of the urban water sector, not only about details of their works but also the bigger picture and future directions.

Further, the development of projects and plans usually relies on coordinated efforts across organisations. This point leads to two main advantages, including the ability to introduce more potential interviewees and the capacity to understand the interactions and relationships between organisations.

Finally, the majority of the interviewees belong to the group of people in the urban water sector who advocate future thinking and innovations. Therefore, the semi-structural format of the interview allowed for more in-depth discussions..

Table 4. 3: The breakdown of interviewees' categories

Organisations / States	Water utilities	Government Agencies	Industry Bodies
New South Wales		1 planning manager & projects leader 1 planning manager & coordinator	1 planning manager and projects leader
Victoria	1 planning manager and coordinator 1 policy advisor 1 planning manager and modeller/ projects leader	1 planning manager & coordinator 1 policy & planning advisor	
Queensland	1 planning manager and coordinator	1 planning manager	1 research & innovative manager

There was a total of eleven interviews. In detail, from September 2018 to May 2019, sixteen invitations were sent via emails to potential participants among whom seven agreed to do the interviews. The other four interviews were arranged based on the suggestions and introductions from those seven interviewees. The communication about information on the research, reviewing consent forms, and scheduling the date and time for the interview were carried out via emails and phone calls.

The interviews were organised by different means based on the interviewees' preferences, including face-to-face meetings, Skype and phone calls. The interviews typically lasted anywhere from 40 minutes to 80 minutes mark. All recordings of and notes from the interviews have been kept in both a secured, password-protected database and an external hard drive that can only be accessed by the authors and two supervisors. The recordings were later on transcribed, and then the transcripts were analysed and kept unidentifiable within the NVIVO12 app on a password-protected working laptop.

This round of interviews was set out to reach several objectives. The first one was to gain insights into the interviewees' points of view and their interest in the three approaches of concern. To be more specific, the objective concentrated on finding out how the interviewees perceived IUWM, AM and PP conceptually and what their view was on those approaches moving forward. The second objective was to draw on interviewees' experience with employing and implementing practices or aspects with regard to those approaches to discover any challenges and trade-offs which captured their interest. One of the implicit goals throughout the interview was to draw on their practical knowledge, in conjunction with the findings from document analysis and literature review, to see whether there was a gap between reality on the ground and documented plans.

The interview questions and, subsequently, the conversations with interviewees were guided and facilitated by the conceptual framework (figure 3.5).

4.2.3 The data analysis process

Interview data were transcribed and then thematically analysed in NVIVO12 software through a coding process informed by grounded theory coding methods to answer research questions 1 & 2.

Coding approach

Coding is for managing and analysing transcribed interview data by categorising the codes and determining how the items in categories vary. The goal of this coding process is to translate those qualitative data into themes and ultimately to analyse and interpret them critically. The study followed coding stages outlined by Auerbach & Silverstein (2003) first to identify relevant texts to research concerns and the theoretical frameworks, then record and group repeating ideas into coherent categories to thematise the data. [explain the categories]

After reading the transcripts multiple times, getting familiar with the data, and trying different coding methods, the author found out that, in the beginning, the approach to coding was loosely a mixture of an 'open' and a structured approach. Initial coding was adopted to break down the transcripts into discrete parts to examine and compare (Saldaña, 2013). Initial coding allows the researcher to be open to new ideas that might emerge from the data. Then, the author also had background information about practitioners' perceptions, and the theoretical framework informed issues across the three approaches of concern (figure 3.5). Therefore, to explore participants' perspectives on IUWM, AM and PP and how they perceived them working together, the author also coded the data for concepts and practices related to the three approaches in the urban water sector. For example, those concepts and practices included collaboration between actors within projects/plans, whole system approach, modelling capacity and availability of data, understanding of stakeholders on the approaches' definitions.

Furthermore, this process also involved coding for the manifestation of aspects laid out in the theoretical frameworks (figure 3.5) that highlighted the challenges across the three approaches and how they surfaced when the approaches were married in particular contexts (mentioned throughout the interviews). Those manifestations are, for instance, the conflicted interests among organisations due to differences in value-driven objectives and unsuccessful attempts to bring integrated solutions forward due to different worldviews. Factors that affect the combining of approaches that are unaccounted for in the theoretical framework, such as the changes of personnel and process champion, the ability of stakeholders to elaborate the concepts of complexity and uncertainty, etc., were also coded. Instances in coding were particularly considered when the good practices were changed by higher decisions or the mismatch between literature and practical perceptions. Through this coding process, empirical evidence of interviewees' perspectives on the three approaches and scattered challenges in the context of urban water planning was captured.

Afterwards, as 'a theory is a description of a pattern that you find in the data' (Auerbach & Silverstein, 2003), axial coding was utilised to draw connections systematically and to find patterns between the 'fractured' codes to then group them into more prominent, more abstract categories that underpinned the answer to research question 1 & 2 (Saldaña, 2013). Such 'axials' are codes generated in NVIVO12 such as 'certainty – uncertainty – worldview' or 'complexity of the concepts'.

In Chapter 5, the outputs of coding processes were analysed in accordance with the research objectives, and the findings were elaborated in conjunction with the outcomes of the literature review.

4.3 The development of the research focus

After the first round of data collection and analysis, there were a few influencing factors that led to changes in the course of the research. This section is dedicated to specifying the shift in research focus in response to the implications from previous analysis, as well as the changes in qualitative research methods due to COVID-19 pandemic.

The theme that emerged most often from the first round of data collection was that the interviewees had struggled to deal with the complexity that accompanied the adoption of sustainable practices (within the frameworks of Integrated Urban

Water Management (IUWM), Adaptive Management (AM) and Public participation (PP)). There are various aspects of this to which participants found hard to delve into which are discussed further in section 5.3. The challenges of complexity that was implicitly and explicitly highlighted by the interviewees are consistent with the concept of 'complex' or 'wicked' problems associated with the transition of the Australian urban water industry toward a more sustainable planning and management approach (Farrelly & Brown, 2011; Floyd et al., 2014; Malekpour et al., 2016). The term complex or wicked problem, coined by Rittel & Webber (1973) in the social and policy planning field of research, is constituted by several characteristics. It is an ongoing problem with no stopping rule or a clear definition; there are multiple explanations for the wicked problem. Since it involves non-linear interactions between multiple disciplines, aspects and actors at various levels without a clear understanding or set of solutions; thus, they must be considered experiments (Peters, 2017). As a result, the unintended repercussions of interventions are to be expected. Also, the wicked problem might be a symptom of another underlying problem.

The challenges of complexity revealed the more fundamental problem that needs to be address in order to inform the transition to a more desirable sustainable paradigm that imbues with elements of the three approaches of concern. As a result, the author chose to pursue the shift of the initial focus from purely identifying and analysing the tensions arising when integrating the three approaches (IUWM, AM & PP), to investigating more closely the questions of complexity. For that reason, a complexity theory perspective was adopted as a new perspective to gain better insights into urban water planning and management. To be more specific, after considering a variety of tools and approaches, the Cynefin framework (CF) was chosen to explore the issues and practices related to complexity and uncertainty which were highlighted by interviewees. The CF is a conceptual sensemaking tool which arose out of complexity theory, and from the knowledge and organisational management fields of research (Snowden, 2002). Further analysis on how the complexity and uncertainty found from the first round of interview had led to the change in research direction can be found in Chapter 6 (section 6.1).

The shift in focus led to a change in research questions and objectives compared to the initial plan, and the scope of the research was narrowed down to Sydney case study.

A deliberative workshop was planned with a wide range of participants to explore the questions of complexity to try pinpointing the underlying causes, and to 'socially construct' the meaning of CF domains and their boundaries in the context of urban water planning and management in Greater Sydney. Then, the possible ways forward would be investigated accordingly.

However, the research took another turn after the Australian Government issued social distancing and lockdown policies in response to COVID-19 pandemic. Since early 2020, the pandemic has introduced critical challenges to the data collection processes via two multiple-months lockdowns in Sydney. The prohibition of physical contacts forced the researcher to find alternatives for the planned deliberative workshop with professionals across the urban water industry, while at the same time invitations had already been sent out. Hence, the research progress was put on hold to seek online alternatives which could be relevant to the research's data collection requirements. Considering the resources available for a PhD project and due to the technical and logistical difficulties at that time in holding an online workshop, technique that was chosen for the second round of data collection is online semi-structured interview.

4.4 The second round of data collection and analysis

As discussed in the prior section, the purpose of the second round of data collection was transformed from purely searching for the appropriate response to identified challenges into a more specific exploration of the 'complexity question' and the potential available methods or tools in Sydney. To embark on that journey, the set of complementary methods including documents analysis, literature review and semi-structural interview were once again enacted. Published journal papers and grey literature on CF applications, and current tools and methods used for complexity and uncertainty in urban water sector were examined in order to facilitate the discussions with the interviewees and to elaborate arguments on those topics. On top of that, CF was utilised to guide the open-ended set of questions (Appendix B) and the analysis of the outputs from the interviews. The second round of data collection aimed to answer research questions three and four by drawing on and critically analysing interviewees' perceptions on the underlying complexity, as well as the possible available tools or methods to tackle the issues emerging from that complexity through the lenses of CF.

As the scope of the research was focused on the Sydney case study, invitations to participate in the interview were sent to the people in Sydney who especially involved in the development of the 2017 Metropolitan Water Plan (more detail discussed in section 4.2). There was a total of five online in-depth semi-structural interviews, conducted between March and April 2020.

4.4.1 Why was CF chosen?

This part provides an explanation for the choice of CF by critically reviewing other approaches from various disciplines, this includes Soft-System Methodologies, Socio-Ecological Systems framework, Multi-level Governance framework, One Water, New institutionalism theory. This section also provides the reasons why the author believe that Cynefin framework is a better fit to the study compared to others. Before that, the author provides a brief description of how system thinking, and complexity theory helped position the research.

Discussion on Systems thinking and Complexity theory

According to the concept of systems thinking (ST) the 'whole is larger than the sum of the parts' (Smuts 1926, cited from (Pollard et al., 2011)). In a way, this concept was embedded into this research from the very beginning. This study embarked on a journey to explore the challenges associated with the paradigm shift in urban water management from the current one which is still largely influenced by the ontological assumptions of Newtonian science (Dunn et al., 2016; Floyd et al., 2014), to a holistic, adaptive and inclusive paradigm. In this research, system thinking is used implicitly and explicitly to inform the water industry about this transition. Further, the use of system thinking has investigated multifaceted issues from different viewpoints within the system. These viewpoints include socioeconomic, technical, and administrative perspectives. However, while the shift to system thinking is helpful in dealing with complicated problems, it is not necessarily sufficient for dealing with complexity, or complex problems.

Systems thinking (ST) first emerged in its modern form in the 1950s in response to the shortcomings of the traditional scientific approach to solving complex problems in the real world (Midgley, 2000). In that era, a single discipline perspective was at the centre of the conventional scientific model. A reductionist approach was applied to solve problems by breaking them into components parts to study and address separately using mathematical models. The reductionist approach totally ignored the interconnectedness of the component parts and of the problems studied in different disciplines (Pollard et al., 2011). Such approaches can potentially bring unexpected reactions or invite 'systemic resistance to reductionist solutions' (Midgley & Rajagopalan, 2019).

As a result, ST was born to challenge all aspects of the traditional scientific approach. The characteristics of ST were compiled as shown below (Pollard, Toit & Biggs 2011; Midgley & Rajagopalan 2019):

- ST adopted a transdisciplinary approach, focusing on defining and redefining the system without considering disciplinary restraints, and on elaborating the understanding of the system and its boundaries from different perspectives.

- ST discarded reductionism and focused on the interactions and interrelationships of components within and between systems.
- ST discarded subject-object dualism and acknowledged humans as being part of larger systems such as socio-ecological systems and saw them as being able to change those system or be changed by them.

In order to unpack more of the thinking behind ST, it is better to take a look into the three paradigmatic waves of systems thinking from when it first emerged in in the 1950s. The first wave of systems thinking (from 1950s to 1970s) was referred to as 'hard systems' in which 'insights from both the quantitative and human relations branches of applied science, amongst other traditions' were incorporated (Midgley, 2000). Experts from single disciplines using quantitative modelling to solve the problems were at the core of this hard systems analysis. Authors in the first wave offered various deterministic approaches to make sure the individual parts of the system were thoroughly analysed and integrated into the systems understanding (Cabrera & Cabrera 2019) using the approaches listed below:

- System dynamics, in which feedback loops, stocks and flows were focused on (Forrester, 1989).
- System engineering, from the fields of engineering and engineering management, focused on the design processes, methods and management of the system over time to enhance performance.
- Viable System Modelling highlighted the connections between human organisations and operational environments.
- Socio-technical system thinking brought together human relations, psychodynamics, action research, and the theory of open systems (Midgley, 2000)

The philosophical assumptions behind this first wave was criticised as it considered models as a representation of reality and disregarded the inter-subjective understanding between people with different perspectives, leading to impediments to learning and exacerbating unsolved conflicts (Checkland, 1985; Churchman, 1970). As interventions were determined by a few experts without consulting the other parties that were involved with the decisions, the compliance was low, and this narrowed down the chances of implementation (Midgley & Rajagopalan, 2019).

These criticisms led to the paradigm shift of theory that characterised ST and gave birth to the second wave (from the 1970s to the 1980s) – soft systems – in which thinking was emphasised in terms of systems, and consideration of multiple perspectives was encouraged. The focus was on 'dialogue, conflict resolution, mutual appreciation and the inter-subjective construction of meaning' (Midgley & Rajagopalan, 2019). Therefore, mutual learning and the appreciation of diverse points of view were improved. (Ackoff, 1979; Checkland, 1985; Churchman, 1970) were some of the key contributors to the second wave. The use of the new 'soft system methodology' (SSM) approach (Checkland, 2000) started to become popular during the second wave (more detail on SSM can be found further down). Also, operational research and Strategic Options Development and Analysis (SODA) were evolved throughout this second wave to apply to groups rather than individuals (Midgley, 2000).

In the early 1980s, the developments in systems thinking theory in the second wave started to be criticised. The main issue was that 'participative methodologies characterising the second wave did not sufficiently account for power relationships within interventions, and/or conflicts built into the structure of society' (Midgley, 2000). Furthermore, (Galliers et al., 1997; Jackson, 2003) argued that while a focus on participation is a good thing, there is a need to strengthen the methods by adopting a 'theory of emancipation' (of a non-Marxist kind). As the methodologies introduced in the second wave were not well-matched with the approach of first wave system thinking, there were conflicts between proponents from the two waves (Midgley & Rajagopalan, 2019).

Third wave authors then came along and tried to resolve the conflicts by introducing methodological pluralism which basically means mixed methods from both waves. The central idea of the third wave is Critical System Thinking where the 'practice of exploring value and boundary judgements in projects in order to address conflict and marginalization' was emphasised to address power relations during interventions' (Midgley & Rajagopalan, 2019). This practice was combined with methodological pluralism to form a new approach labelled systemic intervention.

Having delved in ST theory, the authors realised that ST played crucial role in exploring the interrelationships between variables in the system to discover non-linear emergent properties. Thus, ST is a great skill to unpack complexity. However, within complex contexts or 'un-ordered' domains (as referred to by Snowden (2005, p.47)), it would be challenging for ST methods to explore the causal relationships which usually 'do not repeat, except by accident, and the number of agents interacting with other agents is too great to permit predictable outcome-based models' (Snowden, 2005a). To be more specific, the way ST is applied in real life is that participative methods are used to reach consensus on the objectives and the expected outcomes among various actors. Then, analytical and sense-making tools are utilised to guide strategic actions in order to fill the gaps between the current situation and desired future states. Nevertheless, complexity theory, especially Complex Adaptive System theory, suggests an evolutionary approach that focuses on the present to analyse cause and effect in retrospect without the belief that there will be a clearly identified future outcome ((Snowden, 2005a); Marco 2017).

From the author's point of view, the differences between the epistemological approaches of ST and complexity theory can be distinguished using the concepts of 'ordered' and 'unordered' systems from the work of Snowden and Kurtz (2003) and Snowden (2005). Basically, in ordered systems the causal relationships between components of the system 'are clearly identified (or identifiable) which once discovered will enable us to control the future' (Snowden 2005, p.47).

Ordered systems theory assumes that through extensive analysis based on both traditional science approaches and participatory approaches, one can derive 'empirically verified' general rules and hypotheses that support the definition of *desired outcomes, objective* to inform planning and implementation processes (Snowden & Kurtz, 2003). On the other hand, this assumption does not hold in 'unordered' systems. The term 'unordered' implies that the causal relationships do not repeat. An unordered system is one 'in which the number of agents interacting with other agents is too great to permit predictable outcome-based models, although we can control starting conditions and monitor for emergence' (Snowden 2005). In general, while causal relationship can be understood in retrospect, it is not possible to define expected outcomes, since one does not know exactly what to expect in the future. The author found the concepts of 'order' and 'unorder' beneficial in positioning the role and application of ST and complexity theory in this research.

The above discussions provide a theoretical foundation for the Cynefin sense-making framework. One significant reason why CF fits within the context of this study is its clear framings which distinguish between simple, complicated and complex situations. As Snowden points out, 'not all systems are unordered', as far as analysis goes, and there is a need to be critical about 'universalist claims' about complexity just as much as there is a need to be critical about the claims of 'engineering and systems thinkers' (Snowden 2005, p. 50).

Despite the fact that interviewees from the first round generally referred to all problems related to integrated or adaptive approaches as complex problems, there was no further discussion of how complex they were, or about the point of reference from which they identified the complexity. This created an appropriate situation for CF to be introduced. Within CF the framings of different kinds of systems are ontologically and epistemologically dynamic. The nature of a particular system, and the ways in which a situation changes and shifts between domains, can be described using CF. There are many other framings in the literature which can be used to differentiate between complicated, complex and chaotic situations, such as the seminal works of (Armson, 2011)) and (Patton, 2010). The framing of such situations within the CF was used because of its user-friendliness. The descriptions in CF share many commonalities with those of Armson (2011) and Patton (2010) but the robustness is in the use of simple language. The language of CF is clear enough to communicate with respondents who are unfamiliar with the concepts but sophisticated enough (considering the underlying theoretical basis) to enable conversations and discussions with participants. Moreover, CF also suggests appropriate strategies to address issues in each of the domains in which the problems reside, because it is crucial to deal with problems in those four types of situations differently. A mismatch between issues and solutions not only results in an inability to solve the problems but also increases the chance of unexpected catastrophes (more detail on this point will be discussed in Section 6.3).

Regarding the tools available for making sense of complexity, there are various methods from different disciplines that are closely connected with system thinking. Some of the most common tools are (Institute for Sustainable Futures, 2017):

- rich pictures (Checkland, 2000)
- influence diagrams and systems dynamics mapping (Armson, 2011)
- human activity system (HAS) diagrams (Armson, 2011)
- input, transformation, output (ITO) models (Armson, 2011)
- the T.W.O C.A.G.E.S process (Armson, 2011)
- systems games (Meadows et al., 2005; Sweeney & Meadows, 1995)
- collective impact process (Kania & Kramer, 2011)
- the Twelve Systems Leverage Points (Meadows, 2008)
- the Four-Stage Systemic Change Process (Stroh, 2015)

Discussions on Soft System Methodology (SSM)

In addition, the seminal Soft System Methodology (SSM) developed by Peter Checkland (1999) and (Wilson, 2001) is probably the most popular problem structuring method ((Mingers & White, 2010). SSM focuses on addressing the unambiguous and usually conflicting views of various stakeholders about the definition of the problem. In that sense, through action research, SSM (Figure 1) was developed as a pragmatic approach for understanding and dealing with a diversity of views and interests to identify 'soft ill-defined' problems and solutions (Burge, 2015; Mingers & White, 2010). Also, Checkland (1999) and Wilson (2001) suggest a set of tools to fit with steps in SSM including: rich pictures, conceptual models, customers – actors – transformational process – world view – owners – environmental constraints (CATWOE) and the Formal Systems Model.

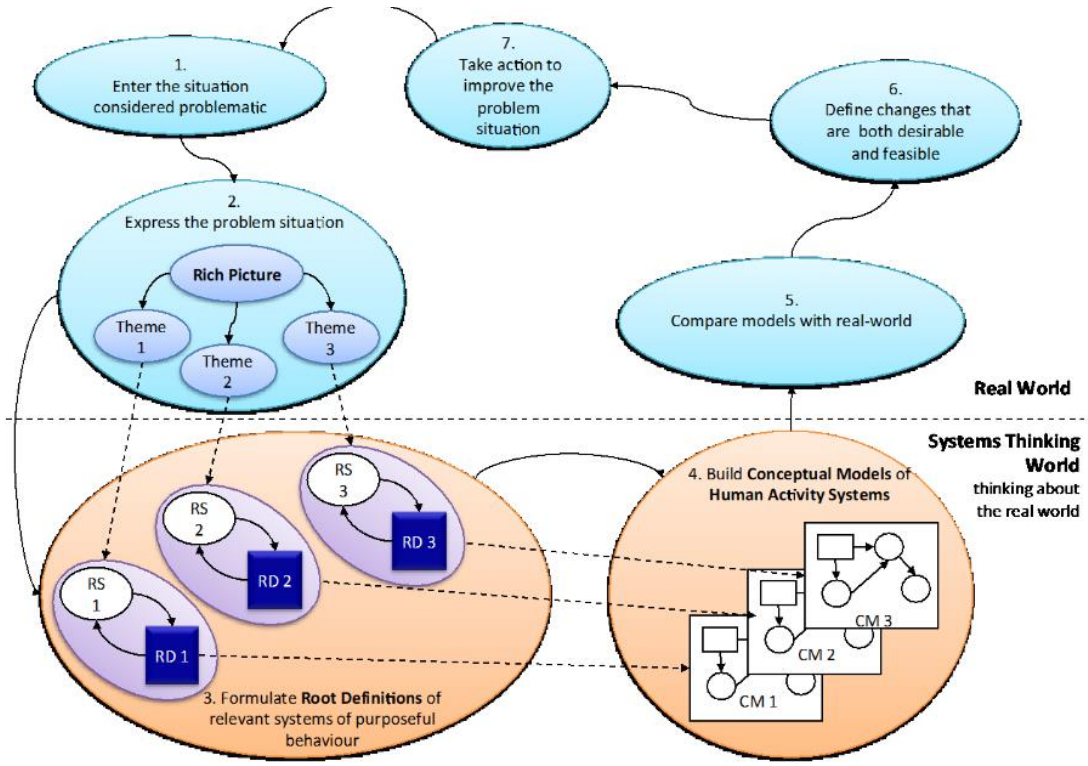


Figure 4. 1: The seven-step SSM (Burge, 2015)

Each of these tools offers an approach for exploring different aspects of systemic problems. In particular, SSM is a powerful tool for comparing what 'good' looks like according to different participants in a real-life situation, and it can be used to define strategies and actions to bridge the gaps between these perspectives. In the author's opinion, what differentiates SSM from CF is that SSM provides exploratory power to uncover particular issues but does not provide the explanatory capacity specifically to describe the level of complexity to the users. Rather, such action research methods provide a platform for discovering the issues (that might be complex) through the participants' own framings. Furthermore, SSM provides little guidance on the development of strategies to deal with the emerging problems as the focus with SSM is on problem structuring rather than structuring potential solutions.

CF, on the other hand, suggests appropriate strategies for each of its domains. As mentioned above, an overarching problem that this research was able to identify within the urban water sector was the lack of an effective yet accessible method for screening the level of complexity of the issues in order to assist with decision-making and the development of appropriate strategies. Therefore, while the aforementioned action research methods are well established in investigating complexity and conflicting perspectives through participatory processes, CF was chosen for this research because of its ability to navigate through complexity by identifying the level of complexity of the context that the events or systems are operating in.

Discussions on Socio-ecological systems (SESs) framework

The author considered the SESs framework as a potential tool to better understand the issues related to the development and application of the combined approach that this research concerns. The following section reviews the SESs framework's origin, what it entails, and how it has been utilised to argue whether it is applicable to this research.

The blueprint approach to governance of social-ecological systems (panaceas) was criticised (dated back to the 1980s) which paved the way for a new idea of continuous learning processes that pinpointed an adaptive management approach to analyse and make decisions about complex adaptive systems (Korten, 1980; Walters, 1986).

It was the realisation that the coevolution of social and ecological processes resembles complex adaptive systems. Thus, it required a holistic/inter-disciplinary approach to tackle the systematic social crisis involving common-pool resources and public goods (Partelow, 2018). Therefore, Ostrom and her team (1990) presented empirical evidence of social and ecological variables and institutional arrangements that facilitated the stakeholders' engagement and self-organised governance under the theory of collective action. However, the capacity to understand and explore the complexity of those interdependent social and ecological variables became a significant influencing factor to archive self-organised governance. In addition, as specific scientific disciplines use different approaches and languages to explore complex social-ecological systems (SESs), there are limitations in understanding factors and processes that hamper or improve the uses of natural resources (the commons). Hence, there is a need for a common framework to organise findings, connect disciplinary research and practice, and analyse and classify variables to accumulate and integrate holistic knowledge (Andersson et al., 2021; Ostrom, 2009).

That is when the SESs framework comes in as a diagnostic tool offering a list of generalizable variables to assist the governance of environmental issues (Ostrom, 2007, 2009). SESs framework is a nested, multi-tiers structure of concepts and variables that can be used to pinpoint significant factors influencing the decision-making of a given issue within socio-ecological systems. It consists of a resource system (e.g., fishery, lake, grazing area), the resource units generated by that system (e.g., fish, water, fodder), the users of that system, and the governance system as the first tiers (figure 4.2) which accompanied by the associated second-tiers variables listed in figure 4.3.

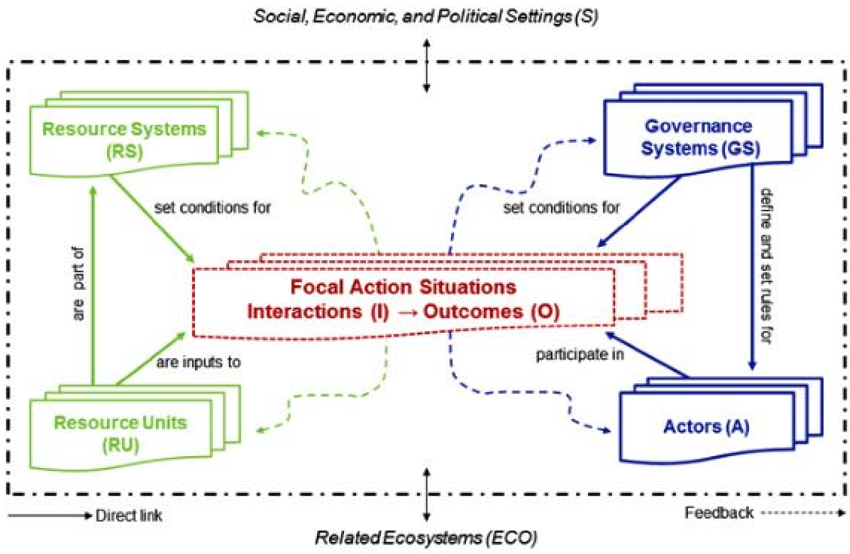


Figure 4. 2 :First-tier components of the Socio-ecological Systems framework (McGinnis & Ostrom, 2014)

First-tier variable	Second-tier variables
Social, economic, and political settings (S)	S1 – Economic development S2 – Demographic trends S3 – Political stability S4 – Other governance systems S5 – Markets S6 – Media organizations S7 – Technology
Resource systems (RS)	RS1 – Sector (e.g., water, forests, pasture, fish) RS2 – Clarity of system boundaries RS3 – Size of resource system RS4 – Human-constructed facilities RS5 – Productivity of system RS6 – Equilibrium properties RS7 – Predictability of system dynamics RS8 – Storage characteristics RS9 – Location
Governance systems (GS)	GS1 – Government organizations GS2 – Nongovernment organizations GS3 – Network structure GS4 – Property-rights systems GS5 – Operational-choice rules GS6 – Collective-choice rules GS7 – Constitutional-choice rules GS8 – Monitoring and sanctioning rules
Resource units (RU)	RU1 – Resource unit mobility RU2 – Growth or replacement rate RU3 – Interaction among resource units RU4 – Economic value RU5 – Number of units RU6 – Distinctive characteristics RU7 – Spatial and temporal distribution
Actors (A)	A1 – Number of relevant actors A2 – Socioeconomic attributes A3 – History or past experiences A4 – Location A5 – Leadership/entrepreneurship A6 – Norms (trust-reciprocity)/social capital A7 – Knowledge of SES/mental models A8 – Importance of resource (dependence) A9 – Technologies available
Action situations: Interactions (I) → Outcomes (O)	I1 – Harvesting I2 – Information sharing I3 – Deliberation processes I4 – Conflicts I5 – Investment activities I6 – Lobbying activities I7 – Self-organizing activities I8 – Networking activities I9 – Monitoring activities I10 – Evaluative activities O1 – Social performance measures (e.g., efficiency, equity, accountability, sustainability) O2 – Ecological performance measures (e.g., overharvested, resilience, biodiversity, sustainability) O3 – Externalities to other SESs
Related ecosystems (ECO)	ECO1 – Climate patterns ECO2 – Pollution patterns ECO3 – Flows into and out of focal SES

Figure 4. 3: Second-tier variables of the Socio-ecological Systems framework (McGinnis & Ostrom, 2014)

The SESs framework provides a powerful tool to identify and, in some cases, quantify the significant influencing factors to governance processes. However, it is not evident that the framework has been successfully tailored to apply in the urban water context. To the best of the author's knowledge, the most prominent attempt to employ the SESs framework was to diagnose the substantial variable influencing governance decision-making about green infrastructure implementation in urban stormwater management programs in the U.S. context (Flynn & Davidson, 2016).

From the author's perspective, the way Flynn & Davidson (2016) applied the SESs framework somewhat resembled the process of provisional coding. Literature review on influencing factors in GI implementation and documentation of national stormwater meetings were coded and grouped following pre-determined categories (first, second, third, and fourth tiers) and the keywords that might fall into those categories (attributes and variables within tiers). Key findings from their work pointed to the fact that the SESs framework is versatile and flexible and can be powerful as one can put more effort into refining the set of variables in a particular SESs. Thus, the trajectory that the SESs framework should be developed specifically for GI can be explored by testing various theories, adding more place-based research, and quantitative analysis of how GI can help archive SES outcomes.

However, the author believes that this is also a limitation of the framework that since urban water systems are integrated and complex, it is challenging to determine whether enough efforts have been invested in the research. This point also aligned with the lesson found in Walters (1997) which emphasised the over-extensive research that might yield little outcomes in adopting an adaptive framework in coastal ecosystems management. Moreover, it is also tricky to maintain clear institutional boundaries and develop a feasible methodology for evaluating the economic value of sustainable practices such as GI or water recycling (Flynn & Davidson, 2016; Frontier Economics, 2018). In addition, while the SESs framework is rooted in the same discipline (ecology) as resilience theory and complexity theory and is a valuable classification tool, within the scope of this PhD research, it does not provide a method for exploring the complexity that emerged from the first round of interview since the findings lean toward a mismatch in the level of complexity between the interventions and the issues at hands. Hence, the author maintains the decision to choose the Cynefin framework, a heuristic tool from the complexity realm, to keep the exploratory nature of the research intact.

Discussions on Governance and Institutional Analysis frameworks (Multi-level governance framework, One water and new institutionalism theory)

This part brings out the discussions on frameworks that the author had considered to explore further the institutional issues. The three frameworks were considered specifically since their associated concepts and challenges are relatable to the findings from the first round of interviews.

Multi-level governance framework

The author found that some of the issues that emerged from the first round of interview are relatable to the challenges of implementing multi-level governance (MLG) approach within the framework of the European Water Framework Directive (WFD)[1] founded in the literature (Hooghe & Marks, 2003; Huitema et al., 2009; Moss & Newig, 2010; Naustdalslid, 2015). Also, while the literature on MLG stemmed from the political studies discipline, the integration of governance systems and institutional arrangements resonates with issues that IUWM advocates face. Hence, the author considers MLP framework as a potential perspective to investigate the institutional issues.

Multi-level governance theory underpinned the transition from the central government as the centre of authority to a diffusion of authority in which a wider range of participants across scales and levels of government also have authority in the decision-making process. European scholars believe that the shift to multi-level governance happened during the significant EU structural policy reform (1989) as a part of the new way of thinking that considered the European Union as a political system rather than the process of integration (Bache & Flinders, 2004). Multi-level governance is particularly relevant to EU water resources management

[1] EU's WFD aims to get the EU's water cleaner by applying an integrated, ecosystem-based, and collaborative approach to river basin management. The directive established a knowledge-based system across multi-level governance and management and integrated planning systems between water and land use within borders of river basins by coordinating and engaging participants/ stakeholders from local to national and EU levels (European Commission, n.d.; Naustdalslid, 2015).

since major programs to implement the EU's WFD shared a single approach: the River basin management approach. In other words, network governance is multi-levelled and multi-layered that needs to be coordinated with participants and stakeholders from local to national and EU levels and collaborated with different sectors (such as land use planning, transport, and agriculture) (Naustdalslid, 2015).

MLG is similar to IUWM processes because it involves multiple stakeholders with different perspectives and priorities. Naustdalslid (2015) emphasised that stakeholders at different levels need to be involved on an ongoing basis so that the conflict of interest can be managed to keep the program's purpose intact. This issue also emerged from the interview and was analysed in sections 5.2.1.2 and 5.3.2.4. Also, Hooge and Marks (2003) brought up the exponential additional transaction costs incurred from inter-jurisdiction coordination in implementing MLG.

Moss & Newig (2010) illustrated the issues of overlapping governance arrangements across scales, such as finding the most appropriate scale, issues with interplay and misfit between different levels, and problems of upscaling and downscaling. Since the nested regional systems overlap and WFD also requires integration with other sectors such as transport, land use planning, agriculture and ecosystem conservation, the implementation of MLG is complex.

The vital role of strong leaders' presence, process champions (such as capable project managers/coordinators or leaders of communities) and bridging organisations was also emphasised by Naustdalslid (2015).

One water

From a combined U.S.A., Australian and U.K. perspective, Mukheibir & Howe & Gallet (2015) identified the institutional challenges in implementing OneWater (more detail in section 2.2.3, pages 32-41) that aligned with several findings from the interviews.

OneWater is an integrated approach to planning and management of water supply, wastewater and stormwater in an urban context that aims to 'minimise environmental impacts and maximise potential economic and social benefits' (Mukheibir, Howe, et al., 2015); more detail of the approach can be found in section 2.2.3. Mukheibir, Howe and Gallet (2015) reviewed 28 case studies from the U.S.A., Australia, and the U.K. to come up with a list of factors that are hampering the transition to 'OneWater' management. Among others, issues such as overlapping and prescriptive legislative and regulations, rigid organisational and professional cultures, the lack of skills and systems knowledge, and the lack of system thinking and integration between levels of governance, other organisations and entities are also similar to findings from the interviews.

New institutionalism

New institutionalism is a movement and an institutional theory in political science and sociology termed by March & Olsen (1984). It was advocated by many theorists and researchers for providing an approach, that places the collective action at the centre and emphasises the equal role of 'political collectivities and their socio-economic environment' in shaping each other, to understand institutional changes (Peters, 2019).

The contemporary institutional theory concerns with how the 'rational choice' in political analysis is informed by the cultural and socio-economic roots (Scott, 2005). In contrast, in the 'old' institutionalism, 'political life' is constituted by autonomous choices by relevant individuals, and 'the fact-value distinction on which such contemporary social science has been constructed was simply not acceptable as a characterization of social life' (Livingston, 2008; Peters, 2019). The new institutionalism fundamentally differs from traditional approach to institution in that it moved away from considering institutions as organisations to acknowledge an institution as an established procedure or social pattern in society (Livingstone 2006). In other word, the contemporary institutional theory holds 'institutional matter' accountable for social processes (Scott, 2005).

The expansion in theory base led the New institutionalism to diversify from a single approach to a 'genus with a number of specific species with it' (Peters, 2019) and those approaches to institutions should be use in complementary fashion to understand political phenomena (Ostrom, 1990). Scott (2005) reviewed theoretical basis of the contemporary approach to institutions and categorized those variations into rational choice, normative, and cultural-cognitive approaches. It is noteworthy that because of the expansion of New institutionalism to normative and cultural-cognitive theories, the goals and objectives are opened to change in response to social action (as opposed to rational choice theory) (March & Olsen, 1989).

Scott's analytical framework to understand institutions' capacity to withstand major and sudden changes was also evolved from the foundation of these strands (Scott, 1995). The central tenet of the framework is that for institutional changes to materialise, institutional practice must mutually reinforce the shift within the 'three pillars', namely regulative, normative and cognitive (Scott, 1995). For example, Keath & Brown (2008) indicated that regulations could fail due to forcible introduction that might go against norms and values (normative) without consultations and engagement to understand people's perceptions (cognitive).

Rational choice approach/theory concerns with how social behaviour is essentially explained based on individual preference and choice (Scott, 2005) or 'function of rules and incentives' (Peters, 2019). Thus, the construction and utilisation of institutions via rules, regulations and administration system are considered the outcome of individual behaviour in pursuing their goals (Peters, 2019; Scott, 1995). In the author's opinion, some of the issues discovered in the first round of interviews that related to the regulative pillar can be better understand through the lens of rational choice theory. For instances, there is a lack of adequate institutional arrangements to facilitate collaboration amongst cross-scalar organisations and the lack of leadership commitment to acknowledging uncertainty and long-term planning. These issues might be conducive to the information and calculations limitations of individual rationality where the benefits that motivate individual taking institutional actions are not fully understood. Thus, the potential outcomes might not be aligned with the individual goals.

As analysed by Peters (2019), normative theory is the root of the contemporary institutional theory where March & Olsen (1989) placed 'logic of appropriateness' (what ought to be rather than what is) in the centre of the new institutionalism to emphasise the role values and norms play in determining social behaviour rather than 'logic of utility' or 'logic of consequentiality'. The prescriptive 'rules' and obligations are formulated by informal systems of shared norms and values; thus, they are 'natural, rightful, expected, and legitimate' (March & Olsen, 2011). As a result, the rules are internalised by actors leading to the social behaviour being shaped by their own identify and role within institutions given a particular situation (March & Olsen, 1989; Scott, 2005).

Cultural-cognitive theory, emerged from sociological literature on institutions, is the third strand of new institutionalism. As Peters (2019) specified, while March and Olsen version of new institutionalism roots from sociology, it recognises normative dimension as the basis of institution. On the other hand, sociological literature on institutional theory emphasises the cognitive component which how actors' decisions are informed by the frame that they use to perceive the situation. Moreover, the cultural rules emerged from the wider environments provide a context that help shaping the institutional structure and behaviours (Scott, 2005). In short, actions of a member within an institution are influenced by the shared semiotic representations of social reality, and the socially constructed meaning and conceptions by the actors that evolved over time through continuous interaction and development (Berger & Luckmann, 1991; Peters, 2019; Scott, 2005). The cognitive dimension of the framework can be useful to explore the institutional inertia manifesting through the actors' perceived risk-averse that prevents them acknowledging uncertainty and long-term planning, and the entrenched behaviour of working within individuals' own frame/discipline that hampers the integration of vertical organisations.

Scott's framework of three institutional pillars (regulative, normative and cognitive) has been used in a number of research done by Australian urban water scholars and practitioners. The list below does not mean to be exhausted, but rather, to highlight prominent application of institutional theory in Australian urban water context:

- Brown (2003)used the framework to investigate the crucial factors for institutionalisation of sustainable stormwater management for local government through multiple case studies.
- Colebatch (2006) applied the framework to understand institutional context in in governing water recycling.
- Stenekes (2006) explored the stakeholder engagement in water recycling through the lens of institutional theory and governance approach in three case studies.
- Brown et al. (2009) combined urban water transition and three institutional pillars framework to analyse the institutionalization of sustainable urban water management in Australian cities.

New institutionalism, especially Scott's version, provides a useful lens and an analytical tool to analyse institutional changes in urban water sector, the same goes for the other two. However, the initial finding of this study did not indicate institutional issues as the root cause for the impediments. Rather, the interviews pointed to the need to explore the more fundamental issues with complexity and uncertainty based on various aspects of urban water systems and more fundamentally, how to identify and address the mismatch between interventions and the level of complexity of given situations. In addition, while institutional changes play a vital role in the implementation of sustainable urban water management, this research centred around strategic urban water planning practice in the context of adaptive, integrated, and participatory approach more so than concerning the efforts to institutionalise such approach. Therefore, this study did not take an institutional perspective from political science and sociology as the frame to investigate potential problems but borrowing the lens from complexity theory via Cynefin framework, a sense-making tool.

4.4.2 Why the Cynefin framework was chosen over other similar sense-making frameworks

Within the realm of complexity theory, there are approaches that share similarities with CF such as Stacey's matrix and Zimmerman's variation on Stacey's matrix (Davies 2010).

In fact, the Stacey matrix was the 'initial stimulus' for this kind of thinking on a sense-making framework in which various degrees of complexity are differentiated based on different factors (Snowden 2019). Stacey's matrix was originally used mainly in strategic organisation management (Stacey et al., 2000), and later on in project management and software development that applied the Agile methodology (Kurtulaj 2015). Zimmerman's variation is a simplified version of Stacey's matrix and has also been used by 'people in the Agile world' (Snowden 2019).

Essentially, the biggest difference between Stacey's matrix (and Zimmerman's variation of it) and the CF is that Stacey's matrix has two axes which are absent in the Cynefin framework. The two dimensions which are used to identify the degrees of complexity (assigned with different zones) are shown in Figure 2. They are: certainty (the predictability of the events) and the level of agreement among stakeholders over those events. While the two axes are convenient for stakeholders to use to determine the state that events are in (e.g.: the edge of chaos), Snowden (2019) argues that they represent a rather a linear approach in which the changes are categorised along two axes. In contrast, the 'four tables contextualisation' in CF allows for the consideration of multiple shifting movements between domains. This produces a resilient and dynamic approach to decision-making (Snowden 2019). Also, while the underlying principles of the Stacey matrix are derived from system thinking, CF upholds the assumption that ontologically incompatible systems can co-exist (Snowden 2019). To be more specific, CF works in a way that helps people realise the boundary between the present and what they have done in the past instead of rejecting it, and it encourages them to do things 'differently on both sides of the boundary' (Snowden 2019).

A large part of why CF was chosen for the research in this thesis in preference to Stacey's or Zimmerman's matrixes relates to CF's universal compatibility with all types of problems, as well as the fact that it has been previously introduced to the water sector. Not all issues in the water sector can be explored using the Stacey matrix. Its use depends on levels of agreement and degrees of certainty. For example, from the first round of interviews, the complexity that comes with the overlapping of various planning scales, or the lack of a mechanism for organisational collaborations, or the complexity related to technical capacity, are difficult to categorise in accordance with the two axes. In contrast, the four domains in CF offer a more flexible option for contextualising the issues. Furthermore, the CF concept was initially presented to the Australian urban water sector through a series of introductory workshops in Sydney, Canberra, Melbourne, Perth, and Brisbane and via a series of public engagement processes to inform the Melbourne Healthy Waterways Strategy in 2018 (Maribyrnong Catchment Collaboration 2018; Collaborative Implementation Lab 2018), it was also used in the stakeholder consultation processes for the 2017 Metropolitan Water Plan.

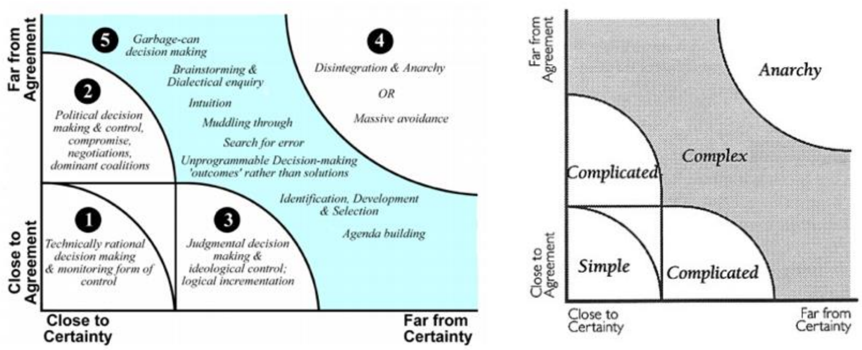


Figure 4. 4: Stacey matrix and the Zimmerman variation of Stacey matrix

4.4.3 Background to Cynefin Framework

Emerging from research conducted into the theory of complexity, complex adaptive systems and cognitive science, the Cynefin framework (CF) was developed by Snowden (2000) as an influential sense-making tool to assist decision-making processes (Snowden, 2002; Snowden & Boone, 2007). Elsewhere, the CF was found to be useful in health care and medicine (Gray, 2017; Lunghi & Baroni, 2019; van Beurden et al., 2013), as a tool for developmental evaluation (Ramaswamy et al., 2018), for exploring wicked problems in electronic records management (Childs & McLeod, 2013), for evaluation planning to select evaluation methods and approaches for answering evaluation questions (Britt, 2011), and for evaluating safety in electricity utilities (Sardone & Wong, 2010). However, CF has been used in many areas, but not extensively in urban water.

The strength of this framework lies in its ability to explain situations based on an understanding of their operational contexts and its capacity to provide suggestions for appropriate responses (Britt, 2011; Ramaswamy et al., 2018). Also, it can help people to 'break out of the old ways of thinking and to consider intractable problems in new ways' (Snowden & Kurtz, 2003). Moreover, it is believed that the Cynefin framework is able to assist practitioners to understand 'the complexity of the issues, identify appropriate strategies and avoid the pitfalls of applying reductionist approaches to complex situations' when it is used as a sense-making tool (van Beurden et al., 2013). The Cynefin framework is also appropriate for applying in this research, as one of the most significant concerns raised in the first round of interviews was the resistance of stakeholders and the wider public to changing their outdated perspectives on urban water-related matters.

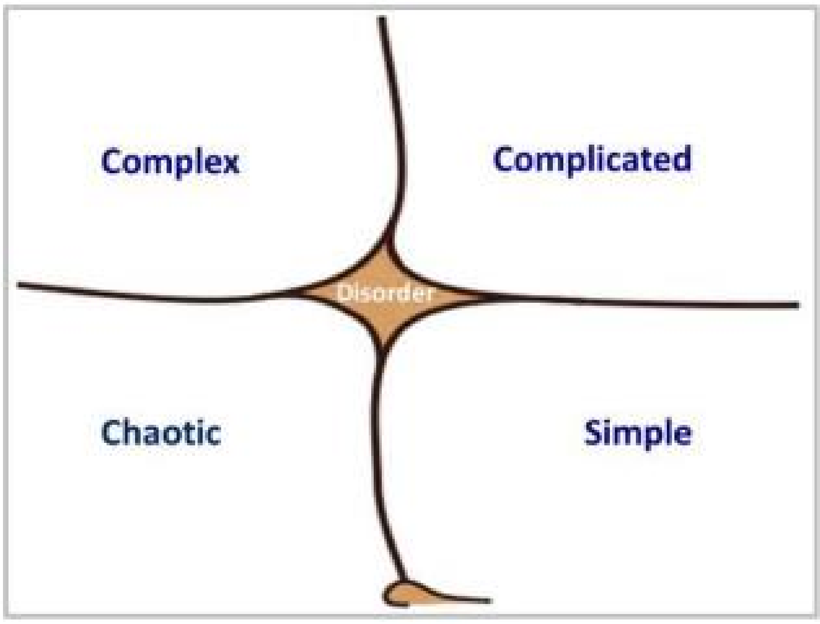


Figure 4. 5: Cynefin framework (Snowden & Boone, 2007)

The framework provides a template of various spaces in which issues and decisions/problem solving might occur, and it also brings forth the associated sequence of responses. The framework highlights four primary domains. The systems or issues which operate in the *simple* and *complicated* contexts can be characterised as being somewhat ordered, and as requiring conventional responses based on current good practice. Those which function in *complex* or *chaotic* contexts do not have a logical ordered appearance, and the responses in these contexts require emergent or interventionist responses (Snowden, 2002, 2005a; Snowden & Boone, 2007; Snowden & Kurtz, 2003).

a. *Simple context* – the domain of best practice

In the simple context, the system is stable, and its cause-and-effect relationships are apparent, linear and agreed upon. Moreover, as causal relationships are linear and repeatable, an evidence-based, best-practice approach is appropriate for arriving at solutions (Kempermann, 2017). Thus, the outcomes are predictable and trusted. As a result, standard procedures and processes, manuals and guidelines are used to achieve desired pre-determined outcomes. The recommended model for responding to issues in this context is 'Sense–Categorise – Respond'. This model highlights prior knowledge obtained from historical data to categorise the problem. Since the recurrent issues and their counter measures are understood, it is easy to sort out the best way to respond. In this context, top-down command and control is the appropriate management model, and there is a clear role for the management team to coordinate and assign resources and responsibilities among employees (Snowden, 2002). The connections between other agents in the system might be weak, but they are coordinated by the planning team.

b. *Complicated context* – the domain of experts

The complicated context is the domain of experts because ordered causal relationships exist but are not fully understood until further investigation by experts in the relevant fields is undertaken (Snowden & Boone, 2007). Operating in this context, one might 'sense' that something could go wrong, but one does not know for sure what will happen. Research is required to understand the nature of cause-and-effect connections. Expert opinion is needed to define the critical elements of 'good practice' which differs from 'best practice' in that there might be multiple good answers instead of one right answer (Snowden & Kurtz, 2003). Analytical power from particular disciplines is the key characteristic in this context (Sense – Analyse – Respond). The main principle embedded in this context is the belief that the system is the sum of its parts, and that by breaking down components for separate investigation, the causes and effects of various components, as well as the interconnections between them, can be analysed and understood. This context/domain is characterised by cooperation between decision-makers and researchers.

c. *Complex context* – the domain of emergence

The complex domain is to some extent the main focus of this study. Systems operating in this context work in an 'unordered' way that involves non-linear causal relationships that are obscured by the constantly changing conditions of the various components (Snowden, 2005a). It is impossible to predict exactly how the system will behave, or to use conventional analysis (analytical or deterministic modelling approach) to understand the system. Only by capturing the emerging pattern of the system's behaviours can the system be comprehended. The logic is that the current emerging pattern identified through 'retrospective coherence' is 'only one of many patterns that could have formed, any other would be equally logical' (Snowden, 2002). Therefore, it is impossible to predict, using 'expert opinions based on historically stable patterns of meaning', whether the pattern will continue or repeat or change into another pattern. Nevertheless, the emergence of a pattern can be recognised, disrupted, reinforced or seeded (Snowden & Kurtz, 2003). As a result, the decision-making model suggested for this domain is first, to 'probe' by disturbing the system in order to cause a pattern to emerge, and then to 'sense' it and 'respond' with actions that can stabilise desired trends and destabilise undesired trends. To be able to apply this method in practice, multiple perspectives on the nature of the issues, as well as innovative approaches, are required through collaboration between bottom-up agents to encourage shared learning from diverse perspectives in order to construct the most suitable 'probe' for the system. The complexity and uncertainty of this domain are characterised by the fact that a small change in one part of the system might lead to unexpected and major effects elsewhere. In addition, it is suggested that complex adaptive systems (CAS) can be well described in relation to the characteristics of this domain where the system is largely unpredictable, self-organised and emergent.

d. *Chaotic context*

The last domain, the chaotic domain, is referred to as a turbulent system in which there are no visible causal relationships. It is no use analysing the data and there is no time to wait for a pattern to emerge because there is a state of emergency. Instead, the urgent need is to act swiftly to reduce the turbulence and to minimise damage. The feedback from the actions taken needs to be 'sensed' in order to decide what action to take next.

It is important to notice that there is a 'cliff' on the boundary between the simple and chaotic domains. This analogy implies that disastrous consequences come after the rapid 'fall' from a simple to a chaotic state. The typical reason for this is the dependence of actors in the system on predetermined processes and practices that create inflexibility and remove the capacity to be creative and resilient. As a result, any disruption could bring chaos to the system.

To summarise, the tables below describe the main characteristics of the domains in CF, the type of sense-making practice, and the overall strategy for each domain.

Table 4. 4: Summary of the Cynefin framework's characteristics (Gray, 2017)

Type of problem	Predictability	Cause and effect?	Type of practice	Strategy
Obvious	Stable and predictable by all	Clear cause and effect	One right answer **Best Practice** Protocols essential	Sense Categorise Respond
Complicated	Stable and predictable by experts	Cause and effect discernible with analysis	Several right answers **Good Practice** Protocols helpful	Sense Analyse Respond
Complex	In flux and unpredictable	Cause and effect may be there but only understood in retrospect	No right answers **Emergent practice** Protocol unlikely to work	Probe Sense Respond
Chaotic	Turbulent	Situation too turbulent and changing to consider cause and effect	No time to search for answer **Act to gain control** Protocol no help	Act Sense Respond

Table 4. 5: Types of sense-making (adapted from Snowden & Kurzt (2003) and William (2010), in Britt (2011))

Sense	Collect sufficient data to identify the characteristics of this aspect of a situation.
Categorize	Identify where these characteristics fit within the known world.
Analyse	Rely on expert opinion and diverse stakeholder perspectives in order to identify cause-effect relationships and select appropriate response.

Respond	Carry out the practice that has been proven to be the most appropriate to that category (e.g. best, good, emergent or novel practice).
Probe	An experiment that makes patterns more visible and knowable by sensing.
Act	A strong intervention designed to shock a chaotic aspect of the situation back into some form of order.

Table 4. 6: Overall strategy for each domain (Britt 2011)

Domain	Description	Strategies
Simple/ Known	Everyone knows the right answer	Sense – Categorize – Respond
Complicated/ Knowable	What we need to spend time and energy finding out; an expert would know	Sense – Analyse – Respond
Complex	What we can pattern retrospectively	Probe – Sense – Respond
Chaotic	What we need to stabilise for patterns to emerge; there is no right answer	Act – Sense – Respond

4.4.4 The application of CF in this research

This sub-section outlines the two main applications where the CF was incorporated into the research.

Firstly, the author used CF as a lens to break down and make sense of the current urban water planning and management approach and the associated issues in metropolitan areas on the eastern Australian seaboard. The aim was to get better insights into a high-level case study by investigating the current planning and management practices for urban water with regard to their respective operating CF domains. In other words, while data from the first round of interviews suggested an overall high level of complexity in many aspects (as described within the Introduction to this chapter), not all of them have to be complex. Therefore, this exercise was used to test whether or not the CF had the explanatory power to locate the problems of urban water planning and management on the matrix, and whether it had the exploratory power to identify the appropriate strategies to possibly 'phase shift' the practice to another domain with less complexity.

The characteristics of each domain, as well as the description of the response strategies which were used to evaluate current practice, were extracted from publications by the originator of CF (Snowden, 2002; Snowden & Boone, 2007) with the consideration of newer publications from CF practitioners such as (Britt, 2011; Gray, 2017; McLeod & Childs, 2013b; van Beurden et al., 2013), etc. The data from the first round of semi-structured interviews (first round of data collection) and information from the analysis of relevant planning documents and reports in the study areas were scrutinised. The output was a more holistic view of the complexity of urban water planning and this was useful for identifying what part of the system or what problems were either 'ordered' (in the simple or complicated domains) or 'unordered' (in the complex or chaotic domains) (Snowden, 2005a). Moreover, making sense of the movement of the problems between domains highlighted the flexibility and robustness of the conceptual tool. It is noteworthy that within the scope of this research, the chaotic domain will be discussed but not extensively analysed. Events like prolonged droughts or bushfires on a large scale are unavoidable. Chaotic situations such as these are the result of extreme climate change combined with the inappropriate responses of agents in the system over time. While it is useful to identify appropriate courses of action to take if chaos happens, in the author's opinion it is more constructive to prevent chaos from happening in the first place by analysing the challenges and responses of the agents in other domains.

The outcome of this critical analysis on current situations related to complexity and uncertainty of urban water sector in the study areas highlighted two main features of the CF. The first one is that CF is a robust tool which can be used to provoke and challenge prior thinking, and hence, it is useful for improving explanatory prowess. It is robust in the sense that it provides a simple yet thought-provoking description of the domains, and thus it can be employed in a number of ways. The most prominent way is to use CF as a 'social constructed sense-making framework' as suggested by the creator, Dave Snowden (Snowden, 2005b) where multiple narratives from stakeholders are gathered from facilitated workshops to define the domains and boundaries of events or the system under consideration. In other words, 'with sense making the data precedes the framework, the boundaries of which emerge from the data', in contrast with categorisations where the framework precedes the data (Snowden, 2005b). However, CF is most frequently used in a 'hybrid' socially constructed way as a frame to make sense of the data that is collected through individual or group interviews within case studies (K van Beurden et al., 2011; McLeod & Childs, 2013b; Sardone & Wong, 2010). Further, a number of authors have applied CF as a conceptual framework to guide their thinking and analysis based on a review of the literature and relevant documents to generate their own interpretations of the problems (Gray, 2017; Kempermann, 2017). The author followed this approach for the evaluation of current urban water planning and management paradigms, which yielded insights on the complexity of the existing issues and understanding on why the current paradigm fails to secure and maintain urban water services. The fact that users found various ways in to usefully apply CF shows the versatility of the framework in addressing complexity.

The second feature is that CF is effective in constructively extracting personal experiences and narratives on the problems that users wish to explore. In the author's experience, CF helped guide the interviews and the document analysis process by providing criteria to distinguish between domains which are general enough to cover various factors and descriptive enough to enable critical reflection on past experience. This demonstrated the exploratory and diagnostic power which can be used to gather experts' opinions on the topic of complexity and uncertainty within urban water systems.

These identified features led to the second application of CF in this research. It was used to structure a second round of data collection including five key online semi-structured interviews, with the focus on Sydney as a case study, especially around the 2017 Metropolitan Water Plan. The overall aim was to explore the underlying complexity, and the level of complexity of the tools and methods from the respondents' perspectives. In order to do that, the concepts of CF were introduced to the interviewees, and they then used them to reflect on their experience and practice to explore their innate complexity and uncertainty.

This application of CF is different from the former one and is a unique application of CF that has not previously been described in the literature, in the sense that it gathered qualitative data from interviewees' perspectives through the lens of CF. That is, the approach to this second round of interviews was to some extent similar to narrative inquiry methodologies used in social science research. The personal points of view of respondents were captured based on their reflections and experiences over time and based on the relationships between their individual experiences and the contextualisation provided by the concepts of the four domains in the CF (based on the definition of narrative inquiry by Clandinin and Connelly (2000).

As discussed earlier, the author initially planned to carry out a facilitated workshop in March 2020, in order to ‘socially construct’ the meaning of the CF domains and their boundaries in the context of urban water planning and management in Sydney (as suggested in Snowden (2002)). However, shortly after the planning phase, the COVID-19 pandemic struck and put everything on hold. Due to the limitations of time and resources available for a PhD program, the data collection approach needed to be adjusted. For that reason, an in-depth semi-structured interview technique was chosen, since it avoided the technical difficulties associated with running an online workshop on a very complicated topic.

An interview brief which contained information on the purpose of the interview, and the definition and characteristics of CF, was sent to the interviewees beforehand. Although the material was sent in advance, the brief introduction to CF was once again communicated to the interviewees at the beginning of the interview. The interview questions were structured in an ‘open’ manner based on the four main domains of CF with the aim to create a space in which to have a conversation exploring the respondents’ views on the tools and methods, as well as the issues within their planning and management practice. Although CF was presented as a two-by-two matrix, the objective was not solely to let participants locate their experience, but also to use the matrix as a frame to elicit their interpretations of the rationale for those categorisations.

The outputs of this process, which will be analysed and discussed in chapters 6 and 7, were: the mapping of issues, and tools/methods onto CF domains; and the interviewees’ narratives on why they were positioned as they were. While the narratives regarding issues provided context and knowledge to develop the six main themes of the issues which arose due to complexity, the mapping and narratives regarding the tools and methods opened up discussions on the potential ways forward in dealing with complexity and uncertainty in urban water planning and management.

4.4.5 Some implications from applying CF to this research

Regarding the analysis of the usefulness of CF in this research, the concept of the domains in CF offered a constructive and descriptive theoretical basis to evaluate the degree of complexity of the planning approaches and their suitability for addressing complex issues. For example, the conventional predict-and-control approach operates in the simple domain and therefore is appropriate for addressing simple issues. In contrast, the IUWM approach can operate in both the complicated and complex domains, based on the contextual conditions, and therefore address complicated and complex issues. Moreover, the response strategies attached to the concepts of the domains in CF offers guidance on identifying the appropriate tools and methods that might be most useful for each situation. As a result, the CF increases the capacity to critically analyse events that happened in a particular domain. For example, the analysis of how strategies applied to drought management from the period between the end of the 2000s Millennium Drought (around 2012) and the recent severe drought (2017-2020) and bushfire season called the black summer (early 2020) shows how using a simple approach to deal with a complex problem can lead to the dangerous consequence of the system falling into the chaotic domain.

In applying the CF in this research, a key area for improving the used of CF in analysing the complexity of tools and solutions for urban water management was evident. Because the CF is a sense-making tool that is open to interpretation, it is inevitable that human biases can come into play in terms of differences in how people perceive the domains. The approach of CF, which involves evaluating the causal relationships of an event or a system, is prescriptive but not descriptive (i.e. the CF does not provide extensive detailed guidance on how to categorise a given situation into one of the four domains). Therefore, it would be good practice to specifically define the system boundaries, the components, and the scale in which the subject is discussed. For example, interviewee W1 argued that controlling the coronavirus outbreak is a simple problem since the causal relationship is humans transmitting virus to humans; therefore, forbidding social interaction is the obvious solution. This argument is valid from a narrow standpoint. From system thinking perspective, humans as actors have interactions with other actors or subsystems such as other humans, or nature, the economy, natural resources, other subsystems or even other aspects of the same subsystem such as mental health, physical health or family well-being. Therefore, the appropriate question to ask is: To what extent should human interactions be limited, and how should the solutions be implemented in a way that prevents a further outbreak, while at the same time, minimising negative impacts on all other interactions? Framing the problem in this way helps identify the complexity and improve the chances of implementing successful solutions.

4.5 Ethical consideration

This study will involve participants who are over the age of eighteen. The question of whether or not they belong to minority groups does not raise any concerns since the focus of the project is not on indigenous research, and the research will not take into account the status of such groups. Thus, the risk of this research is estimated as low. The research design meets several relevant ethical guidelines, including the University of Technology, Sydney (UTS) guidelines for ethical conduct of research involving humans which aligned with the Australian Code, National Statement on Ethical Conduct in Human Research, the New South Wales User Guide, the National Privacy Principles, the Institution for Sustainable Futures (ISF) Code of Ethical Research Conduct, and any additional articles agreed to in consultation with research partners (if any). The project strictly follows these overarching ethical principles in the National Statement on Ethical Conduct in Human Research, namely respect for human beings, research merit and integrity, justice and beneficence (section 1, National Statement, 2015).

Moreover, in compliance with the Institute for Sustainable Futures' approach to conducting research, which emphasises that ethical research is good quality research, the design of the study aims for the highest possible quality of outcomes.

The research engaged with government agencies. Therefore, it is likely to have some associated risks. One concern is the possibility of uncovering malpractice or practices frowned upon by superiors or the public. This was dealt with following guidance on how to respond of illegal or harmful practices that are discovered by the UTS Human Research Ethics Committee. De-identifying individuals or organisations was used to protect the confidentiality of data. Due to the exploratory nature of the research questions, ownership of any potential findings will need to be discussed beforehand. Further, the researcher is well-aware of the fact that his different cultural background and different mother tongue might lead to problematic expressions or phrasing of the questions. However, the researcher spent seven years studying in English and being lectured by professors from the US and the Netherlands during his studies for a Bachelor of Water Engineering and a Master of Integrated Water Resources Management. In addition, he has had previous work experience as a guest researcher in Delft University of Technology for more than one year. Therefore, he has acquired the ability to understand and interpret academic language as well as the language that people in the water industry frequently use. Moreover, he is familiar with Western cultural norms, and this helps in overcoming differences.

To ensure the intended research design achieved ethical clearance the researcher had several consultations with research supervisors and the UTS Ethics section, plus making reference to various guidelines and policies such as the UTS Research Ethics and Integrity Policy, the Guidelines for Ethical Research and Evaluation in development by Australian Council for International Development.

The ethics application with a detailed risk assessment attached, was submitted to and approved by the UTS Human Research Ethics Committee following the Stage 1 assessment.

Prior to the interviews, Participant Information Sheets were prepared and sent to the participants specifying the aims and objectives of the PhD, the reason for recruiting that individual, what will entail in the interviews, the associated risks, the voluntary status, and confidentiality conditions. Moreover, a consent form was also sent to ask for audio and video recording permission.

5 Chapter 5- Analysis of interviewees' perspective on the three frameworks (PP, IUWM & AM)

5.1 Introduction

Authors and practitioners have called for an integrated, adaptive, and participatory approach to sustainable urban water management. While these approaches exist in the literature individually, there is an absence of analysis of cases in which all three approaches have been adopted successfully. Therefore, in this research, the the first round of interviews aimed to understand better the extent to which the PP, AM, and IUWM approaches have been combined in practice and applied in strategic planning studies.

To that end, the perspectives of senior water professionals were obtained in a series of semi-structured interviews, which were designed to draw on their experience and knowledge related to the research concerns. The interview data were then scrutinised and analysed by applying grounded theory coding techniques (Initial coding and axial coding), and the essential features of the interviewe were brought out as a series of insights and outcomes. The findings have been synthesised and captured in this chapter, which has two main parts. In the first part, the interview transcripts are analysed. Through the interviews, the participants' perspectives regarding using the three approaches of interest (PP, AM and IUWM) were sought. In the second part, the data is broken down and regrouped into key topics based on the thematic areas identified via coding.

Overall, while the interviewees confirmed what was reported in the literature, it was also found that the three approaches were highly interconnected in practice and could be complementary to each other. However, there were hardly any cases in which all three approaches were implemented together.

Regarding the public participation approach, in general, the interviewees believed it could bring benefits for decision-making and that the greater the level of engagement, the greater those benefits could be. However, the extent to which the approach could contribute to the overall success of a project, or a plan remained unclear. Also, the respondents expressed concerns about the resources required to implement meaningful public engagement processes and about the difficulties of communicating about the complexity and uncertainty of integrated and adaptive systems with communities and stakeholders.

Concerning the adaptive management (AM) approach, there is little evidence of implementation in the Australian water sector, but this approach has recently gained traction by being discussed in some official documents. In the interviews, it was found that, despite interest, there was a lack of clear understanding of the AM concept. Also, the interviewees reported that the extended timeframe required for the application of AM could be challenging for any engagement, whether it involved stakeholders or the public. Moreover, uncertainty about the approach was identified as a significant hurdle hindering it from taking off.

True integrated urban water management (IUWM) was found to be rarely implemented in practice despite its popularity in the literature. The respondents believed that IUWM implementation could be improved by giving attention to the following key areas: collaboration between stakeholders, the clear allocation of responsibilities between organisations, resistance to change on the part of organisations, and public participation.

Analysis of the interview data on the three approaches using various coding techniques revealed twelve main themes (table 5.1). Among them, four themes stood out were:

- People's reluctance to accept uncertainty;
- The difficulty of communicating about complexity and uncertainty when engaging with stakeholders and the public;

- The complexity of IUWM and AM concepts,
- Difficulties with respect to defining temporal and spatial boundaries.

These four topics are highlighted because they are the top four most frequently referenced throughout the interviews.

Further detail on the analysis of interviewees' perceptions about the three approaches and a synthesis of the issues and tensions associated with combining them, are unpacked in this chapter. The structure of this chapter is as follows: Interviewees' perceptions about each of the three approaches (PP, AM and IUWM) are covered in Section 5.2, in which their personal experiences and perspectives are drawn upon. In Section 5.3, prominent emerging themes are identified using qualitative data analysis methods of provisional and grounded theory coding. A summary of the findings and key implications is presented in Section 5.4.

5.2 Perceptions of water professionals on the three approaches

5.2.1 Integrated urban water management (IUWM)

The literature on IUWM is vast and covers a range of areas and topics, but overall the body of knowledge is fragmented and, therefore, somewhat ambiguous, as discussed in Section 2.2 (Furlong et al., 2015). As a result, it is challenging to pinpoint a concise definition of IUWM or an agreed set of concepts that characterise the approach. Therefore, this section aims to distil participants' points of view on the key IUWM concepts, its key elements, and how well IUWM is being applied in practice. The analysis highlights the associated difficulties and emerging issues when IUWM is incorporated with other approaches (specifically participatory approaches and adaptive management).

5.2.1.1 Execution of IUWM

Through the interviews, this research reveals the participants' perceptions of the key elements of the approach, their judgement on how well IUWM has been carried out to date, and what issues IUWM raises in practice. The concept of using integrated approaches in urban water management is not new and has been discussed and analysed in many documents. However, the execution is rare, and the idea has not been picked up as ‘common practice’ in the study areas; this point was found in both the literature review and interviews (Furlong & Silva 2016; N2 2018). As interviewee N2 emphasised, ‘IUWM is not usual, it's not business as usual (BAU)’ and ‘IUWM is not done very well in Sydney. Although the approach has gained more traction recently, examples of systemic changes on the ground at the initiation of the plan or project are hard to come by’.

The IWM framework for Victoria, published in 2017, might be the most significant effort to mainstream the approach in recent years. The collection of Melbourne water strategies was developed using the platform that this framework provided (more detail in section 3.2). What makes the document so impactful is the clearly articulated mechanisms for collaboration between organisations and the guidelines and tools for integrated planning. On the other hand, although an integrated approach was articulated in the Integrated Water Cycle Management guidelines in NSW in 2004 (NSW Office of Water, 2014a) and the Total Water Cycle Management framework in Queensland in 2009 (Queensland DIP, 2009), these approaches have not been updated. They are yet to capture the current thinking on IUWM.

In general, the reasons for the patchy adoption of integrated approaches are related to various issues, as pointed out by the practitioners in the interviews. The most cited issues related to the complexity and scale of application, and these are exacerbated when they occur in the context of combining an integrated approach with PP and/or AM. Those problems/tensions and the opportunities that arise are analysed later in this chapter to form the basis for the arguments in the next chapter, also.

5.2.1.2 Collaboration and engagement within an IUWM approach

In general, 'Collaboration and engagement' frequently emerged as key requirements for IUWM to work in practice. Interviewees emphasised that collaboration between responsible organisations from all parts of the water cycle is crucial and that community engagement plays a vital role in improving the process.

Firstly, collaboration was raised as a key feature and an issue across fragmented governance systems. For example, as stated by V1, as IUWM is concerned with 'multiple systems at multiple scales', 'collaboration between the key organisations involved is a key point'. Interviewee V2 also suggested that two vital elements of IUWM are 'having an approach where you are looking into the whole water cycle and collaborating with all of the organisations that have responsibility'. However, this crucial feature was also considered challenging to implement by participants. As interviewee Q2 described:

> By having different department and having such a highly fragmented different parts doing different elements of water, you will not achieve the optimum result for the community. IUWM is where we try to cope with the fact that we have such a governance system in place

Two main difficulties arose from this situation. One of the conflicts identified is about how to *re-allocate the responsibilities of organisations* when carrying out integrated plans or projects and then how to assign actions accordingly. Respondent Q3 reported that the complexity of IUWM projects usually involves 'cross-jurisdictional boundaries' and said that 'there are more than one entity that is responsible for different elements of the integrated system'. Stormwater management in NSW can be a case in point since both State Government, and local authorities are responsible for ensuring services are provided reliably. While it is common practice for multiple organisations to be responsible for any component of the water cycle, there is still overlap in terms of authorities from different entities, and there are conflicts regarding the priorities when implementing plans. Interviewee Q2 pointed out that the view is that sometimes people 'do not want to spend money or time or effort in Integrated water management as a priority; they think the priority is to reduce the cost'. In the case of Melbourne, this kind of complication was reported by participant V2 to have occurred in integrating stormwater management into the water supply and in sewerage management and flood control strategies. In both NSW and Victoria, it was reported to have occurred in balancing water for waterway health and water supplies, as implied by interviewee N1.

Leadership with high commitment to carry out IUWM approach was found to be among the most important enablers to collaborative processes. Interviewee N2 pointed out the vital role of key stakeholders, who hold great authority, in the collaboration process and in getting the IUWM projects up and running:

> Major water utilities did not agree with what the Metropolitan Water Plan (MWP) came up with, so they tried to dismantle it and once the team was dismantled, then it went back to business as usual (BAU) in the organisations. BAU is not an integrated approach, not an adaptive approach

The lack of leadership commitment to IUWM and long-term planning due to short-term political agenda was also documented in literature (Farrelly & Brown, 2011; Mukheibir, Howe, et al., 2014).

Another issue is *resistance to change due to the entrenched cultures of organisations*. This problem was found repeatedly in each state under consideration in this research as IUWM is all about holistically solving water issues with the unavoidable consideration of future conditions, complexity and uncertainty in the investigation and implementation processes. This prevents people in organisations such as 'water utilities', who are 'not comfortable with complexity', from replacing traditional ways of dealing with separate issues and technical-structural solutions with a proactive, holistic approach that focuses on all types of innovation. Various interviewees, including N2 and Q1, described this notion. Respondent Q1 suggested that ‘it [the ability to share knowledge and information about innovative approach across the water industry] all boiled down to the individual people who just work within their frames of preference’ and ‘it's always limited by the outlook and the job of the person who is leading this stuff, so it's an inherent limitation due to the individual’s inability to truly think holistically’. This notion was also reflected in the existing literature on IUWM. More specifically, the traditional view on management across organisations (especially public agencies) was seen as preserving a risk-averse culture that is resistant to new ways of responding and adapting to complex, unpredicted problems and that works to 'kill off' innovations due to an unwillingness to 'try something new' (Marsalek, Rochfort & Savic 2001; (Wong, 2006).

Secondly, besides the collaboration between organisations, as discussed briefly above, community engagement is a key element of IUWM. The interviewees vividly depicted how community engagement programs supported IUWM implementation in different regions. For instance, interviewee V2 shared information about a community engagement process involving the development of the Melbourne healthy waterway strategy in which 12 community meetings were held over 12 months. Interviewee N2 cited the community workshops for people to play a part in managing environmental flows and determining the water restriction thresholds under the Sydney Metropolitan Water Plan’s framework. Also, respondent Q2 mentioned a massive and intensive public participation program for integrated servicing strategies in Brisbane and Ipswich by Queensland Urban Utilities (QUU).

However, it is interesting that there is a mismatch between this argument and the findings in the literature. In the literature, while it is undeniable that community engagement plays a vital role in IUWM and other similar approaches (van de Meere and Brown 2009; Bahri 2012; Wong et al. 2013), it has previously been found that community engagement had not been well adopted in real life. Even in cases where it was implemented, the community’s values and perceptions have not been adequately incorporated into decisions (Fegurson et al 2013; Furlong

2016). From the author's point of view, this mismatch might suggest two hypotheses. One might be that the benefits of the participatory approach are beginning to be realised, and people are trying to take it up and refine its implementation. Another might be a lack of evaluation tools or performance indicators to assess the outcomes of engagement programs within IUWM implementations. Nevertheless, there are still some practitioners who remain sceptical about community engagement. Interviewees N1 and Q3 suggested that programs not only use a lot of money and time but also involve the risk that the community will be biased about the matters under discussion.

5.2.2 The public participation (PP) or participatory approach

Findings from the literature review (chapter 2) indicate that public participation has been well discussed in natural resources management, water management and integrated water management (at the basin scale). However, it has been less well articulated in integrated water management, adaptive management or adaptive planning in an urban context, especially in ways that reflect real-life practices in Australia. Therefore, this sub-section explores the participatory approach in an urban water planning and management context, drawing on the practitioner interviews.

Overall, some key themes can be drawn from the interviews. Although respondents N1 and Q3 suggested that public engagement is a requirement for both IUWM and AM, in real life, it is not 'business as usual', and even if it is meant to be standard practice, it is not. However, some detailed examples were given in the interviews of the approach being applied successfully in urban water management projects and planning processes in various locations, including Brisbane, Melbourne and Sydney (as discussed in section 5.2.2). In general, matters related to public engagement took up a significant amount of the interview time, and hence it is reasonable to infer that the importance of the approach has been realised and practitioners are now more invested in it. Since it was being carried out more on the ground than was the case in the past, the interviewers reported several practical issues associated with it.

As a side note, the IAP2's framework for public engagement was repeatedly referred to in various interviews and was reported to be widely used among Australian practitioners by interviewees V1, V2 and Q2. However, it was unclear whether the framework was used to define the level of involvement as they proceeded or to evaluate the process after it was completed. The interviews did not reveal the desired level of public participation in the cases. Interviewees from Victoria referred to the framework as the 'IAP spectrum' and pointed out the aspirations to be 'further to the right' (V1) on that spectrum (which means higher levels of engagement) or 'it is great to be into the higher end of the spectrum' (V2). Queensland respondent Q2 asserted that '[the IAP2 framework] was actually adopted by the Queensland urban utilities for all community engagements'.

The advantages and importance of community engagement in the planning and management processes are manifold and were recognised throughout the interviews. Critical issues with participation that emerged from the analysis of the interviews are discussed below.

5.2.2.1 Informing and being informed

Some interviewees were concerned about people's right to know, and to allow community members an opportunity to have input into decisions that will change things in their neighbourhoods, as reported by V2 and Q2. Interviewee V2 acknowledged the importance of community engagement by pointing out that it is 'an opportunity to have input into the things that they will see in their neighbourhood and into the way that this infrastructure will be built and operated, how will this look'. Interviewee Q2 asserted that 'we were not just consulting by telling, but we were also listening and reflecting'.

This notion of the right to know and to contribute to the decision-making process resonates with the 'normative claim' about public engagement, which has been singled out in the literature as being one of the most important fundamental ideas in the development of the participatory approach as detailed in Section 2.3

(Cambell & Salagrama, 2001; Fiorino, 1990; Habermas, 1991; Laird, 1993). 'Normative values' were not discussed in detail in the interviews, but views on these issues can be inferred from multiple interviews related to the umbrella idea of '[informing] better decisions' as referred to by participants V2 and Q2. For example, respondent Q3 suggested that engaging the community in the process might 'get the community really on board with what you're doing' and interviewee N2 shared that 'you get people's buy-in at the beginning of the process.

Moreover, participants from utilities in New South Wales and Queensland (N1 and Q2) from this round of interviews pointed out the social learning process benefits where lay people not only contributed their knowledge, values and experience but also learnt from each other and from the experts throughout the process of IUWM and adaptive planning to come to a shared understanding. An example is the multimillion-dollar community engagement programme from 2009 to 2016, initiated by Metropolitan Water in New South Wales to provide knowledge about the water system and how it is managed, as well as to include lay people in the decision-making process and to provide them with a platform to express their ideas about how to deal with issues (N1 & N2). It was also reported by interviewee N1 that 'during these deliberative exercises [where participants were asked to play the role of decision makers], each person had the agency to make their own decisions and then they would discuss them to see if their views shifted'. Another example was the two-way engagement program held by Queensland Urban Utilities to identify solutions and strategic responses to issues in Brisbane and the Ipswich region. The practice was described as 'a full learning involvement' in which the level of engagement was seemingly up to the 'collaborate' level on the IAP2 spectrum (Q2 2018; IAP2 2014). This level of engagement is defined as the process where multiple parties learn from each other to co-formulate solutions, and where the community's perspectives and recommendations are incorporated into the decisions to the greatest possible extent (IAP2 2014).

Nevertheless, details of how the community's ideas were incorporated into decisions remained unclear. Lastly, according to Victorian interviewee V2, community engagement programs to support Melbourne's healthy waterways strategy were portrayed as going beyond informing the community about the issues and solutions and being the 'biggest engagement in strategy development'. Twelve community meetings were held over twelve months. Hundreds of community members were taken through the journey to share their values and ideas to develop decisive strategies.

5.2.2.2 Diversity in decision-making

Besides the 'normative' values discussed above, some members approached the engagement process in a more instrumental way emphasizing the potentially powerful impacts of the sharing diverse perspectives. Such benefits were described by the interviewees in several ways. Interviewee Q2 suggested that community engagement holds the potential to resolve conflicts and to have 'more brain muscle available for dealing with uncertainty'. A more or less similar idea was highlighted by respondent N1, stating that an engagement programme can 'broaden the thinking, the options' in the plan in which 'groups of people [stakeholders and the community] were involved in the early stages of the process'. Moreover, participant N2 mentioned the potential to foster a social learning process among members of the community during the process.

Those notions align with 'pragmatic' claims in Section 2.3. The potential for better decisions refers to changes that directly impacts a particular community or group of customers, such as an improved level of service, lower costs for delivering services, or the impact on water supplies of proposed environmental flows. Interviewees N2 and Q3 proposed that being involved in part of or the whole process 'increases participants' buy-in' in the plan or the project. By taking the community on board with the final plan and decisions, whether this is done within an adaptive plan or an integrated urban water management process, the chances that the plan might be implemented are increased, respondent Q3 specified. This point is valid not only when discussing community engagement but also when considering collaboration with organisations that have responsibilities for various parts of the plan or project. As interviewee V1 suggested, 'it is difficult to maintain collaboration [between and within organisations] maintain the focus to have the answer, get something on the ground'. While most interviewees realised the benefits that public participation and engagement more generally brought to the table, a few were more concerned about the limitations of this approach at a large scale. This is discussed further below.

5.2.2.3 The strain on resources

There is a perception that is carrying out a community engagement program at a large scale usually takes a lot of money and time, mainly when it is done alongside integrated or adaptive planning and management approaches. One example cited loosely by participant N1 as the 'mass marketing campaign within the 2007 and 2010 Metropolitan Water Plan (Sydney)' costing about '$2 million per year' which was 'reinforced by another $10 million expenditure by Sydney Water on communicating about water restrictions. This programme falls under the category of participatory approach because it formed a foundation for the later community engagement programme where the public was asked for an opinion on the restriction threshold during the millennium drought.

From a slightly different point of view, respondent N2 asserted that community participation processes need to be comprehensive within the plan or the project regarding time and resources. N2 said that to prevent the project from running 'off-track', 'sometimes I think you got to be assertive and say the work needs to be completed, there are deadlines, and we just have to get on'. Moreover, respondent Q2 indicated that when 'you apply your public participatory approach and get people to participate and engage, going through the process, it will slow down the whole project'. Similarly, while commenting on how the community should be engaged in an ongoing manner for the adaptive approach to work, interviewee Q3 shared that 'it takes a lot of time' and 'some people become a bit frustrated with the obligation to be engaged. It adds an excessive amount [of work] although I see the reason for it'. Matters of resourcing and the allocation of funds are also highlighted in the literature on the participatory approach and adaptive management in the water sector (Sabatier & Leach 2005; Leach 2006; Mandarano 2008) (see Section 2.4.3.1).

There were different views about the timing of community engagement in the context of plan development or project implementation. According to New South Wales interviewee N2, involving 'groups of stakeholders and the community in the early stages of the process' could 'broaden the options, the thinking' and 'get people's buy-in at the beginning of the process'. Others, such as participants from Victoria State V1 and V2, recommended that community involvement 'should not be too soon or too late' (V1) and 'should be at the right phase of the process' (V2). Although the interviewees did not provide any details about what the right time would be (or how to determine the right time), several authors share the same view that early engagement might not necessarily be better than involving the community at a later stage of the planning process (this was also elaborated in literature review Section 2.3 by (Sarno 2013; Koontz and Newig 2014; Reed et al. 2017; Stuart 2017; Sterling et al. 2017)). While there were different views on the timing of public participation, there seemed to be an agreement that the higher the level of engagement the better, as mentioned above in Section 5.2.1.

5.2.2.4 Complexity of concepts

The struggle to get public engagement is not limited to the question of how much should be spent or the timing– it is also about how the complex nature of these approaches leads to difficulties in effectively communicating and engaging people with different backgrounds. According to interviewee N2, there is a perceived risk when unpacking complex systems that the participants might dive into the 'rabbit holes' and 'drive the process off track'. Also, respondent Q2 asserted that public engagement could delay the implementation process and introduce 'less timely responses to community requests' since 'there are more complex solutions to the issues' and 'also a lot of stakeholders that you have to keep happy'. Also, part of the problem is that the system's complexity introduces the question of the 'level of detail' or 'how much information do you give to the community' for meaningful contributions while simultaneously avoiding delays in the process, as reported by interviewee V2.

Moreover, communicating the complexity of either AM or IUWM to the community through participatory processes in a beneficial way is challenging. Interviewee Q3 believed that it is challenging to 'translate and communicate with people' due to the complex nature of the systems in question when adopting integrated and adaptive approaches. Q3 suggested that 'planning has become more complex and much harder to explain to the community (than the IUWM)' when combined with AM. Holding a similar view, interviewee V1 expressed concern about the capacity of the public to understand the complex decisions that they are influencing, stating: 'we can't expect the public to have the same level of understanding as the professional' and 'we need to be really mindful of providing information in the way that is readable for the spectators'. Further, respondent V2 suggested that in order to be involved in the 'collaborative space [at the higher end of the IAP2 spectrum]', people need to be educated, and 'that can be a challenge, especially when it comes to IUWM, which is very complex'.

To pique people's interest in public engagement programmes and strive for meaningful contributions, interviewee V2 suggested that the local context has to be one of the most important determinants. Within the discussions on the application scale, V2 expressed that public participation should be implemented within local, place-based establishments rather than high-level plans or large-scale projects where specific impacts of the interventions cannot be clearly explained to local dwellers. Further, V2 reinforced the statement by describing two examples contrasting their effectiveness. The effective one, where 'hundreds of community members' were taken 'through the whole journey for the whole year, was an 'intensive' community inclusion in the development of the Melbourne healthy waterway strategy. The ineffective was the public engagement initiative to develop a sustainable water strategy for the Central Region. Since Central Region is vast, the 'community linkage' was unable to form, and the meaning of 'sustainable water strategy' was difficult to convey to participants leading to the absence of 'passionate' engagement among them. This concern relates to appropriate 'spatial boundary' questions and is linked to issues of underlining 'complexity' and appropriate 'temporal scales' for engagement. It is evident that from a practitioner's perspective that while offering multiple benefits, a participatory approach, when implemented with IUWM or AM or both, involves more challenges in terms of time span and complexity. These problems will be discussed in more detail in Section 5.3.2.

5.2.3 Adaptive management (AM)

The literature shows that the adaptive management concept has been around for about four decades in the field of natural resources management but is 'less common' in the water sector and has only been considered recently in urban water (Brown & Farrelly 2009; Mukheibir et al. 2012; N2). This aligns with what interviewees said about urban water management in the study areas (N1; V1; Q1).

In recent years, an adaptive management approach has been employed to assist key strategies to increase system resilience against the risks of drought and floods. The commitment to adopt an adaptive approach is likely coming from the realisation that catastrophic events outside the planning envelope will likely cause more damage to society in the long run unless uncertainty is acknowledged and incorporated into the planning approach. The favourable tool that the urban water sector currently chooses is the adaptive pathway planning approach, which has appeared in many planning and strategic documents (more detail in section 3.2.2). The adaptive approach in different forms is central to delivering sustainable strategies in all those documents.

Nevertheless, interviewees' views on the concept are varied. They favour different terms, and most of the time, it was unclear how the concept was defined and how they felt it should be adopted in urban water management. In the analysis below, perspectives on adaptive approaches are therefore discussed from various standpoints, including the meaning of the terms of use and both operational and strategic points of view.

5.2.3.1 How the interviewees perceived adaptive management approach

Although the author attempted to address the subtle differences between an adaptive management approach and an adaptive planning approach (in Section 3.2), how the interviewees perceived those concepts will be further discussed in this section.

It is observed that confusion arose in using the term adaptive management and adaptive planning. While most interviewees used them interchangeably, this did not sit well with some. In fact, what is happening in the industry is that practitioners seem to be attracted to the adaptive planning pathways approach. Thus, interviewees referred to this concept in one way or another when discussing the concept and practice of adaptive management. An interviewee argued that AM is about responding to changes as soon as possible, given that understanding the system is sufficient to adapt. On the other hand, adaptive planning resembles thinking about the future and setting up the system to be resilient to future changes and shocks. As a new and growing field of research, the adaptive approach in urban water management has not yet been unambiguously defined.

Theoretically, adaptive management is an approach for dealing with future uncertainty by probing the conditions of the systems using diagnostic management experiments to gain new knowledge and adapt accordingly (Rist et al., 2013; Walters, 2007). As a result, the author believes that learning and adapting processes were carried out iteratively in the order of an adaptive management cycle where the system is updated whenever a cycle is completed. Therefore, in the natural resource management field of study, the statement is that an adaptive planning process is nested within an adaptive management cycle. Also, the output of an adaptive planning process is an adaptive plan that is expected to be adjusted whenever new knowledge is made available (at the end of the cycle).

From an operational point of view, interviewee V2 considered AM heavily dependent on the 'ability to utilise data in a productive way'. It is believed that better access to data of all types can lead to more resilience and responsive adaptation of the system. Also, participant Q2 described the use of data as a highly recommended element for 'testing options against different uncertainties'. While the author thinks that those notions are accurate, there is also a caution mentioned by Walters (2007) about how excessive attempts to perfect the modelling approach can result in the waste of money and effort by yielding inconclusive and impractical models.

From a decision-making perspective, there needs to be a readiness to change, and all kinds of solutions need to be considered. According to interviewees N1 and N2, options must be kept open, and there should not be 'lock-in to any infrastructure options'. There are three main reasons for this.

Firstly, delayed large-scale investments might create opportunities for innovations to emerge along the way. As interviewee N1 suggested: 'You might change technologies so that you might have something come along that is better than the past, and you might therefore have the cheaper or more resilient options than you had before'. Within the framework of AM, the basic assumption is that the future is uncertain, so if a locked-in large-scale infrastructure is ill-suited for coping with future conditions, there might be a tremendous amount of capital used to try to fix the situation, as mentioned by respondent V2. Secondly, interviewees N1 and V2 believed that finding ways to make investment efficient and least cost by not creating excessive redundancy will help 'lessen the economic burden on future generations'. Thirdly, looking at AM from different angles, some practitioners, such as Q2 and N2, referred to AM as an educational or learning process where all stakeholders share knowledge and experience to learn from each other and to learn as the future unfolds to deal with uncertainty. The thinking can be related to the literature on the organisational learning cycle (more detail in section 2.4.2). However, interviewees' perceptions of this readiness are closer to aspiration than what happens on the ground. As mentioned by authors such as Mukheibir and

Mitchell (2014) and Fletcher et al. (2015), urban water management practices are still primarily involved with large-scale infrastructural options, which tend to be path-dependence and reduce the flexibility to change direction or switch to other interventions.

From a practical standpoint on how urban water plan is developed, however, the interviewees' responses were mostly unsystematic and involved abstract ideas about the approach. Thus, it is not easy to describe how the approach is currently used or can be translated into an urban water plan. The most widely agreed idea seems to reference the concept of adaptive planning pathways, as mentioned by participants N2, V1, V2, Q2, and Q3. This idea draws on concepts such as adaptation pathways (Bosomworth et al. 2015; Bosomworth et al. 2018) from the climate change adaptation literature and dynamic adaptive policy pathways (Haasnoot et al. 2013; Flood and Lawrence 2017). As stated by interviewee V2, an Adaptive planning pathway approach is a methodology and a method in which scenario planning is taken to a whole new level. Moreover, interviewees V2 and Q3 explicitly used the term 'adaptive pathways planning' and described part of the idea as developing a roadmap of future situations via scenario building. Participants V1 and Q2 implicitly referred to the essential roles some considerations played in determining the preferred pathways of these developed scenarios, such as system thresholds or system limits and sets of actions under those thresholds. Other interviewees, including N1, N2 and Q1, referred to adaptive approaches in planning at a more conceptual level in which a proactive approach and an ongoing process of adapting through monitoring and evaluating were highlighted.

When discussing how adaptive planning has played out in recent real situations, examples like Melbourne's sewerage strategy, the Greater Metropolitan Melbourne healthy waterways strategy, and the management of environmental flow rules for Warragamba Dam within the Metropolitan Water Plan in New South Wales were singled out by the interviewees. Both cases in Melbourne adopted the adaptive pathways approach to inform future decisions and infrastructure planning, with the ongoing monitoring of key performance parameters (Melbourne Water Corporations 2018; V1 2018; V2 2018). In New South Wales, an adaptive management approach is being employed to protect the health of the Hawkesbury-Nepean River via the adaptive management of environmental flows from Warragamba Dam in response to findings from the monitoring procedure (Metropolitan Water 2017).

From the author's point of view, it is interesting that all interviewees' perceptions above, while valid, were unstructured. The interviewees' understanding of the adaptive management approach seems fragmented. When compared to the general theme of strategic documents in Victoria, for example, there was always a classic adaptive management cycle as a structure to carry all the management processes over time and an adaptive pathway planning approach to assist planning and decision making.

Overall, adaptive management or adaptive planning is gaining considerable attention in the industry, and background knowledge at the conceptual level about the adaptive approach and the reasons for applying it is widespread. However, from the interviews, it could be concluded that there is still a lack of clarity regarding the application of the concept in practice.

5.2.3.2 Issues in adopting adaptive management/planning

It was suggested by interviewees V1 and V2 and also implied by such authors as Engle et al. (2011) and Frisch (2017) that adaptive management/planning is the next major step in the development of IUWM and the current issues associated with implementing the IUWM approach will be inherited when applying AM. Moreover, another layer of uncertainty is added since the main purpose of the adaptive approach is to tackle uncertainties in planning and management. Therefore, the level of complexity and uncertainty is elevated, as indicated by interviewee V1: 'IUWM is always complex, adding the AM elements - it's just added more complexity'. Besides inheriting all the issues associated with the collaboration and engagement elements of the IUWM approach (Section 5.2.1), the emerging issues encountered when integrating the three approaches that are related to the temporal and spatial scale, public engagement, and uncertainty will be discussed in detail later in the document (Section 5.3.2). Several concerns are intrinsic to the adaptive approach such as the on-going planning, the understanding of the involved parties, and the lack of confidence due to uncertainty.

The basis for urban water planning using an adaptive management approach/theory is to carry out the ongoing planning process as opposed to the conventional one-off implementation that characterises conventional urban water management practice (Mukheibir et al. 2012; Q2; Q3). The ongoing planning would invite several challenges regarding collaboration between organisations and the consistency of institutional arrangements. As pointed out by participants V1, Q1, and Q2, cooperation between organisations in sharing understanding, data, and agreed-upon priorities are much harder to maintain in the long term due to changes in staff or changes to the people in charge. Moreover, for AM/AP to happen, the leadership and institutional arrangements need to retain a certain level of consistency, and since AM/AP projects should happen over more extended periods, there is a risk that political changes could hamper the process. Furthermore, respondent Q2 suggested that longer time horizons with the ongoing approach means more resources must be allocated to see the process through.

Since AM is a new approach in the urban water sector, and there are no precedents, it is challenging for the stakeholders and the community to picture how AM/AP will work on the ground. Furthermore, it creates tensions for the organisations in charge as most of the officers have never been exposed to the concept of uncertainty and are not comfortable with the 'soft' approaches and measures that might potentially be able to address uncertainty. This is especially the case for deterministically minded engineers who have spent years designing structural solutions as mentioned by interviewees N1, N2 and Q2; this notion also aligned with what authors like Brown & Farelly (2011) and Marlow et al. (2013)

found out. In the opinion of interviewees V2 and Q3, the same thing happened with the community, as they were 'trained' to deal with tangible data when reacting to issues.

As mentioned repeatedly by respondents N2 and V2, uncertainty makes it difficult for authorities to make decisions and act due to the lack of confidence. This is because they are not familiar with embracing the unknown, and secondly they need to consult with the public about their decisions. Also, when the community understands the risks involved in the investment decisions, this is another critical challenge because people are uncomfortable with uncertainty as it makes them doubt the whole process, as stated by participant Q2. Furthermore, interviewees N1 and V1 specified that while the majority of the customers do not want to spend more money on water services, in order to keep options open to gain more resilience in the system, investment for the future at the moment of discussion may need to be higher than expected, and this can create tensions between planners and those that control the finances.

5.2.4 Difficulties when integrating PP and AM into IUWM

It has been stated earlier that for many practitioners, the three approaches (which are the focus of this research) are considered intertwined, and in practice, the IUWM approach seems to be the most common focus at the moment. Therefore, this section is dedicated to compiling some of the key issues when integrating these approaches.

The costly and time-consuming aspect of engagement process for IUWM and AM

As mentioned above (in Section 5.2.1.3.), public participation programs are perceived to be costly and time-consuming when attached to strategic integrated or adaptive plans and project implementation. From the author's point of view, marketing through one-way engagement programs (in which information flows from the authorities to lay people) is not necessarily the best way to encourage diverse perspectives. As the interviewees and various commentators in the field point out, being on the right-hand end of the spectrum (IAP2's level of engagement), where participants' views and values are exchanged and included throughout the decision-making process, is beneficial in both the normative and the instrumental sense (more detail can be found in Section 2.3.4). However, to foster meaningful collaboration within the framework of IUWM and AM approaches, there is a need to educate the people who participate in that process about the associated complexity. Respondent V2 pointed out that: 'when you start talking about IUWM with so many different organisations with so many different types of infrastructure, so many different funding models, it gets really complicated to communicate with people'. In addition, incorporating various perspectives is a blessing, and a curse since the conflicted points of view might or might not reach a consensus, and potentially dragging the process 'off-track', as maintained by participant N2. Interviewee N1 from NSW gave an example where some participants who were conscious of the importance of waterway health were willing to pay extra money to achieve better environmental outcomes while others wanted to seek out least-cost interventions. Thus, significant time and resources could be spent on informing people about topics without achieving consensus. While the author believes that all perspectives should be respected, the role of the mediator, which would be the authorities in most cases, should be to organise knowledge-sharing events and to present the information in the way that best describes practical benefits thoroughly. Furthermore, as opposed to the one-off manner characterising the IUWM approach, one vital feature of AM is the ongoing monitoring, evaluation and adaptation over a long period. However, continuous engagement is costly to maintain in terms of time and resources based on the arguments presented in this part.

While the timing of engagement programs was not explicitly addressed concerning integrated water planning processes, some comments addressed this issue indirectly. It seems like it is an underdeveloped area that water professionals are still grappling with since no preferred guidance or criteria were cited to indicate which phases of which kinds of projects are the most suitable for involving the public. Also, there is no mention of what should be considered when deciding how frequently the public should be consulted or how long engagement programs should go. However, there are indeed lessons and suggestions regarding various aspects of participatory processes in the literature on different fields of research, such as environmental management, ecological restoration, biodiversity conservation (Reed et al. 2017; Sterling et al. 2017), land management (Vente et al. 2016) and the urban water sector (Dean et al., 2016; Dillon et al., 2016).

The inherent complexity of IUWM and AM

The inherent complexity of the concepts related to IUWM and AM was singled out as one of the main obstacles to community engagement and stakeholder collaboration.

Regarding the effects on public participation, it is challenging to communicate the complexity of IUWM and AM to lay people for the vast amount of unfamiliar information. It was reported that when engaging people in a project that focuses on a specific problem that may directly affect their livelihood, for example, the environmental impacts on waterway health, it is reasonably easy for the participant to picture the situation. However, it is too complex for laypeople to grasp when incorporating IUWM concepts such as multiple planning scales, various organisational collaborations, integrated system modelling or different funding models. Also, this raises the unanswered question of how detailed information should be when transferred to the community to foster meaningful collaboration or coproduction of the decisions or policies. Moreover, lying at the core of the AM approach is the concept of uncertainty. This adds another layer of vagueness to the conversation, and it is harder (than it is in IUWM) to explain to the participants. Further, the interviewees indicated that a lack of certainty was found to lower the confidence of the community in the plan or project.

Concerning collaboration between organisations involved in the process, the interviewees said that a fragmented governance structure and risk-averse attitudes were key problems. The interviewees reported that they struggled to deal with problems caused by overlapping responsibilities of various organisations. Because IUWM projects usually cross jurisdictional boundaries and because there are usually multiple organisations taking care of different parts of urban water systems, there can be conflict about what goals they are trying to achieve. Moreover, the misalignment of the views and values of organisations might sabotage the progress of project/plan development and implementation. An example can be the case mentioned above of the Metropolitan Water Plan (Section 5.2.3.1).

Moreover, the risk-averse attitude of members of some departments was found to be a significant hurdle to the use of IUWM and AM approaches. This means that there are people from organisations who have for many years been comfortable with, and used to working within, their frames of reference and their disciplines, to the point that they might not be ready to be involved in sharing and incorporating the knowledge and experiences of others in a common platform. Moreover, as claimed by interviewees N1 and Q3, uncertainty was shown to be a problematic concept since 'people are comfortable with certainty'. The way uncertainty relates to new technologies and climate risk aversion has resulted in the increase of resource intensity (increase in the cost of validation testing) and investment in preventing cross-contamination (in the case of water recycling) was also confirmed in Mukheibir et al. (2015) and Watson (2017).

5.3 Synthesis of the topics and the associated issues

It has emerged from both the literature and the analysis of the interviews that current urban water planning and management within the study area is on a transformative journey from conventional approaches to more integrative, adaptive and inclusive ones in both theory and practice. It has reached the point where the conventional way of planning and managing urban water is no longer appropriate, but there is little information or knowledge on adopting new thinking and implementing new plans. In addition, current approaches to urban water planning and management practices are believed to be ill-suited to dealing with complexity and uncertainty by both commentators in the field and multiple interviewees in the first round of data collection (Dunn et al., 2016; Farrelly & Brown, 2011; Marlow et al., 2013; Mukheibir & Mitchell, 2014).

While examples of public participation, integrated urban water management, and adaptive management approaches being used in combination are nowhere to be found in both published literature and in practice, interviewees V1, V2, and Q2 suggested that these approaches are highly intertwined and should be considered together. This observation supports the basic assumption that the three frameworks should complement each other in a harmonised manner (Farelly & Brown 2011; Mukheibir et al. 2012).

Also, it is observed from the interview data that more nuances are emerging from discussions which could be overlooked by solely adopting the descriptive approach through the scaffolding of interview questions. Therefore, this section examines the main areas of discussion where issues and tensions could potentially arise and synthesises the information into key topics. To that end, the author realised that the interview data could be thematically analysed by applying a different lens other than that of the frame of the interview questions in the last section (Section 5.2). Therefore, axial coding, a grounded theory coding technique, was employed to bring out the critical themes that emerged when discussing the three approaches in combination.

5.3.1 Overview of the data

The method for categorising the issues by theme is by coding relevant texts under the overarching topics, which are more abstract than the categories. So, twelve themes have been identified based on how frequently the ideas emerged throughout the interviews (by looking at the number of quotes and the number of interviewees mentioned). The topics are what interviewees returned to most often and maybe were a focus of their thinking in this area. It can be observed that the themes that were raised most were: the issues with community engagement, the complexity of the concepts, the consideration of uncertainty, and the scale of the problem. The identification of these themes is based on the number of references and the number of interviewees who mentioned them (see Table 5.1).

Table 5. 1: Overview of the topics

	1	2	3	4	5	6	7	8	9	10	11	12
1 : Certainty - Uncertainty - worldview	20	1	6	6	0	1	0	1	0	0	0	0
2 : Collaboration of organizations	1	6	1	1	0	0	0	1	0	0	0	0
3 : Community engagement	6	1	29	8	0	0	1	0	0	0	0	0
4 : Complexity of Concept	6	1	8	27	0	1	1	1	1	0	0	0
5 : Cost and benefit	0	0	0	0	4	0	1	0	0	0	0	0
6 : Importance of champion - leadership - personnel	1	0	0	1	0	10	0	1	0	0	0	0
7 : Opinions on scale	0	0	1	1	1	0	14	0	0	0	0	0
8 : Political influence- power play	1	1	0	1	0	1	0	8	0	0	0	0
9 : Sectors integration	0	0	0	1	0	0	0	0	1	0	0	0
10 : Technical - technology related	0	0	0	0	0	0	0	0	0	2	0	0
11 : Temporal scale	0	0	0	0	0	0	0	0	0	0	1	0
12 : Time and resources	0	0	0	0	0	0	0	0	0	0	0	4

The issues emerged from multiple discussions during the interviews, which reflects the use of explorative semi-structural questions. The interview looked for responses from professionals working in the field on the current situation regarding the adopting the IUWM, AM and PP approaches, as well as the common issues and trade-offs across those. Thus, the themes are comprised of any emerging issues that were analysed from each conversation among those responses.

Among those four most mentioned themes, all participants mentioned community engagement in one way or another. It was the most popular topic for discussion, with 29 references (29 quotes from all interviews). While for the most part, the issues related to this theme were somewhat covered in section 5.2.2, where the interviewees' perceptions about the participatory approach were explored.

There was not much difference in the frequency of the most popular and the second-most popular themes, as all interviewees cited 'complexity of the concepts' and it was mentioned in a total of 27 quotes. This theme focuses on how the concepts, theories and practicality of IUWM, AM, and PP were hard to convey and comprehend by either the stakeholders (organisations in charge) or the public.

The third key theme relates to different aspects of uncertainty. This theme involved people's worldviews or the different types of uncertainty that influenced adopting the three approaches. It was mentioned in 17 quotes.

The fourth theme concerns issues engaging spatial and temporal scales of problems and their analysis. It can be observed from the table that these themes are highly connected. Especially themes 1, 3, and 4 since there are higher numbers of related mentioned. It can be understood that the issues from one theme emerged from the discussions on the issues within other themes. It is noteworthy that the top four topics are explored further in section 5.3.2.

Following the four most mentioned topics, the two topics of political influences on decision-making and the importance of the champion [people who drive the process forward], leadership and personnel were next in line and equally mentioned by interviewees.

Overall, participants N1, Q1 and Q2 expressed relatively strong opinions on role of politics in decision-making in the urban water sector. It appeared that politics held the most significant decision-making power, as Q1 asserted: 'politics always dictate what happens at the end of the day'. Respondent N1 reinforced the point by indicating: 'politicians might forget modelling and forget the adaptive planning, and bring forth options inadvertently, and bring it on the agenda because they were reacting to the crisis and trying to cease it'. Moreover, on a slightly different note, interviewee Q2 emphasised the impacts of political changes on the direction or focus of the organisation by stating:

> Priority changes due to political changes, the new council or the change of leaders, they see things differently that they do not want to spend money or time or effort in IWM as a priority, they think the priority is to reduce the cost

These insights on political influences pointed direct to power issues and partly reflect what authors such as Brown & Farrelly (2009), Van de Meene et al. (2011) and Mukheibir et al. (2014) commented on the lack of political will and political capacity toward IUWM and sustainable urban water management.

On the topic of the significance of project champions, personnel and leadership, the vital role those actors play in getting the projects on the ground and keeping them running on the track, this was singled out repeatedly by interviewees N2, Q1, Q2, V1 and V2, among others. The phenomenon in which key people keep pushing the projects through approval for implementation as well as driving those on track was raised multiple times throughout the conversations with the interviewees:

> Officers of projects changes overtime, over the year, so you lose your key people... you got new person and they go 'what is the AM stuff you are talking about?' (N2)

> If you don't have someone to push it [the concepts and aspects of projects] to the people that involved in and push it to approval, it will not go anywhere (Q1)

> It is all about the champion, it is really important that a selective people of champion push through and make sure we stay on track (Q2)

The disappearance of a key 'champion' and changes of personnel might also introduce more issues for the collaboration process, as interviewee V1 reported that 'it is difficult to collaborate and maintain the focus' or as V2 shared the situation in Victoria State as: 'the collaboration is very organic, it depended on the champion, the network'. Moreover, some participants believe that leadership is the determining factor in sustaining the 'direction' and 'priority' of the organisation. As respondent Q2 suggested:

> If they understand it [the concepts of IUWM and AM] and support it, and they understand that they need to be a part of their business looking into the future and planning for the future, and their work is not going to response to the current issues, you're all good.

Further, strong leadership is required for the ideas to turn into reality, as respondent N2 emphasised: 'unless you got clear leadership, really strong launch capacity, and the real commitment as senior level in other organisations across Government, then these projects just ultimately fail'.

5.3.2 Issues associated with the four key themes

This section's focus is on the four most mentioned topics (as shown in Table 5.1), namely Community Engagement, Certainty vs Uncertainty, Scale, and Complexity.

5.3.2.1 Community engagement

Community engagement seemed to get the most attention from participants, and many issues emerged from this topic related to the other three most popular themes. While issues under this category were discussed in sub-section 5.2.2, the author believes that discussing them in conjunction with other themes provides a refreshing lens that might lead to new insights. Moreover, as mentioned at the beginning of this section, findings in section 5.2 accounted for the descriptive analysis of qualitative data through the scaffolding of interview questions. In contrast, this section focuses on discussions on the issues and tensions by thematizing codes.

As mentioned in the previous part, uncertainty was a big concern as challenges arose from how the public responds to it in the planning and management processes, especially when an adaptive approach is adopted. As far as the interview went, the industry, its customers and the public seem to be not yet understanding and ready to embrace uncertainty. The respondents described it as something that is very difficult to engage with. Q2 said 'most people cannot deal with uncertainty' since they are used to and 'comfortable with certainty' in problem analysis and with having clear answers to issues at hand.

Based on what participants referred to as being 'comfortable with certainty' (Q2) or 'anxiety' associated with high-risk uncertain options (N2), 'doubt with the solutions' and 'create a lot of frustration' when engaging in the adaptive planning process (Q2), it can be understood that there was a part of the community who adopted a 'Newtonian' or 'mechanistic' worldview. This worldview is mainly based on reductionism and determinism. It is when the belief evolves around the main doctrine that the nature of a matter is the 'sum of its parts'. This worldview ignores the existence of human values and interference, the evolution of the components and their relationships, and hence, overlooks uncertainty. Further analysis of the issues with worldviews can also be found in the following sub-section.

This restricted worldview did not only hinder the process of communicating and explaining the concept of uncertainty associated with the AM approach in the opinion of interviewees V1 and Q3 but also led to hesitation in supporting decisions to invest more money now for future resilience, as stated by participants N2, V2 and Q2.

Furthermore, public participation is a complicated process within the context of IUWM but adding another layer of uncertainty from adaptive planning puts 'more stress' on the system regarding resource investment and the level of detail required when delivering engagement processes. A number of participants, including N1, V1, V2, and Q3, agreed with this statement. The pressure on the resources required was discussed in more detail in Section 5.2.2.3. Another issue is detail level that should be engaged with for the community to understand the project and make a meaningful contribution, which correlates with the amount of time and effort spent in the engagement programme (Q3).

The spatial scale of a problem/project influences how the public participation program is designed and how the necessary resources are allocated. While there is an idea that public participation should be rolled out at the local planning level where the decision directly affects people's lives, as shared by interviewee V2, there is no standard method or guideline on how comprehensive the engagement should be, who should be involved, or what the boundaries should be for the engagement.

5.3.2.2 Certainty – uncertainty – worldview

Within this theme, the issues were not just about how best to understand and treat uncertainty in all aspects of the participatory approach, IUWM, and Adaptive Management/Planning but also about how to shift people's mindsets away from the technocratic, deterministic, top-down ways of carrying out urban water management. It is noticeable that some of the problems were mentioned before in 5.2. However, more nuance emerged throughout the process of thematizing the issues; therefore the author believes this particular topic should be unpacked further.

Issues raised under this category are numerous; however, the one that kept coming up from the interviews is that there is common resistance from people in the water industry to acknowledge and embrace uncertainty or the complexity associated with finding a sustainable way forward. It can be seen in the literature on 'complex' or 'wicked problems' that uncertainty and complexity are closely intertwined and that different types of uncertainty can emerge from complexity (Head, 2019; Kirschke et al., 2019; Kovacic & di Felice, 2019). Therefore, from the author's perspective, a level of resistance to adopting a new way of thinking that accommodates uncertainty and complexity further contributes to the system's overall complexity.

Participant Q2 revealed that one of the reasons for this resistance to change might be that ‘people are comfortable with certainty’ within their discipline and way of doing things time. A common argument made by the interviewees was that water professionals operated conventionally were focused on deterministic approaches and paid much less attention to other points of view. Interviewee Q1 from Queensland pointed out that if the planning process 'is led by the engineering section of the council, it will have that engineering flavour and the lack of a broader understanding to it ... it is an inherent limitation to those individuals to think holistically'. Further, a Victorian participant shared that 'it is difficult to shift from ordinary practice operations [the traditional framework] ... and it takes time and leadership' (V1). On a similar note, interviewee N2 described how 'water engineers' always prefer 'building something that gives you 100 years of secure water' rather than using an 'adaptive approach' or considering more 'sustainable options like recycling water'. Also, N2 from Sydney shed light on the fact that 'the need for an integrated approach to water management was recognised a long time ago' but 'people have not done it at all' as 'the greater the uncertainty in IUWM, the greater the risk, anxiety and risk of failure'. This might contribute to the 'complex issues when implementing in a large city'. Reinforcing the view that people are comfortable with certainty, respondent N1 described how some government agencies chose to deal with individual short-term problems instead of adopting a long-term proactive approach where there is too much uncertainty:

> They [the government bureaucracy] want you to come up with a small slice of what the issue is and work on that and response' and 'long-term planning, research and innovation, experiments, I don't think that is what bureaucracy want to think about, they want to think about what is here now, how the management is now and how to make it through the next few year

Furthermore, the issue is not experienced only by organisations but also from the community's perspective. One possible reason might be that as engineers deliver infrastructure options following the traditional mode of planning and managing urban water over the years, the community might be indirectly trained to receive and process deterministic information about a particular issue and response at a time, rather than looking at the big picture, considering which issues are connected and conducting interpretations via probabilistic tools. As discussed by interviewee N1, since the community expectation is to see plans with high-level certainty, it is challenging to carry out an adaptive approach centred around uncertainty.

> So, people want certainty and criticise the government if they do not have certainty of planning and certainty of supply for the indefinite future

> They [the community] want to know that you ready to response to all of the scenarios, even some of the scenarios are difficult to response because they are simulated by the environment

While it is valid that the community expects definite responses to risks in planning, the author also believes that the authorities are responsible for explaining and educating laypeople on resilience and the role that flexible planning and contingency options play in adapting to potential uncertainties and risks over time.

Besides expressing concerns about different types of social-physical uncertainty, such as climate change and population growth, the majority of the participants considered the most crucial uncertainties they had to deal with to include changes in government policy or political orientation due to personnel modifications, as reported by participants N1, N2 and Q3, and the changes of people who used to drive the process forward, usually referred as 'process champion' by interviewees N1, V2, Q1 and Q2.

Due to the seemingly long-time horizon for IUWM and AM projects, especially AM projects, according to participants N1, N2 and V1, it is likely that changes to high-level positions or changes in political systems might occur before the end of the program or even before its implementation. So, unless the new leader, who could significantly influence the programs' success, has a similar vision to their predecessor and acknowledges the purpose and objectives of the program, the program will fall apart. Changes in high-level positions will have huge impacts on the process. Therefore, this type of socio-political uncertainty is attracting attention from practitioners.

In addition, it is worth noting that concerns about organisational capacity and the knowledge needed to carry out the plan or project in the context of IUWM and the AM approach is one type of uncertainty that was brought up several times in the interviews with participants Q1 and N2. Part of the concern is due either to the fact that the people in charge are likely to resist change, as mentioned above, or they may lack knowledge about how IUWM and AM should be rolled out in the urban water context, as reported by respondent Q1:

> The department thought it was a great idea to have IUWM. But they did not have enough water knowledge, they engaged a fairly traditional engineering consultant to do it. As we found down in our review, deep down he [the consultant] did not have a commitment to IUWM.

The lack of understanding of the system is further complicated with the introduction of AM since the complexity of IUWM increases significantly due to the uncertainties that AM brings. However, this was not confirmed by the data from the interviews, although it has been mentioned many times in the literature on the use of adaptive management in natural resources management that a lack of understanding about the system could well be countered by the process of ongoing learning and adapting to changes over time within the framework of adaptive management (Holling & Walters 1978; Walters 1986).

5.3.2.3 Opinions on the scalar issue

Issues associated with the scale of problems/projects, whether related to the participatory approach, IUWM or AM, are intertwined with the complexity of the system in which issues were situated..

From the interviews, there are two perspectives to discuss regarding the scale issue. The first one is that the level of complexity is proportional to the expansion of the project's spatial and temporal boundaries, which leads to an increase in the number of stakeholders involved (N1 and N2). The second viewpoint is on what scale is the best when carrying out the different phases of the project.

Concerning the layering of different temporal and spatial scales, interviewee N1 said that:

> So the thing with the level of complexity in the range of players, range of scale and trying to bring together the different planning scales to make decisions that are based on economic considerations brings out benefits to the community at all of those levels.

Respondent N2 showed that the spatial scale is a crucial issue in coordinating local and city-wide integrated planning in terms of resources and the complexity of the implementation teams. The most prominent factors are the size of the management system and the number of stakeholders involved in the process. Interviewee N2 said that: ‘they [local managers] would manage it as a whole project, the scale is smaller, and the responsibility and number of players is so much simpler than [in a] large city'. A local council can quickly assemble a team to manage urban water in an integrated system because usually, water supplies, wastewater and stormwater are the local council’s responsibility. The smaller the scale, the smaller the responsibilities and the smaller the number of players in the field. Hence, the implementation process is also more straightforward, according to interviewee N2.

On the other hand, in a big city such as Sydney, at different scales and with different components of water cycles, there are different people in charge of the processes. Management is connected with the complex and overlapping nature of various planning systems and the fragmented governance systems highlighted throughout the interviews. The overlapping of different planning scales combined with the fact that different authorities are responsible for those made it ‘really difficult to get the cascade between’ (N1). As respondent N1 explained, it is challenging to get the different tiers of organisations to talk to each other as the IUWM plan at the city scale is developed by the Local Government, while Sydney Water might do district-level planning strategies for wastewater. WaterNSW and Sydney Water do regional strategies for water supply. Furthermore, N1 asserted that it is challenging ‘to analyse the options in relation to the regional scale, and to tie into the broader Sydney scale, as well as into the strategic planning that Sydney water might do for subregions’.

The situation is similar in other places such as in Queensland where interviewee Q2 shared that:

> Within a services provider, you have different departments looking after stormwater management, different units looking after catchment quality and waterway quality, and the state government which looks after the drinking water supply, the dam, long-term water, development approval, planning schemes and town planning aspects of the city… it creates a lack of clarity in the responsibilities.

Getting all these stakeholders to talk to each other and integrate all the strategies and plans is not easy. The matter of collaboration is of concern. Interviewees emphasised the lack of a framework to support collaboration between organisations and conflicts due to organisations' differing priorities. In a conversation about IUWM implementation, interviewee N2 said 'We have got a huge number of different players in that debate. There are often silos; they do not speak with each other'. N2 added that 'they're driven by different drivers, business drivers, environmental drivers, commercial drivers'. According to N2, problems also arise 'where you have multi-jurisdictional projects and … you can involve all people in the planning, and spending years getting their views and putting together a plan, and now they go "no, we don't like it'. In other words, complexity is influenced by the sheer number of actors involved and the contrasting objectives they bring to the table. This view was supported by respondent V1, who reported that:

> To truly collaborate and truly understand complex systems in the way everybody in the circle would understand, it takes time … when you go into organisational collaboration, you need to convince your home organisation that what you are actually trying to do is of benefit to the community, and not necessarily to your organisation … you need to balance the benefit to these two groups.

The second viewpoint highlights the debate on what scale should be applied in different phases and/or in different types of projects. In terms of IUWM, interviewees N1, V2 and Q3 believed that the assessment of options in a project or plan should happen on a small scale – either the sub-regional scale or the local scale where interactions between specific interventions and the water cycle happen the most. However, when looking at cost-effectiveness, the level of service and the system's resilience simultaneously, participants N1 and V2 suggested considering a larger scale such as the city-wide scale. Thus, it would be better to operate at the local level, do planning at different scales and then integrate them into the whole water plan and then make decisions on the holistic picture rather than based on separate considerations in the opinion of participants N1, V2, and Q3. Regarding (AM/P), there are very few examples to learn from in the urban water context, and thus it is agreed that AM/P brings more benefits when carried out at a large scale by both interviewees V1, V2, and Q3 as well as by literature such as Walter (1986,1997), and Rist et al. (2013). Nevertheless, utilities also consider AM/P operating at the precinct or lot scale. Concerning the participatory approach, as mentioned above, since the local context plays a vital role in initiating meaningful conversation with the community, leading to meaningful contributions, it is suggested by participant V2 that the public should be involved in solving problems within their everyday living environments – that is, at the local scale.

5.3.2.4 The complexity of the concepts

Besides the relationship between complexity and the lack of knowledge about IUWM and AM, and the scalar dimension (spatial and temporal scales), from the author's point of view, it is challenging to communicate and explain both the complexity of the integrated system and the uncertainty that is associated with the adaptive approach to the community in a beneficial way. Interviewee Q1 shared that 'the challenge about IUWM and AM is getting people to understand the approaches. Regarding engaging the public in IUWM processes in Victoria, respondent V1 indicated that: 'for IUWM to be successful, there needs to be some understanding and appreciation of the challenges and choices that are available within the community'. Also, interviewee V2 said:

> People can probably comment pretty easily on what their waterways look like, and they probably understand that runoff from the road that is not treated well impacts on the waterway. But then when you start talking about IUWM with so many different organisations, with so many different types of infrastructure, so many different funding models, it gets really complicated to communicate with people in this collaborative space.

It was found to be a widely agreed perception that adding the AM approach makes it even harder to help the public to understand the complexity and uncertainty:

> '[Adaptive] planning has become even more complex, and much harder to explain to the community [than the IUWM]' and 'I think there is great benefit in integrating it all; it's just that it's a very complex task to try to complete that … translating and communicating with people is sort of a complex area at the moment' (Q3, Queensland)

> I think the AM approach is kind of too hard to explain to the community (V1, Victoria).

> Because people are comfortable with certainty, most people cannot deal with uncertainty and complexity and to go through the adaptive planning approach you have got to feel comfortable with uncertainty and complexity (Q2 Queensland).

Introducing this new way of thinking to the public for an extended period is needed for them to become comfortable with it.

Throughout the interview, various issues related to or referred to as complexity and uncertainty were repeatedly connoted. As it emerged from the discussions on many problems one way or another, the author believed that complexity and uncertainty are worth paying significantly more attention to investigating in, and that will be the principal focus to deliberate on the next chapter.

5.4 Conclusion

This section provides summarises the findings from analysing and synthesising the data from the first round of interviews which helped address Research Questions 1 and 2. The findings from the interviews, literature review and document analysis provided an overview of the extent that the three approaches (IUWM, PP and AM) have been utilised in research areas (RQ1) and identified the common issues/tensions that appeared while adopting those approaches (RQ2).

In this chapter, the data was analysed using two methods. The first method was to analyse the data following the structure of the interview questions, which addressed the interviewees' perceptions of the three approaches (PP, AM, and IUWM) and then identified the overarching problems (Section 5.2). Within Section 5.2, the structure reflects the interview questions which were drawn from the literature and findings are also reflected in the light of what was found in the literature review. The second method (in section 5.3) to scrutinise interview transcripts was to utilise qualitative data analysis methods such as provisional and grounded theory coding techniques to investigate what issues emerged within the data and synthesise these into key themes. This involved interpreting the perspectives and experiences of water professionals while considering what literature on the field implies (Section 5.3). The author believes that while the first part investigated the extent to which the three approaches were carried out in practice, the second part emphasises the tensions and broader challenges encountered when using these three approaches together in water services planning.

While there was hardly any evidence of the integration of the three approaches in practice, findings from this chapter show the interconnectedness between the three approaches from the interviewees' perspectives .

It can be discerned that the industry is now paying more attention to public participation realising the inherent and instrumental benefits of the approach.

However, there was still a need for more research into the time and resources needed to initiate and operate the participation process and the challenges of explaining and communicating the complexity and uncertainty of IUWM and AM to the public. Of the three approaches, AM was found to be the one in most need of more information since there were no examples that could be found of it being embedded into planning practice, although water utilities in their official documents have picked up the idea of using AM. Participants' understandings of the definition of AM and its characteristics were scattered. It was recognised that key challenges for making the approach more popular were the associated concept of uncertainty and the long planning timeframe. Concerning IUWM, the key characteristics are collaboration, the allocation of responsibility and the resistance to change among organisations, and public participation.

The author identified twelve themes that emerged from the interviews. Among them, four themes stood out, emphasizing:

- How hard and costly it is to convey complexity and uncertainty when engaging with the community and stakeholders
- How the lack of experience, knowledge of the three approaches and the right tools could pose further confusion to the complexity of the concepts
- How the Newtonian/ Mechanistic worldview and the risk-averse attitude resemble the remnant of the conventional approach that had been pointed out in literature to be no longer fit for purpose
- There are issues with the overlaps of the planning system and the unclear authority and responsibilities among key stakeholders in some areas, such as stormwater management.

The interviewees described how some water practitioners resist new ways of planning and managing services due to risk-averse attitudes toward the complexity and uncertainty of IUWM and the AM approach. From the interviewees' perspective, this attitude seems to be due to the cultural entrenchment of Newtonian, reductionist, discipline-specific approaches with a high level of certainty in parts of the water industry. This conventional approach plays a continuing role in urban water planning and management. Also, it is not only the people in the water sector that want certainty: the community is also more confident with plans or decisions which are based on a deterministic approach to water-related issues.

The author observed that scalar issues were closely linked to the complexity of IUWM and AM. The respondents reported that the level of complexity increased when the spatial and temporal scales of planning and implementation increased. When these scales are increased, there are more organisations involved in the process, multiple overlapping planning scales, and an unclear and fragmented governance structure in which the responsibilities and powers of organisations are complex. Collaboration among organisations that have stakes in the process is negatively affected by all of these factors. Also, the complexity of IUWM and AM is challenging to explain and communicate to the community.

To conclude, from the author's perspective, the challenges associated with complexity that were implicitly and explicitly highlighted throughout the first round of interviews are consistent with the concept of 'complex' or 'wicked' problems in the transition of the Australian urban water industry toward a more sustainable planning and management approach found in the literature (Farrelly & Brown, 2011; Floyd et al., 2014; Malekpour et al., 2016). This research has revealed fundamental problems that need to be addressed to enable this desirable transition. For that reason, the second round of interviews shifted the focus to exploring complexity and uncertainty questions. The rationale for this is discussed in detail in the next chapter.

6 Chapter 6 Complexity in the integration of urban water planning

6.1 Introduction

This section provides the overall context for the chapter and outlines how the research was undertaken. The contextualisation includes a description of how the findings from the first set of interviews shifted the research focus from investigating the tensions of using adaptive management, integrated urban water management, and participatory approaches to an exploration of the complexity and uncertainty that urban water management might have to deal with when trying to put combined approaches in practice. The section includes a brief introduction to the chosen theoretical framework and describes how it was used to answer the complexity and uncertainty questions presented within this section. Finally, an outline of the chapter is presented.

Why did the research focus shift to an exploration of complexity and uncertainty?

It has emerged from the literature, and the analysis of the interviews in the previous chapter, that current urban water planning and management within the study area is on a transformative journey from conventional approaches to more integrative and inclusive ones in both theory and practice. It has reached the point where the conventional way of planning and managing urban water is no longer appropriate, but there is little information or knowledge on adopting new thinking and implementing new plans. In addition, current approaches to urban water planning and management practices are believed to be ill-suited to dealing with complexity and uncertainty by both commentators in the field and the interviewees in the first round of data collection (Dunn et al., 2016; Farrelly & Brown, 2011; Marlow et al., 2013; Mukheibir & Mitchell, 2014).

Although the vision of transitioning to sustainable development based on integrated water management is acknowledged in theory, there is currently an 'implementation deficit in practice' (Holden et al., 2014) due to the entrenched legacy of the conventional management paradigm. In other words, it can be argued that the 'positivist approach of the traditional engineer, economist and policymaker, is still predominant' (Fratini et al., 2012; Malekpour et al., 2017). Interviewee Q1 from Queensland pointed out that if the planning process 'is led by the engineering section of the council, it will have that engineering flavour and the lack of a broader understanding to it … it is an inherent limitation to those individuals to think holistically'. Further, a Victorian participant, V1, shared that 'it is difficult to shift from ordinary practice operation (the traditional framework) … and it takes time and leadership'. On a similar note, interviewee N2 described how 'water engineers' always prefer 'building something that gives you 100 years of secure water' rather than using an 'adaptive approach' or considering more 'sustainable options like recycling water'. Also, interviewee N1 from Sydney shed light on the fact that 'the need for an integrated approach to water management was recognised a long time ago' but 'people have not done it at all', and there are 'complex issues when implementing in a large city'.

What emerged most often from the first round of interviews was that the interviewees struggled to deal with the complexity that would accompany the adoption of sustainable practices (within the frameworks of Integrated Urban Water Management (IUWM), Adaptive Management (AM) and Public participation (PP)). Participants found various aspects of this hard to delve into, which are discussed in the following segment.

It appeared that it was challenging to communicate the complexity of either AM or IUWM to the community through participatory processes in a beneficial way. As interviewee Q3 from Queensland stated while discussing the applicability of AM:

Planning has become even more complex, and much harder to explain to the community (than the IUWM)'

'I think there is great benefit in integrating it all; it's just that it's a very complex task to try to complete that … translating and communicating with people is sort of a complex area at the moment'.

Regarding engaging the public in IUWM processes in Victoria, respondent V1 indicated that: 'for IUWM to be successful, there needs to be some understanding and appreciation of the challenges and choices available within the community'.

The matter of collaboration is of concern, not only when it involves the public but also when it is between organisations. Interviewees emphasised the lack of a framework to support collaboration between organisations and conflicts due to organisations' differing priorities. In a conversation about IUWM implementation, interviewee N2 said that 'We have got a huge number of different players in that debate, there's often silos, they don't speak with each other'. N2 added that 'they're driven by different drivers, business drivers, environmental drivers, commercial drivers'. According to N2, problems also arise 'where you have multi-jurisdictional projects and … you can involve all people in the planning, and spending years getting their views and put together a plan, and now they go 'no, we don't like it'. In other words, complexity is influenced by the sheer number of actors involved and the contrasting objectives they bring to the table. This view was supported by respondent V1, who reported that:

To truly collaborate and truly understand complex systems in the way everybody in the circle would understand, it takes time … when you go into organisational collaboration, you need to convince your home organisation that what you are actually trying to do is of benefit to the community, and not necessarily to your organisation … you need to balance the benefit to these two groups.

Moreover, the complex and overlapping nature of various planning systems and the governance aspects of coordination were highlighted throughout the interviews. Participant N1 revealed the overlap of planning systems and the fragmented institutional arrangements that created complexity in Sydney by saying:

> there are many layers of strategic planning … the complexity about how you cascade between each of the plans … so the thing is the level of complexity in … trying to bring together the different planning scales to make decisions that are based on the economics, to bring out benefits to the community at all of those levels.

This was supported by interviewee Q2 from Brisbane who stated:

> you have water services providers, you have different departments looking after stormwater management, you have different units looking after catchment quality and waterways quality, and we have the whole state government which is separate to councils that looks after the actual drinking water supply, the dam, long-term water, development approval, planning schemes and town planning aspects of the city … it creates a lack of clarity in the responsibilities.

Furthermore, several interviewees revealed the added complexity due to long time frames and the large spatial scales of planning. Participant N1 provided the following examples:

> The problems can be long time frames, large scales … you have many things to worry about, lot of things are happening, you have people changing jobs, leaders changing, management changing, minister changing … it's really become extraordinarily complex to keep things on track.

Respondent N2 reiterated that the spatial scale is an important issue in coordinating local and city-wide integrated planning in terms of resources and the complexity of the implementation teams: 'they [local managers] would manage it as a whole project, the scale is smaller, and the responsibility and number of players is so much more simple than [in a] large city'.

Moreover, the interviewees believed that there is commonly resistance from people in the water industry to acknowledge and embrace uncertainty or the complexity associated with finding a sustainable way forward. It can be seen in the literature on 'complex' or 'wicked problems' that uncertainty and complexity are closely intertwined and that different types of uncertai(Head, 2019; Kirschke et al., 2019; Kovacic & di Felice, 2019). Therefore, from the author's point of view, there is resistance to adopting a new way of thinking that accommodates uncertainty and complexity, which contributes to the overall system's complexity. Interviewee Q2 asserted that 'people are comfortable with certainty; most people cannot deal with uncertainty and complexity'. Participant N2 shared the same perspective, describing how 'water engineers' do not want to associate themselves with uncertainty and always seek certainty by 'building something that gives you 100 years of secure water' and they want to 'build a dam' if 'you need more water' instead of 'recycling water'. Respondent N1 further explained the existing problem in dealing with complexity in the context of urban water governance by saying that:

> It is a big leap for governments to embrace long-term planning, research and innovation, experiments. I don't think that is what the bureaucracy wants to think about; they want to think about what the management is here now, how is now, and how to make it through the next few year.

This highlights a more complex problem where the innate characteristics of the predict-and-control approach adopted by authorities hamper the exploratory efforts required to delve into complexity and uncertainty.

To conclude, the challenges of complexity that was implicitly and explicitly highlighted throughout the first round of interviews are consistent with the concept of 'complex' or 'wicked' problems in the transition of the Australian urban water industry toward a more sustainable planning and management approach (Farrelly & Brown, 2011; Floyd et al., 2014; Malekpour et al., 2016). It revealed the more fundamental problems that need to be addressed to inform this desirable transition. For that reason, the second round of interviews shifted the focus exploring complexity and uncertainty questions.

To that end, the Cynefin framework (CF) was adopted as a conceptual tool to study the level of complexity and uncertainty associated with the existing issues and methods that the urban water industry deals with. A detailed analysis of why CF was chosen, CF's background, and how the framework was utilised in this research can be found in Chapter 4 (section 4.4).

The shift in the research focus is summarised as follows, highlighting the changed research questions:

	The initial research questions	The evolved research questions
1	To what extent are there examples in which all the three approaches have been combined?	To what extent are there examples in which all the three approaches have been combined?
2	What tensions are evident when planning water services using the three approaches?	What tensions are evident when planning water services using the three approaches?

3	How can these tensions be avoided or overcome?	What are the underlining causes of the tensions/challenges?
4	Is the analytical framework a practically relevant tool?	Are the current available tools appropriate for dealing with complex problems?

This chapter focuses on the third research question. Specifically, the author used CF as a lens to test its applicability to urban water and its ability to explain and describe the complexity and uncertainty of current urban water planning and management practices. This was done by drawing on the concepts of CF to analyse the current situation in the urban water sector from a new perspective based on data from the first round of interviews and document analysis. Thus, underlying issues or tensions emerged from the analysis.

The CF was then used to guide the second round of interviews to further explore the issues and the tools and methods to answer research question four. In this round, participants were asked to use the concept of CF to reflect on the issues they faced and the methods they used to deal with complexity. Outputs from the second round of interviews are not only interviewees' perspectives and narratives on their experience but also a map where interviewees located their issues and methods in domains of CF. Analysis and synthesis of these reveal more insights into the existing problems, as well as the way forward in terms of solutions to complex, uncertain issues.

The remainder of this chapter is structured as follows:

- In Section 6.2, CF is utilised to examine the overall situation of urban water systems on the South eastern Australian seaboard from the author's perspective. Literature on the urban water system in the study area and the first round of interviews are investigated and then used to interpret the transition state through the lens of CF.

- In Section 6.3, the emerging challenges when planning under conditions of complexity are synthesised and analysed, drawing from the second round of interviews
- Finally, Section 6.4 provides concluding remarks, discusses the effectiveness of the conceptual tool, and acknowledges its limitations.

6.2 Urban water planning responses through the Cynefin lens / contextualisation CF for urban water

This section aims to provide an interpretation of the current urban water planning and management context in the study areas through the lens of the Cynefin framework. The interpretation attempts to contextualise and make sense of urban water by drawing on results from the first round of interviews and synthesised information from published document analysis. Further, this section served as a 'test-run' analysis of the broader and more general case study of metropolitan areas on Australia's south eastern seaboard to see whether or not CF has the explanatory and exploratory power to make sense of the complexity around urban water issues. In detail, elements of the current water paradigm and the associated issues are discussed following the four main Cynefin domains: simple, complicated, complex, and chaotic.

6.2.1 The simple domain

Which part of the current urban water planning and management regime falls into the simple domain, and the way in which it does so, are discussed in terms of how the management regime aligns with the characteristics of the simple domain, as shown below (extract from Table 4.3):

Type of problem	Predictability	Causal relationship	Type of practice	Strategy
Simple (Obvious)	Stable and predictable	Clear cause and effect	One right answer Best Practice Protocol essential	Sense Categorise Respond

As has been discussed in the literature, despite efforts to transition to a more sustainable paradigm that adopts an integrated approach involving demand management, least-cost planning and water conservation (Turner et al., 2010), parts of the urban water industry are still pursuing a conventional management model (Brodnik et al., 2017; Malekpour et al., 2017; Marlow et al., 2013). The conventional technician-led approach, which worked well in the past to satisfy development and sanitation goals, has been placed under scrutiny due to its inability to deliver the current goals of socioeconomic and environmental outcomes (Ferguson, Brown, & Deletic, 2013; Floyd et al., 2014; Malekpour et al., 2017; Mukheibir & Mitchell, 2014).

In the author's view, the characteristics of the conventional approach to urban water planning resonate with the characteristics of the simple domain. I argue that the conventional approach to urban water planning and management assumes that systems can be understood thoroughly through a reductionist paradigm. Also, it relies on the assumption that best practice approach can be found to solve problems.

Regarding the former argument, the <u>technocratic style of planning and management</u> of the conventional paradigm and the <u>segmentation of urban water system</u> are consistent with the Newtonian approach in which the system is no more than the sum of its parts (Dunn et al., 2016).

As mentioned above, a number of interviewees (all of whom were active practitioners in the field) highlighted the reliance on the predict-and-control model in planning, in which the system is assumed to be in a stable state where the parameters are derived from the historically informed predictions of one preferred future scenario (Brodnik et al., 2017; Floyd et al., 2014). Also, the high level of certainty in both predictions and interventions is achieved based on a well-established understanding of causal relationships, which are analysed through a deterministic process based on linear assumptions. Such processes and standardised practices are known to always provide the single best answer, which usually leans towards large infrastructural solutions. This is not to imply that the tasks involved are always quick and easy to perform (McLeod & Childs, 2013a); rather, it indicates that the process of identifying them is linear and predictable.

Moreover, adopting a discipline-specific approach is one of the main attributes of the traditional paradigm when different urban streams such as water supply, wastewater and stormwater are managed separately. This attribute typically resembles a reductionist approach in the sense that it assumes the disaggregated constituent parts of the system are distinct and will not change in characteristics due to their interactions, nor will they exhibit different properties over time (Pollard et al., 2011). Some commentators in the field argue that without a holistic approach and any type of collaboration, the opportunities for efficient and effective integrated solutions that bring socioeconomic and environmental benefits are challenging to realise (Furlong et al., 2018; Productivity Commission, 2020). Alternatively, as interviewee V1 asserted: 'collaboration between key organisations involved is the key point for IUWM to be successful'. A response strategy that builds in an 'ad hoc', 'set and forget' manner, where issues are dealt with individually in a short-term fashion (Q1), has come under criticism as it is no longer fit for purpose across the urban water sector (Cook et al., 2019; Malekpour et al., 2016; Marlow et al., 2013; Mukheibir, Howe, et al., 2014; Productivity Commission, 2020).

Regarding the assumption of the best practice approach for solving problems, various guidelines and designs have been published by government bodies for standardised services for newly developed areas, water treatment plants, wastewater networks and stormwater management. One example is the development and use of the 'New South Wales best practice management of water supply and sewerage guideline' (Department of Water and Energy, 2007). This document includes an 'integrated water cycle management (IWCM) checklist'. The document was developed to enable local water utilities (LWUs) to construct and tailor their best practices to maximise their triple bottom line (social, environmental, and economic) outcomes. The guideline is an effort to simplify and standardise all relevant processes by creating a system of checklists. LWUs need to tick off a set of criteria to complete their plans. The IWCM module in the guidelines can lead to plans or activities in the complicated domain if LWUs adopt holistic approaches that incorporate knowledge and values of different water systems components and various stakeholder management procedures. However, this outcome is unlikely as the document contains no instructions on how to integrate all these components and no guidance on which platform to use for communication with other components. It is argued that using the integrated approach in NSW is rare and nowhere near becoming business as usual (BAU). The point was referred to as 'IUWM is not done very well in Sydney' by interviewee N2 or 'the core of the Metropolitan Water Plan is water demand and supply' by respondent N1. It is noteworthy that most of the tools and methods commonly used in New South Wales emerged from an economic perspective and were developed to deal with the economic imperatives that drive the industry. In terms of the technical approach, the tools used are generally direct observation, mathematical modelling or numerical statistics, which tend to result in the selection of pre-existing models and procedures, as in the case of NSW mentioned above.

The main aim of community engagement at this point is to inform the public about what the government is going to do and to get the public to understand the problems, alternatives and solutions, and hence this form of community engagement fits with the definition of the simple domain.

In systems that operate with a direct command mindset, there is no sign of activities related to the adaptive management approach. The closest thing that might be worth mentioning is the obligation to review and evaluate the IWCM strategy every six years.

The contextualisation of the urban water system dynamic between the simple and chaotic domains (the 'cliff' that was described in Section 6.2.2) will be discussed later on in 'the chaotic domain' segment.

6.2.2 The complicated domain

Type of problem	Predictability	Causal relationship	Type of practice	Strategy
Complicated (knowable)	Stable and predictable by experts	Cause and effect discernible with analysis	Several right answer Good Practice Protocol essential	Sense Analyse Respond

(extract from table 4.3)

In the complicated domain, the objectives and approaches to urban water planning and management are more akin to the more current approach of Integrated Urban Water Management (IUWM), which water sectors in the study areas are theoretically and practically trying to attain (Marlow et al., 2013; Mukheibir, Howe, et al., 2015; Quezada et al., 2016; Sapkota et al., 2015; Wong & Brown, 2008). Historically, there was a major change in perspective in regard to planning and management practices that resonated with the formative vision of 'the water soft path' (Pinkham, 1999). While the conventional methods used to manage water streams individually (water supply, wastewater and stormwater) were highly influential in fulfilling development and sanitation objectives, 'their functional and economic effectiveness in fulfilling environmental, quality of life, and other objectives are often questioned' (Pinkham, 1999). Therefore, with the overarching aim of maximising the social, environmental and economic benefits, approaches to urban water planning and management need to shift not only toward the integration of those water components but also toward integration with other sectors, such as urban planning and energy planning, making the planning process complicated (Mitchell, 2006; Mukheibir, Howe, et al., 2014; Nair et al., 2014; Sharma et al., 2010; Wong, 2006). Overall, the objective of this integrated approach is to get the most out of the collaboration between various stakeholders, including experts with different areas of expertise and customers with different perspectives, to obtain a better understanding of urban water systems and associated issues, and to identify and achieve common goals. By doing so, integrated solutions can be applied to achieve sustainable social, economic and environmental outcomes (Cook et al., 2019; Mitchell, 2006).

A few distinctive features help place the integrated approach in the complicated domain instead of in the simple or complex domains.

From the author's point of view, the underlying ontology and thus, epistemology that come with the IUWM approach is opposed to the set of beliefs that inform the response strategy within the complex domain. So basically, IUWM encourages more intensive and rigorous analysis of the integrated urban water system to gain better insights that will result in better future projections. To be more specific, in the author's opinion, the current IUWM approach as a process is usually built on well-defined deterministic outcomes and aims to deliver future scenarios that are as certain as possible. As interviewee N1 indicated, in an IUWM project 'you were trying to deliver certainty for land use planning that can be combined with wastewater and stormwater, and infrastructure planning' in terms of 'when people might come to the area, when they will be able to deliver the wastewater and when to model infrastructure would be that fit delivered'. This perspective is in contrast with the main premise of the complex domain where what will happen in the future cannot be predicted and cause-and-effect relationships can only be understood in retrospect (Snowden 2005). In short, the thinking behind IUWM is that people seek certainty in deterministic analyses when carrying out IUWM where 'water engineers are interested more in building something that will give you 100 years of secure of water than taking an adaptive approach' (N2) and 'people are comfortable with certainty, most people cannot deal with uncertainty and complexity' (Q2) .

On the other hand, to put it bluntly, the complex domain is an uncertain operational context where there are things that are not knowable – the 'unknown unknowns' (Rumsfeld 2002; Snowden & Kurtz 2003). Therefore, the author believes that the current state of IUWM practice mostly operates in the complicated domain. The reason for adding 'mostly' is that in this transitional period when the urban water sector is changing at a rapid pace, there are ways of thinking and practices in the IUWM regime that are starting to find ways to address the 'unknown unknowns'. This matter will be elaborated further in 'the complex domain' segment below.

To justify why IUWM should be placed in the complicated rather than the simple domain, the author would like to highlight two main points, the emphasis on the *collaborative element of the integrated approach* and the *characteristic of multiple options*.

Firstly, key ideas on *collaboration* as one of the main pillars identified from the extensive literature on IUWM (more detail in Chapter 2) are summarised here, together with what role this feature plays in differentiating IUWM from the simple domain. In general, the holistic approach to urban water systems exposes more complicated causal relationships that call for a shared understanding of different perspectives. Thus, the collaboration between various organisations responsible for different urban water services is critical (Cook et al., 2019; Guthrie et al., 2020). This notion was supported throughout the first round of interviews: respondent V1 stressed when describing IUWM: 'I think *collaboration* is a key point, the collaboration between the key organisations involved'; interviewee N1 shared that the key challenge for IUWM is 'the collaboration in order for it to be effective'; and participant Q1 said there was a need for 'all the collaboration with the technical people and the regulatory people' to make integration work. Such collaboration is important as the process requires not only different aspects of systems engineering from a technical perspective, but also from a governance and institutional perspective for approval procedures (Furlong, Silva, et al., 2016). As suggested by a number of scholars in the field, IUWM in Australia manifests mainly through wastewater and stormwater reuse and recycling (Ferguson, Brown, & Deletic, 2013; Guthrie, Furlong, et al., 2017) which requires the combined efforts of all individual organisations that are in charge of water supply, water treatment plans and stormwater management. For example, in the case of Sydney, while the task of receiving water from dams to treat and distribute to customers is done by Sydney Water, incorporating stormwater management into the system requires technical and institutional collaboration with the local government that is responsible for urban planning (N1; N2). Moreover, consultation with the public or customers has been highlighted as vital when considering matters such as pricing for integrated solutions, water restrictions or the applicability of recycling and reusing wastewater and stormwater, as has been carried out in NSW (Metropolitan Water, 2017) and in Victoria (Yarra Valley Water 2017). Thus, the process of enhancing system understanding and improving future projections by engaging multiple perspectives from experts with different expertise aligns well with the operating conditions of the complicated domain.

Secondly, having '*multiple good options*' to respond to problems associated with IUWM, instead of 'the best practice – one solution', distinguishes the approach from the simple domain (referred to in Table 1). In the author's opinion, the IUWM approach truly embraces the 'analyse' type of sense-making instead of 'categorise' as is the case in the simple domain (Table 2). To be more specific, while analytical power and predictive capacity still play an important role, they are employed on a more sophisticated level when compared to the simple conventional approach, as the numbers of objectives and variables increase significantly (Furlong & Silva, 2016; Sharma et al., 2019). As the dynamic of interacting variables in the integrated systems creates new patterns which do not replicate past events, further analysis is required which incorporates various perspectives and types of knowledge (Burn et al., 2012). Interactions between variables make every case unique due to its contextual conditions (Sapkota et al., 2015). Hence, there are few standardised or predetermined methods or processes that can be used to 'categorise' them. Furthermore, from the documented analysis of IUWM, a fairly standard practice has emerged across the industry to consider a portfolio of a range of alternative options that are able to deliver outcomes for plausible future scenarios (DELWP, 2017; Melbourne Water & Victoria State Government, 2017; Metropolitan Water, 2017). This standard suggests that best-practice management that favours a single ultimate solution is not suitable for achieving integrated objectives.

For these reasons, the collaborative and systemic approach to the urban water system of IUWM aligns well with the complicated domain.

Some prominent examples of methodologies (or approaches) operating under this complicated management regime are the Water Sensitive Urban Design (WSUD) approach (Radcliffe, 2018; Sharma et al., 2019), the 2017 integrated water management (IWM) framework in Victoria (DELWP, 2017), and the WaterSmart Cities Program under the framework of Sydney's 2017 Metropolitan Water Plan (Metropolitan Water, 2017).

In general, the WSUD is more like an overarching methodological approach that focuses on integrating stormwater management with urban planning and design. Analytical and planning tools/methods have been developed to address associated issues in a way that promotes broader ecologically and environmentally sustainable development in an urban setting (Radcliffe, 2018; Wong, 2006). The range of WSUD systems and applications is vast. Some prominent examples include constructed wetlands, rain gardens, rain tanks, retention basins and buffer strips ((Sharma et al., 2019).

The IWM framework for Victoria provides rigorous, detailed strategies for identifying and prioritising projects for creating a dynamic platform for collaboration across organisations, sectors and disciplines. Those involved range from top-level officers down to people in working groups. In addition, the process involves monitoring the planning and delivery of projects (DELWP, 2017).

The NSW Government and Sydney Water initiated the WaterSmart Cities program to explore opportunities to apply an integrated approach to planning and managing water services in new housing developments (Metropolitan Water, 2017). To that end, two pilot cases were developed for integrated planning to establish collaboration between stakeholders and to investigate challenges and enablers regarding economics, planning and regulations (N1; N2). In practice, most integrated solutions are developed organically at the local scale, and there is hardly any official response rolled out in a systematic manner (Guthrie, Furlong, et al., 2017; Mukheibir, Howe, et al., 2014). Furthermore, analysis of research on how to foster collaboration between various organisations and the community and how to overcome legal and regulatory barriers is hard to come by (Floyd et al., 2014); N1; N2; Q1; Q3). Therefore, the author suggests that the WaterSmart Cities program could be operating at the boundary between the complicated and complex domains since it has attempted to investigate the implementation of integrated systems which align with complicated features. However, it did that by learning from control 'safe to fail' experiments which closely relate to the 'probe' practice in the complex domain. The following sub-section will detail how the program sits within the complex domain.

Some of the analytical tools that are frequently used for planning in this domain are Integrated Resources Planning (IRP), Multi-Criteria Decision Analysis (MCDA), cost and benefit analysis (CBA) with consideration of externalities, multi-objective optimisation, hydrological modelling and/or economic modelling to name a few.

In participatory approaches, as mentioned above, besides technological and economic considerations, the perspectives of community members and customers are considered. The level of community engagement is higher and more frequent, and community engagement is much more organised than it is in the simple domain (N1; V1; V2). Although it is not BAU, there is evidence that the community is engaged at the 'involve' level according to the IAP2 spectrum. At this level, the authorities work directly with the community to gather information, inform the public, a understand their perspectives to develop the most appropriate strategies; as respondent V2 from Melbourne shared: 'we were engaging with the farmers and the government and Traditional Owners on the solutions and engaging with our community on the value. So, we put both of those input in our solutions'. Community engagement in this space includes, for example, citizens' juries such as the one undertaken by Yarra Valley Water to find a balance between price and service (Yarra Valley Water 2017), and various participatory consultation forums at the council level.

6.2.3 The complex domain

Type of problem	Predictability	Causal relationship	Type of practice	Strategy
Complex	Influx and unpredictable	Cause and effect may be there but is only understood in retrospect	No right answers Emergent Practice Protocol unlikely to work	Probe Sense Respond

(Extract from table 4.3)

The progression toward a sustainable urban water planning and management paradigm involves many intertwined problems in a space where socioeconomic, administrative, institutional and natural resources systems interact. In addition, pressures from uncertainties regarding climate change, population growth and urbanisation are only expected to increase (Cook et al., 2019; Dunn et al., 2016). Planners are now expected to bring together multiple objectives and accommodate various future uncertainties. As a result, nowadays, issues in the urban water sector are often identified as 'complex or wicked problems' that need to be addressed in a way that acknowledges the complexity and uncertainty involved, and where the 'predict and plan' approach with a high level of certainty mi(Bosomworth & Gaillard, 2019; Dunn et al., 2016; Fratini et al., 2012). In other words, the author thinks that many contemporary problems are now operating in a complex domain and there is a critical need for urban water planning and management approaches to evolve to catch up with the new reality. Uncertainty and unexpected trends are among the key elements of the *complex* domain.

The urban water industry is currently struggling to address issues associated with complexity and uncertainty. On the one hand, what commentators believe about what current practices should be is not effectively translated into implementation due to various barriers (Ferguson, Frantzeskaki, et al., 2013; Marlow et al., 2013; Productivity Commission, 2020). On the other hand, along with the ambition of implementing long-term planning for future resilience, uncertainties are among the major hurdles that have been identified in the literature (Bosomworth & Gaillard, 2019; Farrelly & Brown, 2011; Grant et al., 2013; Mukheibir & Mitchell, 2014) and such hurdles were acknowledged one way or another by the interviewees in the present study (as briefly mentioned in Section 6.1 and in more detail in Chapter 5).

From the author's point of view, there are signs that current planning and management approaches are moving into the complexity realm. Those signs refer to the parts of the urban water sector which are beginning to engage with uncertainty and to pick up elements of adaptive management in a planning sense. Using the urban water management transition framework (Figure 2.2) (more details can be found in section 2.2.3), the author suggests that the transition from a 'water cycle city' to a 'water sensitive city' in relation to drivers and functions would also require a transition of the analytical approach from the complicated to the complex domain. According to the author's interpretation, the approaches used in the complex domain no longer place technical prediction and planning, or attaining different water supply, wastewater and stormwater objectives, at the centre. Instead, in the face of the 'unknown unknowns' of future conditions, resilience, adaptiveness and flexibility are emphasised. The author realises that to make such a paradigm shift happen, it is necessary to identify the underlying ontology and epistemology clearly, and it is necessary to embrace and align the new drivers and servicing functions with the changes in the planning approach and planning tools.

Some signs of this transition can be seen in various planning documents in which water utilities are committing to adopting more flexible, innovative and adaptive approaches. For example, the 2017 Metropolitan Water Plan document mentions adaptive approaches to managing variable environmental flows from Warragamba Dam to ensure the health of the Hawkesbury-Nepean river in order to enhance socioeconomic benefits from recreational and commercial uses and the aquatic life of the river (Metropolitan Water, 2017). Also, within the same document, the WaterSmart Cities program is introduced as a 'learning by doing' approach that involves pilots as learning experiments to probe and sense the enablers and limitations of integrated systems and to seek opportunities to improve, adapt and scale up practices. The approach to learning more about the system through 'fail-safe experiments' aligns well with the statement that 'the cause and effect relationships can only be understood in retrospect' (Snowden & Kurtz 2003), and it is also a critical constituent of the adaptive management approach. In addition, both the Melbourne Healthy Waterways Strategy, and the Melbourne Sewerage Strategy have adopted the Adaptive Pathways approach to planning for future resilience and sustainable development, with periods of 50 years and 30 years, respectively (Melbourne Water, 2018a, 2018b). In both Melbourne documents, an acknowledgement of uncertainty is clearly stated, and the inappropriateness of the conventional predict-and-control planning approach, and the need for a flexible and adaptable approach to planning that considers both socioeconomic and administrative/institutional aspects, are noted (Melbourne Water, 2018a, 2018b).

However, despite the progressive nature of the thinking described above, it is important to point out that it is impossible to keep track of the progress of most of these planning agendas, so it is unclear whether or not they are actually being implemented. For the 2017 Metropolitan Water Plan in Sydney, for example, there are no progress reports on how it has been implemented, and there are no monitoring and evaluation procedures or documents publicly available. The situation with the WaterSmart Cities program is similar. After being outlined in the 2017 Metropolitan Water Plan, no further implementation was documented. Information provided by interviewees suggests that the program was cancelled for political reasons, which have been described as 'institutional barriers'; 'turf wars between institutions' by participant N1; and the 'breakdown of collaboration between organisations' by interviewee N2.

In the author's opinion, the approach of the WaterSmart Cities program is novel in that it acknowledges the complexity and uncertainty of the systems. As a result, pilots were designed as learning experiments to increase understanding about what works and what needs to change in order to implement integrated water strategies in a cost-effective and sustainable way, and to seek opportunities to scale up integrated practice. The program's ambitious overall approach is adaptive in that it exercises the concept of 'learning by doing', a concept characteristic of the complex domain. However, the lack of certainty and the difficulties in justifying investment do not necessarily make for a good business case, and it is probably susceptible to being undermined by internal politics. Concerning the Melbourne Sewerage Strategy and the Healthy Waterways Strategy, there are hardly any reports and documents on how the strategies are being employed to develop specific projects on the ground. In the author's opinion, once the outputs of the strategy come to life, it could end up being one of the pioneers in dealing with uncertainties in complex systems.

6.2.4 The chaotic domain

As the chaotic domain is not the focus of this study, in this section, the urban water systems located in the chaotic domain will be discussed to illustrate the 'fall' from the simple domain to a chaotic situation. It describes how the reliance on the simple approach might be a factor that contributed to the recent crisis related to extreme drought, which has been located in the chaotic domain by the author. To that end, the Millennium Drought is reflected on before discussing the recent 2019/2020 drought and bushfires.

The Millennium Drought was an extremely dry period that lasted nearly a decade during the 2000s. Despite the seemingly straightforward cause-and-effect relationships, the author believes that Millennium Drought can be classified as a complex problem since the prolonged period was outside of the conventional planning envelope. According to the concept of CF, the causal relationships are apparent when the present can be related to past events to predict future variations in the simple domain or when they can be projected using intensive modelling based on a range of variables from different areas of expertise in the case of the complicated domain. This was unlikely in the case of the Millennium Drought since there was no prediction of the drought's magnitude and timespan, and its impacts were felt in a wide range of areas, including the social, economic, and ecological. In brief, the Millennium Drought was an unexpected event that unpredictably affected the whole human system.

In responding to this 'unforeseen' prolonged drought, governments 'assumed control of planning and approvals processes in order to implement large water-supply infrastructure projects, notably desalination plants, with great urgency' (Chong, 2014; National Water Commission, 2011). Overall, what was done in several states and territories during the drought has raised concerns about the performance of the urban water sector (National Water Commission, 2011). After the drought, desalination plants in the eastern states were put on standby and the Brisbane advanced water treatment plants were closed down without even being used (Radcliffe, 2015). Because a considerable number of major infrastructure investments now provide little benefit, the debate has turned to the effectiveness and appropriateness of economic regulation, and the evaluation of capital investment, technological resilience and public acceptance (Chong, 2014; Radcliffe, 2015). Several important lessons related to planning and management practices can be learned. One of these is the inappropriateness of focusing on large-scale physical solutions to increase sustainability. Another is the weakness of adopting simplistic responses to potentially more complex or complicated issues. Finally, no matter how deterministic a technical approach is, it is not possible to achieve certainty because there will always be unpredicted events in the future.

While the drastic responses to drought, such as water restrictions and the construction of desalination plants ,were all part of the drought response plan, the fact that there was no investment or planning for a drought as intense, widespread and prolonged as the Millennium Drought indicates there was a linear approach which treated the drought as complicated or even simple problem. For that reason, the system became stressed more rapidly than ever due to a rapid decline in dam levels. Thus, the predetermined response strategies were unlikely to have the desired effect, which led to, from the author's point of view, the system falling into chaos where there were no options other than to implement the most drastic interventions.

This is not to say the 'complicated' discourse was completely ignored. Besides large infrastructure augmentation projects, various innovations and efficient operations related to water recycling and water efficiency programs emerged from the National Competition Policy agreements between 1995 and 2005 and from the 2004 Intergovernmental Agreement on the National Water Initiative (Chong, 2014; Radcliffe, 2015). The author contends that these alternative options indicate a step change in the approach to water system problems, which moved the responses from the simple phase to the complicated phase. This new approach recognised the complicated nature of the drought and acknowledged that engineering solutions were not the only correct answers anymore. Instead, alternative integrated solutions such as water recycling, water reuse, rainfall harvesting, and demand management options such as retrofitting water-efficient appliances could increase resilience in a time of crisis.

However, at the end of the drought in 2012, 'national policy attention had turned elsewhere, the Ministerial Council on Environment and Water has been abolished and the National Water Commission closed, leading to a loss of coordinated national policy impetus for water reform and likely reduced uptake' (Radcliffe, 2015). Also, it was evident that funding was no longer available in the Australian water sector for new research and innovative projects, such as water recycling

(Radcliffe, 2015). This situation will likely remain in the future, partly due to the sizeable investment in desalination plants (Giurco et al., 2014; Turner et al., 2016).

While there was a shift toward a more sustainable water sector that might be resilient to future climate uncertainties, decisions made since the end of the drought indicate a reversion to a simple approach. In other words, there has been a tendency to move back to the 'simple' business-as-usual (BAU) practices in which response strategies are built on predetermined procedures, with ad hoc engineering-driven approaches applied to achieve short-term objectives. This 'phase shift' (Snowden 2019) back to the simple domain poses a question about resilience: How would the system cope with disruptive events like the Millennium Drought if it happened again? The author believes that the answer is clearly demonstrated in the recent water security crisis on the eastern seaboard in late 2019 and early 2020. The linear approach to urban water planning and management once again failed to deliver the desired outcomes. The system was in a chaotic situation where many parts of New South Wales and Queensland would have approached their 'day zero' if the conditions had stayed the same for six more months (Barbour 2019). Not only was water security threatened, but severe drought was also followed by the worst bushfire crisis that Australia has ever seen (Morton, Evershed & Readfearn 2019). While uncertainties due to climate change (as well as climate variability) worsened the conditions, droughts and bushfires are nothing new in the Australian context. However, water systems falling off the 'cliff' into the chaotic domain might be largely due to a mismatch between the response strategies and the degree of complexity of the water security issues in urban water planning and management.

To conclude, based on the concept of CF, this section has identified and discussed the overall water planning landscape currently in place in Australia. The discussion can be summarised in the following dot points:

- Contemporary urban water problems are complex.
- The conventional approach to urban water planning is still the dominant practice.
- However, there appears to be a transition in the sector to the complicated domain whereby system thinking is being adopted through integrated and collaborative practices.
- The uncertainty and complexity of issues in the complex domain are being poorly addressed since the adaptive and 'probe' approaches are still in their infancy. Hence, the author supposes that the mismatch between the state of problems (being complex) and the current approach (shifting to the complicated domain and initiating a transition to the complex domain) has led to an inability to address the complexity and uncertainty of existing issues.

6.3 Challenges experienced when planning under complexity

After carrying out the document analysis and analysing the outputs from the first round of interviews, it was apparent that there are fewer practical applications on the ground than were initially anticipated regarding adaptive management/planning and public participation. Also, it has been found that the industry is struggling to deal with complexity and uncertainty when implementing integrated urban water planning and management and community engagement. Thus, the focus of this research has shifted to investigating what those barriers currently are and a possible way to deal with them. To that end, the lens of the Cynefin Framework (CF) was adopted to help to unpack these complexities and uncertainties and to find out the root causes of the seeming complexity and uncertainty by conducting semi-structured interviews with a focus on the Sydney metropolitan area.

The overall implication from the interpretation in the previous section, Section 6.3, is that one of the main reasons why the urban water sector is struggling with complexity and uncertainty during the transition to a new sustainable approach might be the lack of tools and methods that can develop strategies to deal with complexity and uncertainty within the complex domain. Therefore, the objectives of the interviews in the second round of data collection were twofold. The first one was to understand the underlying cause of all these complex problems, which were previously captured in a fragmented way. The second was to obtain better insights into how the tools/methods that have been used help deal with complex problems. Thus, this section provides a synthesis of the challenges involved and is structured into six key themes/topics. The discussion on application of current tools and methods is discussed in chapter 7.

The multifaceted, complex issues of the IUWM approach stem from the increase in complexity and uncertainty that will occur in the future when considering all aspects of the urban water system in order (Floyd et al., 2014; Fuenfschilling & Truffer, 2016; Guthrie et al., 2020); C2; W1). This sentiment was supported in the second round of interviews, which focused on the Sydney context. As interviewee W1 shared: 'you have to really understand how to manage stormwater and wastewater, and reuse, and all these things have to come together'. W1 added: 'but there will be that complexity of how do I implement? how do I get those collaborating partners to do what I want them to do; and am I going to realise the benefits?'. Also, an example from interviewee W2 pointed out that while the management of drinking water quality has 'a very mature regulatory framework … simple utilities … just need to follow certain steps'. The management of drinking water quality is one of the oldest processes in Sydney's water sector, with well-established best-practice technology, management and regulatory frameworks. However, it quickly gets complex once water supply and demand management needs to be aligned with broader wastewater and stormwater services, as well as satisfy environmental flow and waterways health requirements. Due to these multiple objectives, water quality is much harder to control since runoff from rainfall is a non-point source that brings unexpected contaminants from the ground surface into the collecting pipes'.

6.3.1 The technical complexity of integrated approaches

Overall, the concern about complexity related to technical capacity in IUWM is due to the combined influence of the large spatial scale involved, the long-term planning timespan, and the demands on technical knowledge.

In general, modelling the integrated system requires much analytical prowess and places an enormous computing burden on planners who need to comprehend data and incorporate it into their models. As interviewee W1 shared, 'when you have all these scenarios and variabilities … it is hard to understand what integrated water management models are telling you'. W1 added: 'when you try to simplify it to put it into, say, economic models … this then adds a whole lot of other things going on with it, often in terms of risk'. With a similar insight, respondent C2 indicated that 'it is rare that they [stormwater, supply-demand planning and management of environmental flows] are all incorporated into the same analysis … it is complex in terms of the amount of computing power used to optimise [models]'.

The number of variables, scenarios, possibilities and calculations can significantly increase with the spatial and temporal scales changes. Thus, the more complexity there is, the higher the chance uncertainties will arise due to 'imperfect knowledge' and 'incomplete knowledge' (Brugnach et al., 2011; Walker et al., 2003). For example, according to interviewee C2, the South Creek integrated water. and land use planning project might be a case where the area is 'too large and [has] too many growth areas' to plan for. Also, with a 'time frame of anywhere between 30 and 60 years for that city [the growth area] to emerge', it might be too complicated for a holistic approach to try to 'estimate wastewater costs, drinking water costs, stormwater costs, and an alternative set of options is a very complex set of interactions that have a range of different rates' (C1). In fact, within the planning area, there 'will be nowhere near as much development in that region, as we go into depression, as there would have been last year' (C2). Besides, it was reported that having too large a scale could hinder the analytical power of a model by posing a threat of data shortages which would make it impossible to understand the full extent of the pressures on an integrated system, particularly pressures related to climate change and climate variability (G1; W1). Interviewee G1 pointed out in the discussion on modelling integrated systems in the context of climate change and climate variability, 'it is the problem in integrated water management in Sydney. In particular, depending on which scale you are looking at it, you may or may not have the data' (G1).

Besides the computing burden, the lack of technical understanding and experience on the part of the people who carry out the analysis was reported to be a concern in different organisations (G1; W2). As interviewee W2 suggested, other organisations such as 'regional councils are much smaller, they would have much less resources at their disposal [compared to a water utility], so in a way it [the predetermined planning and managing framework, including analytical practice] needs to be simple for everyone to follow them'.

From an engineering point of view, it is challenging to incorporate knowledge outside of one's expertise into the modelling process, regardless of whether collaborative knowledge-sharing sessions are held among the organisations involved. Moreover, regarding integrated urban water planning in practice, there are few hands-on examples to learn from the Sydney metropolitan area (W2). According to respondent W2, the 'only real example' to learn from in Australia where 'treated wastewater [is] inserted into the water supply' is Perth.

6.3.2 The governance and institutional complexity of integrated approaches

While numerous impediments to mainstreaming the integrated approach are related to technical considerations, the governance and institutional challenges and barriers were where participants felt the largest issues resided.

First, other authors have argued that fragmented institutional arrangements have been the cause of weak collaboration among players in the field. This 'silo' effect is not new to the water industry. It has been acknowledged in the literature as a historically entrenched characteristic of the traditional approach to water management and regulation (Mukheibir, Howe & Gallet 2014). The fragmentation of responsibilities from both the vertical viewpoint (from one level of government to another) and the horizontal viewpoint (within the same level of authority) might be the result of the lack of mechanisms/frameworks for collaboration among stakeholders (C1; W2). In the case of Sydney, the issue was often raised in conversations on integrating stormwater management with a water supply and demand planning and wastewater management:

> 'The institutional arrangements for stormwater are complex, so the number of different authorities that have a role in either regulating or managing means that it is inherently complex. So, you've got split responsibilities between state government and local government' (W2).

> 'Sydney Water has responsibility for some stormwater drains, but mostly it's local governments. So you got another split in institutional arrangements in Sydney where you've got councils that are responsible for flooding ... Councils have some responsibility for making sure that development fits with floodplain guidelines ... And when you've got flooding just from a natural river system, there is nobody responsible. We don't have a flood authority. Some places do, and it is a very big issue and they set up flood authorities' (G1).

> 'There were different responsibilities across government agencies. For example responsibility for stormwater was split between local governments and Sydney Water. The governance arrangement around waterways and waterway health was very fragmented' (C1).

For the sake of clarity, compared to what has been pointed out in the literature, Sydney local government generally has the most responsibility for stormwater systems, flooding and local water quality, while Sydney Water has responsibility for drinking water supply and wastewater disposal and some 'major trunk stormwater assets' (Watson et al., 2017b, 2017a). Hence, there is a lack of a unified framework or shared vision for how organisations should collaborate to manage stormwater within the integrated system regarding institutional responsibilities. Despite owning the largest number of stormwater schemes, local governments only generate a small portion of recycled water volume in contrast to Sydney Water which has much fewer schemes but produces much larger amounts of recycled water. Watson, Mukheibir and Mitchell (2017) suggest that the reason for this might be the separated responsibilities for stormwater, as mentioned above.

Also, as reported by the interviewees, the unclear distribution of responsibility due to fragmented institutional arrangements also creates a threat of losing accountability and credibility among organisations. As interviewee G1 reported:

> So there is not a clear authority that is responsible. You know, if you do this or that, they're the ones who choose, and it's signed off, end of story. That's not in the governance ... it is nice to say you can collaborate, but at the end of the day, someone one, one person you can call, you can touch and feel, has to be responsible.

IUWM processes are highly interconnected, and uncertainties about whether or not the involved parties will perform their assigned tasks, and whether or not they are ready to make changes to step away from BAU, should be motivation for establishing a clear framework or policy for collaboration. Respondent W1 said:

> There's lots of players, lots of different people. And everyone's got to collaborate, to rely on one another, and all the things that come with that, like any one organisation wanting to take all the credit, or anyone doesn't play their part ... If any one of those organisations is not ready to make that change [to systems thinking which provides broader views on social benefits], then they'll be pulling you back'.

In the author's opinion, this is an expected problem in a transitional period. Initially, the parties involved in the integrated process were used to operating comfortably in their contexts within a segmented engineering approach. Then, they get 'asked to go and achieve these much broader, better things by collaborating with someone else who may or may not do a task' (W1). Moreover, there is no unambiguous endorsement from higher authorities regarding policies or regulatory mechanisms to ensure that organisations complete an assigned job within an expected timeframe (G1; W1). As a consequence, these organisations do not have much faith in collaboration.

Secondly, organisations might <u>not all have their views and objectives aligned</u> with the IUWM approach. In other words, organisations have different priorities, and sometimes they might conflict with the priorities of others. As reported by interviewee G1, the consequences might be: 'at the end of the day if they did not like what was coming out of the planning process. They won't play ball, so they will subvert the process to their own ends' (G1). Alternatively, as interview C1 suggested: 'Even though we were working in the same government organisation, even between the different parts of the government, there are conflicting priorities for different outcomes in projects'. There could be a conflict-driven situation where some organisations have 'commercial imperatives, shareholder imperatives, etc. … they have to make a return on their investments to government' (G1 \) or 'some people want the lower costs. You know, they think that should be the only way we make decisions' (C1). These conversations were located in a context in which integrated solutions like recycling water are sometimes considered 'too expensive' because of the distance from the sources, so 'no one can make money from that', and that is why 'it [recycling water] is not happening' (C1). So, the financial priority often carries more weight than long-term economic benefits for the community, such as urban cooling and increased resilience, or even 'sometimes the financial costs take precedence over [public health]/ the risk appetite [for public health]' (W2). In addition, the author believes that besides the financial motive of state-owned companies, the economic regulatory framework around water recycling in Sydney also creates barriers for organisations to build more schemes. For example, there is still no mechanism to extend the funding framework for Water recycling schemes to a broader customer base valuing external benefits such as liveability and improving environmental outcomes.

From the author's point of view, this reflects a situation where different organisations values thing differently. In other words, the failure to recognise and prioritise sustainable gains for the broader community in the form of non-market, unquantifiable benefits could be a significant obstacle to the transition to an integrated and adaptive planning and management approach. The lack of methods to quantify the value of benefits that help improve resilience might lead to the avoidance of more expensive upfront investment options (Mukheibir & Mitchell, 2014). On a larger scale, this issue also raises the question of how risk assessments might be affected by a failure to prioritise measures that will improve community resilience. As mentioned above, financial costs sometimes take precedence over minimising risks to public health (W2), while logically, it should be the other way around.

Finally, the interviewees believed there is a critical <u>need for policy support incentivising and creating a more flexible environment</u> for the IUWM approach (C1; C2; W1). The interview responses indicated that efforts to do integrated planning and management have 'run into issues', since it 'always comes out to cost more than just doing BAU water projects with a non-integrated approach' (C1). In many instances, 'the main problem that we encountered was that the funding, the pricing, and the policy [which] set that pricing, the recycled water pricing framework, just meant that recycled water was too expensive' (C2). Therefore, even though recycled water would bring more value to the community and the water system if there is no policy direction and no incentives designed to encourage integrated solutions, the benefits might never be realised (C1).

Moreover, it has been suggested in the literature and the interviews that policy support plays a crucial role in lowering the level of uncertainty for all involved parties (Tjandraatmadja, 2018; C1; W1). Interviewee C1 described a hypothetical scenario in which policies can bring more certainty to implementing integrated solutions regarding economic benefits. If the government comes up with a policy stating that 'this part of the city should use recycled water and the developers whose buildings are in this area need to buy recycled water and use it', it gives certainty to the 'water utility to invest in the scheme because they would know that their investment would pay off because they would then have customers'. This, in turn, gives certainty to the developers as they do not need to wonder, 'why should I make sure my building has been [fitted with] purple pipes and connects to something that is not there?' (C1). In this example, the government would need to be a mediator and facilitator for integrated solutions to emerging. From the interviews, it is clear that uncertainty is one of the most influential factors in the decision-making process. Thus, providing policy-level certainty is crucial in transitioning to a new BAU (C1; W1).

Furthermore, support from policymakers is believed to be among the critical factors influencing how flexible the regulations are for encouraging investment in integrated solutions (Floyd et al., 2014; Tjandraatmadja, 2018). The author observed throughout the interviews that the decision-making space seems to be filled with tensions between water utilities, local governments and regulators (G1; C1; W1).

Options usually make sense in integrated water and land use planning processes; however, their inconsistent performance sometimes cannot satisfy regulatory standards. Notably, the regulatory standards for pollution concentrations, for example, are fixed numbers. Interviewee W1 provided a specific example of the choice between introducing green infrastructure like wetlands and wastewater treatment plants for managing the pollution concentration of stormwater discharge (W1). While wetlands bring additional benefits of urban cooling, energy-saving and amenities for communities, they cannot consistently deliver a fixed and quantifiable pollution concentration. This is because 'a green infrastructure can perform better in summer when the ecological elements function better than in winter … [when] the performance that you get from the systems is not so good' (W1). So, 'a regulator that's been wanting 5.2 is going see 6.0 and then 3.0 and then 6.0 and then 3.0' (W1). Hence, there will always be variability, and whether it is considered acceptable 'to get 3.0 all the time and sometimes get a 6.0' depends on the regulator's perspective (W1). Moreover, as discussed above, if one organisation does not complete its tasks, it is up to the regulator to decide whether some flexibility is needed to support innovative but difficult-to-implement options. In addition, policy support would help address the conflict over 'whose money should be used to invest in which part of the integrated solution'.

6.3.3 Complexity due to climate change and climate variability uncertainty

The essence of conversations around this topic is that the Sydney urban water industry might have failed to recognise and acknowledge the extreme level of uncertainty associated with climate change's impacts on drought and precipitation (C2; G1). Three main discussion topics emerged: the unpredictability of water system/ climate behaviours; the reliability of the data and models that are being used to simulate and explore climate change; and last but not least, the notion of 'unknown unknowns' that are yet to be discovered.

This recent record-breaking drought period, followed by the worst bushfire season on record, raised several hard questions and provided descriptive evidence of how reality can go far beyond the planning uncertainty envelope.

This is true in terms of the unpredictability within the water sector regarding climate change impacts; this realisation of uncertainty is also emerging in other areas. A topical example is the outbreak of COVID-19, the current global pandemic that has put the whole world in a state of emergency and is affecting all aspects of our daily lives. Such events frequently surfaced during discussions on uncertainty and chaotic systems mentioned by interviewees. Likewise, the latest droughts and bushfires that happened in many parts of Australia, including Sydney, were seen by all interviewees as bringing an 'unprecedented' level of uncertainty. While Sydney has been through many drought seasons, some of which have lasted for a long time with 'well below average rainfall', the recent drought exceeded them all, 'with close to no rain for the largest population that we ever had' (C2; W2).

From a climate perspective, the culprit of the latest drought on the east coast of Australia can generally be identified as a phenomenon where the dry cycle of El Nino – the Southern Oscillation (ENSO) was overlaid with a positive phase of the Indian Ocean Dipole (IOD) (Harris & Lucas, 2019). As a result, perennial rivers such as the Shoalhaven and Kangaroo were at historically low flows, to the point where they were nearly dry (C2; Thomson 2019). To put this into perspective, the Shoalhaven River system transfers to Warragamba dam to provide around 15% of Sydney's water supply, and even during the prolonged Millennium Drought, one of the worst droughts recorded since European settlement, the rivers reached 'very low levels but never had no flow at all' (C2). Moreover, sections of the Darling River, such as Menindee, Barwon and Braidwood, were completely dried out for months at a time (Campbell 2020; Davis & Allam 2019, para. 4; Nearmy 2019; Evans 2020: Sheldon 2019, para. 2). The event was far worse than expected from planning and management points of view, not just in the Sydney metropolitan area but also in many places within the Murray-Darling Basin. By being overconfident about the predictive power of models and not acknowledging and embracing deep uncertainty, Sydney was unprepared for this situation. The dire situation should be considered a wake-up call for the water industry to realise that the 'existing frameworks and infrastructures and planning were proven to not fit for purpose' (W2).

Further, the reliability of data, models and current modelling approaches come into question regarding the 'conflicting results that they produced' (C2; G1: W2). Conversations around the topic mostly unpacked the variability of projected precipitation rates provided by climate models (C2; W2). The ways in which future precipitation rates are projected are based on information from the downscaling process and direct observation data. The downscaling process takes coarse-resolution outputs from global climate models, the mathematical representations of the climate system, and they are then downscaled/refined into finer-resolution information in order to be able to represent local climatic conditions/influences (Bureau of Meteorology 2018; University of Tasmania 2020). Then, rates of rainfall and evapotranspiration can be projected based on calculations/ simulations using that information in combination with various sets of direct observation data. As described briefly by interviewee G1, this involves '[putting] together some models to take the climate change modelling that had been done at a fairly broad scale and [moving] it down into an understanding of what changes in precipitation you would see in the catchments around Sydney dams'. Alternatively, it can involve 'taking some precipitation data and broadscale climate models and applying them at a lower spatial scale, so that … it would be relevant just to Sydney, the metropolitan area' (G1).

The problem interviewees witnessed in Sydney was that there are different ways to carry out such downscaling processes (statistically and dynamically). There are also different models and modelling approaches to simulate the projections, and providing different outcomes (C2; G1). As interviewee C2 pointed out, 'there are as many models showing an increase in rainfall as [there are models showing a] decrease in rainfall, and so on'. This was confirmed by respondent G1: 'the results [of models] were not definitive … models were throwing up different, quite varied results, so we could have very little confidence in the data that was coming through'.

The uncertainty created by this low confidence and credibility leads to confusion about which solutions or supply options are needed for future water security (G1). This has led to a discussion on whether or not the expensive 'non-rainfall-dependent supply options such as desalination plants', which are predictable ('sticking pipes in the ocean, manufacture water, throw it into Sydney' (G1)) would be more suitable for future scenarios, in comparison to other more sustainable options such as green infrastructure, water recycling and reuse. Technological advances are needed to deal with uncertainty, which can ignite discussions on planning and management approaches. From the author's perspective, such debates can typically be about whether to embrace uncertainty by learning and adapting, and decisions along the way, or whether to rely on modelling to achieve as much certainty as possible, and then make decisions based upon that information.

The other argument related to the modelling of climate change uncertainty pertains to the lack of knowledge about the water system – the 'unknown unknowns'. Participants were concerned about the inadequacy of recorded data for producing trustworthy future projections. Practitioners were concerned that the rainfall dataset might not be long enough to capture the full range of historical variability (C2; W2). As respondent W2 suggested: 'Practically speaking, in a country like Australia, we only have a bit over one hundred years of rainfall records, so if we use that as a basis for learning, I think it is a very small dataset, effectively' (W2). Or, according to interviewee C1: 'the data and information really was not there … we had to actually script a bit on the climate change' (C1). So, in short, in the author's opinion, the concern is uncertainty regarding the magnitude and frequency of extreme events that predictions based on observational data cannot address. This concern is aligned well with the recent discussions on how paleoclimate data might provide a more insightful understanding and more reliable information on droughts and floods than stationary climate assumptions based on instrumental data (Ho et al., 2015). To be more specific, research on ice cores from Antarctica (Vance et al., 2016); tree rings from Tasmania (K. J. Allen et al., 2015); corals, tree rings, and speleothems from Queensland, Western Australia and Wombeyan (Ho, Kiem & Verdon-Kidd 2015) have provided much information on significant climate drivers like ENSO and IPO. This information dates back 2750 years and can be used to reconstruct rainfall in many different catchments. The reconstructed wet and dry epochs reveal some extreme events, such as the 39-year drought from AD1174 to 1212. They also reveal that wet and dry epochs maybe ten times more frequent than instrumental data appears to indicate. This might have a considerable impact on the way risk assessments and the long-term planning of water resources are carried out. There is no way to validate all the assumptions that have gone into rainfall reconstruction from paleoclimate data. However, the fact that the different methods and models that have used paleoclimate data to reconstruct climate conditions agree with each other, and the fact that the recent drought was far worse than what was expected based on instrumental data, might offer a new edge for this methodology to open up a new way to address climate change uncertainty. Nevertheless, the author believes that while it is crucial to improve technical capacity to better understand the system, uncertainty related to climate change cannot be addressed by a purely reductionist approach.

6.3.4 The rigid mindset/worldview that decision-makers have

The interviews indicated that people's worldviews in the industry are not ready to acknowledge and accommodate complexity and uncertainty. This emergent problem also reflects the output from the first round of interviews and is highly resonant with what the literature suggests (as mentioned in Section 6.1).

The entrenched traditional ways of planning and management sector-wise using a technocratic approach prevent changes to mainstream IWCM practices that are necessary (Brodnik et al., 2017; Floyd et al., 2014). It was also reported multiple times in the interviews that organisations and decision-makers decide to stick to what they have traditionally done in preference to innovative practices. Interviewees C2 and W2 expressed rather strong views about the desire of decision-makers to put problems into simple domains:

> I think we are not very good at thinking long-term, and we are good at thinking short-term. So when we talk about some of the processes and investigations we have done, many of the people, even the smart people that are supposed to be our bosses, they think we're just being too complicated … putting too much effort in and trying to justify our own jobs. They say this is not complicated, we don't need to get that complex about this thing. They drive to the part of the Cynefin framework that is simple. They drive it, everyone wants to operate there, they have a desire to be there, human behaviour is to be in the simple zone … they want to believe that there is nothing that is complex and there is very little that complicated, and they want to believe everything can sit in a simple [context], just [give it to a] project manager and it will be solved (C2).

> 'It is probably more about decision makers like it to be simple, but a lot of things are really complicated' (W2).

Also, as referred by interviewees C1 and C2, one prominent example of how decision-makers view complexity might be the cancellation of the WaterSmart

Cities program, which was a progressive program within the framework of the 2017 Metropolitan Water Plan. The program was developed based on the idea that embracing uncertainty was the right way to manage a complex water system. Hence, it focused on adapting and improving the integration of land use and water service planning strategies regarding Sydney's drinking water, wastewater and stormwater systems in new developments, as well as the tools needed for such processes through *pilots and designed learning experiments* in two pilot growth areas.

Many challenges and uncertainties were associated with such an ambitious program, and it might not have appeared to be the most cost-effective program, or the best business case on the agenda. In the end, the exact reasons why the funding was withdrawn were not revealed. However, interviewees referred to it as a 'breakdown of collaboration between institutions', as the organisation in charge wanted to continue its present way of operating: 'it is the resistance to a new way of doing things' (C2; G1).

Furthermore, from the interviews, it was apparent that the risk-averse attitude among decision-makers is holding back the transition to a sustainable approach to urban water planning and management. This is highly interconnected with the desire for certainty in planning (as mentioned above) and consistent with the literature (Brown & Farrelly (2009); Mukheibir & Howe & Gallet (2014)). In a risk-based approach to infrastructure planning, the complexity and uncertainty of integrated systems lead to difficulties in quantifying risks, making it hard to do cost and benefit analyses to use as parameters for choosing investment options. This leads to a lack of confidence in decision-making processes, exacerbated by the risk-averse attitudes of decision-makers (G1; W1). As pointed out by interviewee W2:

> So broadly speaking the subject matter experts (business experts) think that things are very high-risk and decision-makers at the top of organisations are generally not convinced that risk is so high (W2).

The discussion is around the need for more certainty in processes and the outcomes that result in either overspending time and money on refining models or totally avoiding uncertainty and complexity. As interviewee W1 described it: 'If I had all the models in the complicated space, I could refine that until the cows come home and I could get a better model and I could make it even better again, but it won't help me implement what we need to implement without certain things happening [related to uncertainty from collaboration and leadership endorsement]' (W1). In most cases, decision-makers go for the appealing certainty in 'black-box options' like building more extensive centralised infrastructures despite the associated costs (G1; W1; W2). Respondent W1 stressed how the appreciation for the certainty of such options could hamper the uptake of sustainable options, as in the case of wetlands mentioned above:

> But everyone has confidence in the other Infrastructures because a guy can stand up and say I will deliver you … I just put a black box and a pump energy into it, pump chemicals into, it is not that much money and it's not that many chemicals, just do it and how big should I make it, I will make it the biggest I can make it. Because that's more efficient, economies of scale (W1 2020).

Expressing a similar idea in a different situation, interviewee W2 described how the concept of preparing for future uncertainty through real options analysis was incomprehensible to decision makers:

> Basically what makes sense to us is to build some of it now and to be ready to invest so that we can build the rest of it rather quickly, should we need it. It is a little bit difficult. I will be brutally honest, a lot of people's eyes glaze over when I talk about this stuff, so it's a little bit difficult for people to conceptualise that 'I should spend money now to not have to spend it later'. A lot of decision-makers prefer to spend nothing now and wait until they absolutely have to. The money that you have to talk about here is that you might have to spend $500 million now to save $5 billion later. But if you don't spend $500 million you might be spending $10 billion instead (W2).

All in all, throughout the interviews, it was observed that the there is a risk averse attitude and future uncertainty avoidance among upper management, leading to the oversimplification of the system that poses a threat of undermining sustainable, long-term options.

6.3.5 A lack of communication methods that might lead to oversimplification

The communication of complexity and uncertainty plays a crucial role in decision-making. Planning teams may be meticulous in their analysis and come up with great solutions. However, suppose the knowledge and the associated complexity cannot be effectively communicated constructively, enabling decision-makers to grasp the full extent of the risks, uncertainties and opportunities involved. In that case, it is all in vain, as pointed out by Interviewees C2 and W2. In the context of IUWM in Sydney, the lack of precision in the outcomes of current myriad analyses, reasoning and modelling complexity is exacerbated by unprecedented uncertainty about climate behaviours.

Regarding this complexity and uncertainty, the way 'we talk about it does not appeal to a lot of people', and the situation is not necessarily being presented in a way that helps decision-makers realise the potential opportunities in long-term planning (C2; W1). Respondent W2 said there is 'so much information on this complicated space and I can't get it to be understood in a way that influences what we implement … it's very hard to communicate to those managers [decision makers]' (W2). In many conversations, it is reported that oversimplification occurs because the planners have a difficult time determining which 'space should be simplified while still capturing the variability that matters and then simplifies that variability so that it can be used to characterised options and strategies' (W1). Simplifying a complex idea without distorting it helps save time and resources on analysing. However, oversimplifying creates a simpler scenario that overlooks nuances (C1; W2). Underappreciation for the integrated solutions and overlooking the opportunities they bring are the consequences of oversimplifying.

The interviewees discussed two main reasons for oversimplification. One was to make it easier to understand integrated systems (W1), and the other was to gain certainty to build confidence in decision-making (W2; C2).

One of the reasons for the former might be that the existing frameworks and decision-making processes often fit to deal with only one kind of driver at once. However, when there are 'multiple layers of drivers and processes on top of each other', as is the case for IUWM, this existing platform may no longer be useful (W2). Considering water quality from a wastewater management perspective, as mentioned above, Sydney Water has a specific, robust regulatory and best-practice framework with clear standards for parameters such as pollutant concentrations/loads (W1; W2). Nevertheless, with the integration of stormwater and environmental flow management into the wastewater management subsystem, the volumes and the flows of runoff, alongside the companying pollutants, now need to be added into the equation, not to mention the requirement to pay extra attention to wider benefits such as urban cooling, amenities and recreation (W1). Likewise, in the case of water recycling and reuse, despite being implemented in a few projects, for the most part, the industry is still struggling to understand the complexity around the issue since there are 'only a few examples that exist to learn from' (W2). All the confusion in these extended spaces makes it hard to identify the investment triggers.

Furthermore, it is believed that the need for certainty in decision-making is also contributing to the discarding of, or the oversimplification of, complex options (C2; W2). This notion overlaps somewhat with the last point in the previous section. However, oversimplification can be interpreted as the result of the 'need for certainty' mindset. In general, delving into integrated system analysis, there have not yet been any economic evaluation tools developed to quantify the exact costs and expenditures involved and how the costs weigh against the benefits. Hence, with the mindset described above, decision-makers often resort to either 'reinforcing the status quo' or making simplified assumptions about the value of social benefits. That is why options like 'spend now instead of later' are often discarded, as it is uncertain whether particular catastrophic events will happen in the future. In other words, whether or not the upfront investment would be offset by avoiding future investments for recovery after an unexpected catastrophe or ad-hoc reaction to a crisis is in itself an uncertainty. So, it is not an appealing business case.

6.3.6 The perceived lack of economic evaluation methods to quantify non-market benefits

Various studies have shown the potential financial benefits of adaptive planning and resilience approaches. (Rust et al., 2020) show how adopting small 'incremental' options in the Lower Hunter region that are easily substituted in the future can increase the chances of delaying significant, expensive infrastructural investments until needed. This way of planning offers a more flexible and adaptable set of options to increase the overall resilience of the water supply system, as well as significantly avoided costs. The economic analysis is based solely on quantifiable financial costs. In another example, (Mukheibir & Mitchell, 2014) proposed and analysed an strategic adaptive planning approach for the Melbourne water businesses' fifty-year water supply and demand strategy and arrived at a similar conclusion. Building in ' flexibility through progressively investing in diversity and readiness over time' was shown to be a better financial response to 'trends' and 'shocks' over time than the business-as-usual approach of building sizeable capital-intensive infrastructure. In the case where adaptive planning was adopted, the' cost variability' overtime was significantly less than business as usual (Mukheibir & Mitchell, 2014).

However, from the interviews it appears that at the moment, there is still <u>no accepted consistent economic evaluation method to accurately account for non-market wider benefits </u>for the community (C1; W1; W2). This usually leads to the fact that the intangible broader social benefits are often overlooked when doing planning which leads to the underappreciation of sustainable solutions.

This is demonstrated by the view that the 'new way' of doing things is, in many cases, more expensive in terms of the financial cost than BAU, but it brings more intangible values and opens up more opportunities. For example, an option like recycling water, in addition to offering an alternative source of water supply so more water can be kept in the dam in case of drought, can also help improve waterway health by lessening the amount of wastewater, contributing to urban greening and the biodiversity of waterways. All of these extra benefits increase the system's resilience (C1; W2). Likewise, green infrastructure like wetlands, rainwater gardens and retention basins not only help slow down and treat stormwater but also provide a beautiful landscape for recreational purposes and helps urban cooling by increasing vegetation cover (W1). The values of these benefits do not translate into units that can be factored into decision-making processes. Therefore, it is difficult for decision-makers to justify a preference for such options rather than for projects that have certain and clear economic benefits like supporting 'a specified number of people's livelihoods' and 'creating a specified number of jobs' (W2).

Triple bottom line (TBL) is an approach that, in the recent past, has been adopted widely by water services providers in Australia (Policy and Cabinet Division & Chief Minister and Cabinet Directorate, 2011). Essentially, TBL is an assessment framework that uses social, environmental and economic indicators to evaluate the potential performance and the trade-off between options (Murray Darling Basin Authority, 2016). TBL can be used as broad guidance to decision-making that encourages sustainable practice (Taylor et al., 2006). According to Taylor, Fletcher & Pelio (2006), Multicriteria Analysis (MCA) that is structured with TBL has the potential to overcome the shortcomings of the traditional CBA by providing flexibility, robustness and transparency within the framework of IUWM. The method is flexible because practitioners can use it with a wide range of skills. Plus, how complex or straightforward the processes can be up to the decision of the design teams based on who would involve. Furthermore, incorporating both quantitative and qualitative data makes it robust. While CBA approaches struggle with assigning monetary values on non-market costs/benefits, TBL combined with

MCA, offers robust solutions in which quantitative data from models and qualitative information, such as experts' opinions, can be accommodated. In addition, it is transparent because the processes are meant to be inclusive, where stakeholders' perspectives and values help evaluate the options. While the method is great for stakeholder involvement and multidimensional planning, there is a lack of integration, 'indicators for the three pillars are reported separately without any holistic assessment' (E. Lai et al., 2008). Moreover, TBL is still essentially a linear approach where decision-makers 'still need to determine the relative value of these alternatives, not all of which will be directly or readily comparable' (Policy and Cabinet Division & Chief Minister and Cabinet Directorate, 2011).

More recently, a novel approach for measuring the non-financial benefits that an organisation can bring to the community and environment is the 'six capitals' concept which was first introduced by the International Integrated Reporting Council (2013). It was adopted by Yarra Water in Australia (Pamminger et al., 2017) and by Yorkshire and Anglian Water in the UK (Anglian Water, 2020; Yorkshire Water, 2018), to evaluate the economic values of non-financial parameters in order to assess the values of the products and services which the organisations deliver to the community. In general, the six forms of capital can be summed up in the table below (Anglian Water, 2020; Mukheibir et al., 2020).

Table 6. 1: Six Capitals

Form of Capital	Description	Metric
Financial capital	The financial health and resilience of the organisation and the access to and use of sustainable and ethical finance.	- Taxes and license payments - Salaries and National Insurance contributions - Pension contributions - Profits ('operating surplus')
Natural capital	The health of the natural systems and resources that are relied on and impacted locally and beyond.	- Water consumption - Water saving support - Leakage - Bathing water quality - River quality - Water pollution - Biodiversity - Greenhouse gas emissions - CO_2 absorbed in our land - Pollutants absorbed on land - Atmospheric pollution - Recreation and amenity - Waste
Human capital	A measure of, or the improvement in, the employees' knowledge, competencies, capabilities and experience, and their motivations to innovate. Also included is their wellbeing, health, workplace safety and organisational culture	- Employee engagement - Engagement in performance reviews - Apprenticeships - Employee volunteering - Health benefits - Succession programmes - Injuries - Commuting - Protracted paid overtime - (Un)equal opportunity - Wage inflation - Sickness absence

Social, economic and relationship capital	A measure of the economic value of the external social benefits and costs due to the service and product delivery business model. It is here that broader societal benefits could be included, such as safety, greening, cooling etc.	- Supporting customers - Customer satisfaction - Education - Charity and volunteering - Late payments to suppliers
Manufactured capital	The physical assets created and used by the utility to deliver resilient services, such as dams, treatment plants, buildings etc. These are usually reflected on the company balance sheet.	- Fixed asset value - Energy generated
Intellectual Capital	Organisational knowledge, such as intellectual property and tacit knowledge, systems and procedures that have been developed and shared within the business and with alliance partners.	Fixed asset value Energy generated

The author believes that this way of thinking is an extension of TBL wherein the social, economic and environmental dimensions are characterised by more detailed indicators and more sophisticated tools to quantify the dollar value of indicators. For example, in the case of Yarra Valley Water (YVW), Trucost and GIST advisory were incorporated in the Integrated Profit and Loss to report on the economic value of indicators.

However, while the YVW economic analysis is novel, in the author's opinion, future uncertainty did not make its way into the report since it was more like an evaluation process of impacts that the company (YVW) had induced on natural, social, human, and financial capital up the point of the analysis. Also, the four capitals adopted by Yarra Valley Water are still expressed in monetary terms (Pamminger et al., 2017). Qualitative assessments of the non-monetised impacts and benefits have still not found their way into these high-level economic assessments. From the author's point of view, the six capitals concept is relatively new and still needs to be developed further to the point that it allows future uncertainties to be incorporated into the calculations.

6.4 Summary

This chapter set out to answer Research Question 3 (*What are the underlining causes of the tensions/challenges?*). At a high level, it was found that one of the overarching issues is that (mis)treating complex issues with simple solutions might jeopardise and potentially push the system into a chaotic situation or generate more complex issues. It was also found that the lack of methods or approaches to methods that operate in the complex domain might be one of the root causes for the identified issues. Furthermore, results from the analysis of both first and second-round interviews offered insightful elaboration of the challenges related to the complexity that the urban water sector is struggling with in general.

More specifically, in this chapter, I have explained the motivation to shift the research focus to exploring the question of dealing with complexity in the practice of urban water planning, by reflecting on data from the first round of interviews.

Furthermore, I have presented and briefly explained the choice of a conceptual sense-making tool (the Cynefin framework) to answer the research questions that emerged with complexity. More detail on the background of CF and how this framework was used to guide the second round of data collection using semi-structured interviews can be found in chapter 4.

Before applying the CF in data collection and analysis, the chapter illustrated the value of applying CF to assess and explore complexity and uncertainty existing within the Australian urban water sector. This was unique in the sense that the employment of CF in the context of the urban water sector in the metropolitan areas of the South Eastern Australian seaboard has not been attempted before.

Section 6.2 categorises and analyses the current approach to urban water planning and management in the study area and the associated problems identified from the first round of interviews and document analyses as simple, complicated, complex or chaotic using the CF. It also categorises the methods for addressing these problems in these 4 domains. It was found that there is often a mismatch in that the methods often are not appropriate for the level of complexity that they are used to address.

The overall findings from the analysis in section 6.2 indicate that fragmented parts of the water sector show signs of operating in the complex domain. More suitable tools are needed to address the emerging challenges in areas where contemporary complexity and uncertainty reside.

Secondly, section 6.3 focused on urban water planning and management practices in Sydney, and the author was able to use the concepts of the domains in CF to guide the interview processes to unpack and synthesise the critical topics of the challenges which arise due to the complexity. Moreover, the outcomes open up a path to identifying and evaluating the potential tools and methods in terms of their ability to operate in the complex domain in the next chapter.

The synthesis regarding the critical topic of the challenges which arise due to complexity is complementary and, to some extent, confirms the literature in identifying barriers to transformative and sustainable urban water management. The key findings are related to six main topics of challenges.

The first topic concerns the *technical complexity* related to large-scale and long-term planning, where the parties' analytical power and technical knowledge are emphasised.

The second topic is the *complexity of governance structures and institutional arrangements*. Fragmented institutional arrangements and the unclear responsibilities arising from the vertical viewpoint (from one level of government to another) and the horizontal viewpoint (within the same level of authority) lead to a lack of mechanisms for cooperation and collaboration among stakeholders. Moreover, differences in priorities and how organisations value sustainable options lead to conflicts of interest among them. The lack of policy and political support for incentivising 'more sustainable' options and creating a more flexible environment for IUWM practices to emerge are highlighted.

The third key theme is the *complexity introduced by climate change/variability*. The discussions focus on the unpredictability of water cycle behaviours in the context of climate change, the reliability of climate simulation and climate projection models regarding the data, the methods used to reconstruct rainfalls and stream-flows, and the notion of 'unknown unknowns' that are yet to be discovered.

The fourth topic discussed the *rigid mindsets of stakeholders* and pointed out how this might foster the risk-averse attitudes of organisations which contribute to the impediments to mainstream IWCM practice.

The fifth topic is the *lack of methods to improve communication* between various actors and the effect on the system. In this section, the author clarified how this problem could lead to the oversimplifying situations. As a result, the benefits of integrated solutions might be overlooked.

Finally, the sixth topic documented how interviewees called for developing *economic evaluation methods* that can quantify non-market benefits to provide more comprehensive insights into alternatives for evaluation in the decision-making process.

A further underlying planning issue that emerged from the interviews was the challenge around the useful and practical analysis and engagement tools when planning under complexity. The author considers the possibility that there might be a mismatch between the available tools and the complexity embedded within contemporary urban water issues. In the next chapter, Research Question 4 (*Are the current available tools appropriate for dealing with complex problems?*) will be addressed in-depth and will aim to draw together potential strategies to overcome the challenges in responding to complex problems identified in this chapter.

7 Chapter 7 – Potential tools for complexity

7.1 Introduction

As mentioned in Chapter 6 (section 6.3), the supposition arising from the first round of interviews was a mismatch between the tools and methods used for urban water planning and the complex issues being addressed. Some urban water systems had even fallen into chaotic states because of the selection of inappropriate methods and associated tools. The latest drought in New South Wales — which went beyond the planning envelope in some locations — showed how the mechanistic approach that characterises the predict-and-control model is unsuitable for responding to complex systems' inherent uncertainty. Therefore, the second-round interviews intended to explore the supposition further using the Cynefin framework.

Cynefin framework in this study was used as a heuristic device for making sense of how the tools and methods could fit within each domain considering the interpretation of domains' characteristics. The outcomes shown in figure 7.1 indicated that there were methods and tools interviewees believed could be helpful to operate in the complex domain. However, it is also argued in this chapter that some of those methods and tools work in only 'ordered' contexts (simple and complicated domains), and only a few show potential in the complex domain. Further discussions can be found in section 7.8.1.

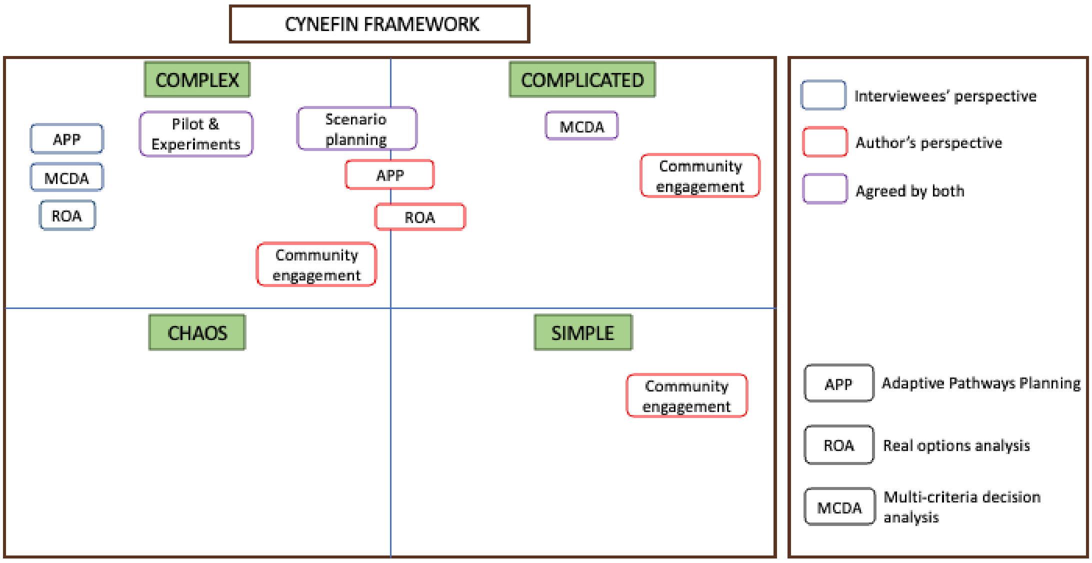


Figure 7. 1: Tools assigned in different domains of the Cynefin framework

From the perspective of combining integrated urban water management (IUWM), adaptive management (AM), and the participatory approach, the tools that can potentially deal with complex issues should embody several characteristics. Consistent with the IUWM approach, they should consider multiple objectives in planning. Likewise, they should be able to account for multiple uncertainties and different portfolios of options following an adaptive planning approach. Also, if centred on participatory processes, the tools need mechanisms that promote respectful and meaningful engagement with stakeholders and the wider public. Moreover, they should be transparent enough for stakeholders, the public and decision-makers. With that said, even though the tools might be engineering-intensive or technically complex, there should be a mechanism to communicate aspects of the complexity to the involved parties, especially the decision-makers, to enable better-informed decisions. Based on the analysis of interviewees' inputs on the tools and methods in practice and the literature review, the author proposed a positioning diagram of how those tools could fit within the context of the combined frameworks (figure 7.2). The rationale for the results is discussed in depth in section 7.8.3.

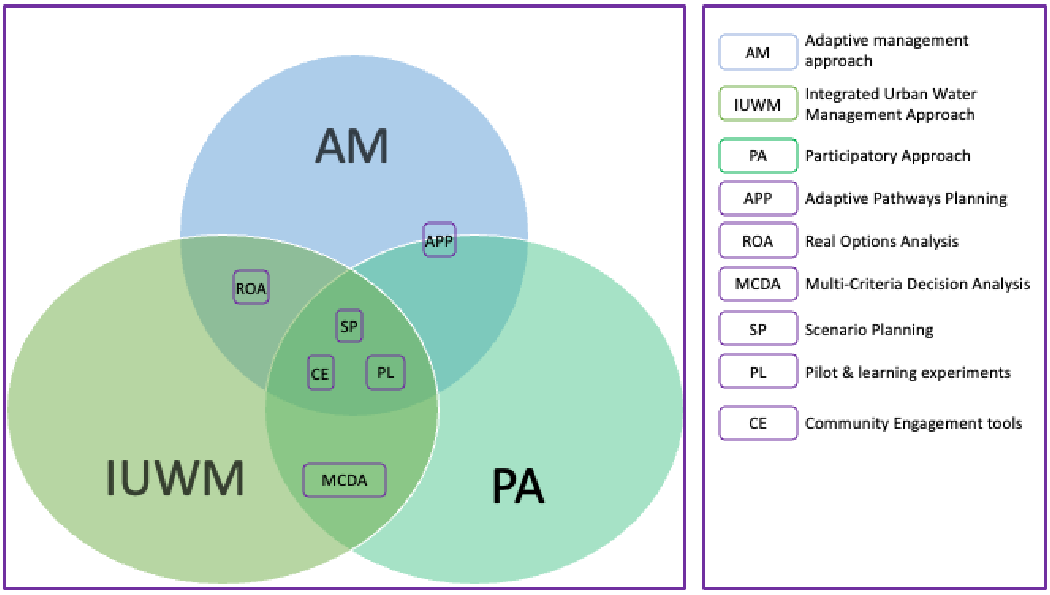


Figure 7. 2: How the tools fit within the combined framework in practice

This chapter sets out to answer Research Question 4: *Are the current available tools appropriate for dealing with complex problems?* To that end, the potential tools/methods emerged in the interviews are critically analysed through different perspectives, including a Cynefin Framework perspective, a combined framework perspectives and an assessment of how well the tools/methods might perform against issues identified in the previous chapters. The author used results from literature review and data analysis to make the points across. The sources of the arguments/discussions in this chapter, either from literature or interviews, were stated explicitly with supporting evidence and references.

7.1.1 Introducing the tools

The tools discussed and analysed in this chapter are those that multiple interviewees believed should be used in response to issues that reside in the complex domain of the Cynefin framework. Uncertainty is inherent to complexity. Hence, as expected, the methods and tools interviewees selected arose from and embodied the adaptive management approach principles. At the outset, interviewees strongly recommended adaptive pathways planning (APP) as an efficient method for dealing with future uncertainty and improving system resilience. Also, currently used analytical tools for decision-making associated with the IUWM approach — such as real options analysis (ROA) and multi-criteria decision analysis (MCDA) — were highly regarded as potential ways to support planning for complexity and uncertainty in the future.

Additionally, interviewees mentioned methods that could be described as thought experiments or thinking tools, such as resilience frameworks, vulnerability assessment, and scenario planning. In a more general sense, the 'pilot and learning experiment' method was viewed as a good fit with the complex domain. This list is by no means exhaustive, but it illustrates the tools that are considered potentially useful when dealing with complexity.

7.1.2 Structure of the chapter

Focusing on the potential tools, section 7.2 discusses APP and ROA together, while MCDA is scrutinised separately in section 7.3, followed by 'scenario planning' in section 7.4. Then the 'pilot and learning experiment' method is briefly unpacked (section 7.5) before section 7.6 explores the role of tools for community engagement. Subsequently, in section 7.7, a prominent example that illustrates how the tools could be used together within a combined approach is reviewed. Finally, section 7.8 summarises the findings and some concluding remarks.

The analysis within each subsection substantially draws on the insights that interviewees shared in the second round, combining these with a reflection on the literature and how those tools might address identified complexity issues (as raised in section 6.3). The same caveats outlined in section 4.4.3 around the study design and applications of the Cynefin framework cover these findings. Moreover, the tools are specifically scrutinised from the framework's perspective and the lens of the combined approach (i.e. participatory, IUWM and AM).

7.2 Adaptive pathways planning and real options analysis

As indicated above, the APP methodology and ROA will be discussed side by side in this segment to explore whether, in combination, the two methods might be useful to tackle issues in the complex domain. The rationale (acknowledged in the literature) is that they have complementary features in addressing uncertainty. Also, the interviewees referred to them in combination, and the methods appear to be embraced by major water utilities. For example, APP is the prominent planning tool for future uncertainties in Melbourne sewerage strategy and Melbourne Healthy Waterways Strategy (Melbourne Water, 2018b, 2018a; Melbourne Water & Victoria State Government, 2018); it increases 'preparedness' (C1; C2; G1). Moreover, ROA has been advocated by water planners as an economic tool for analysis of uncertainty and was used in the Greater Parramatta and Olympic Peninsula adaptive water plan and 2021 Lower Hunter Water Security Plan.

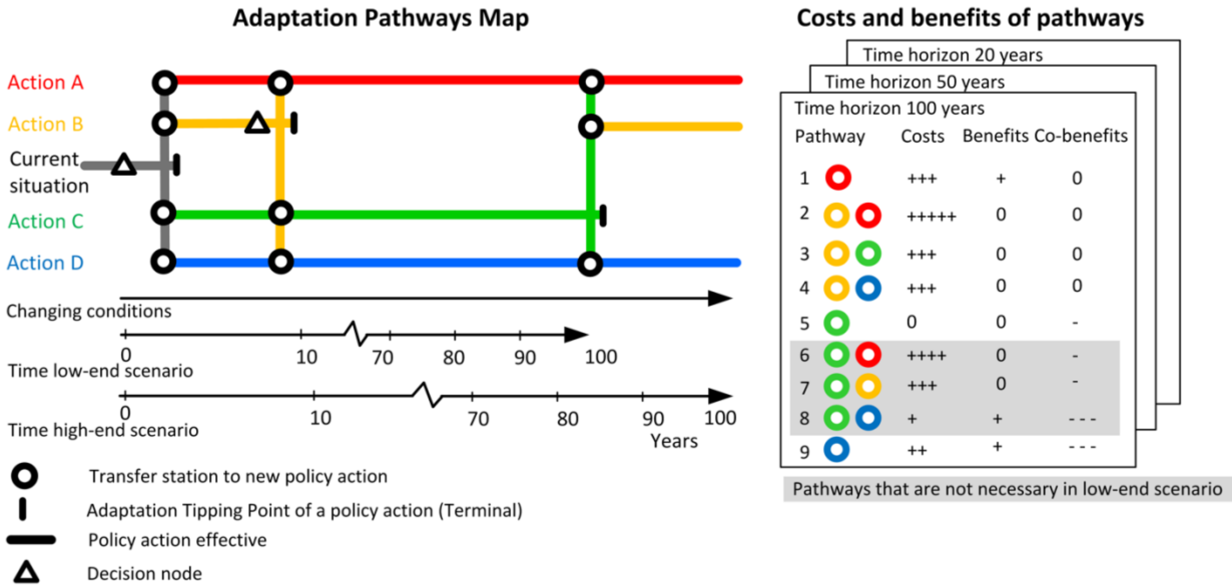


Figure 7. 3: Dynamic Adaptive Policy Pathway - an example of APP

While they have similar core principles, some differences set them apart. On the one hand, APP is a holistic planning approach that embodies a range of processes, including problem definition, scenario investigation and development, options and pathways assessment, monitoring and evaluation of triggers (indicative threshold values), and adjustment of interventions. On the other hand, ROA is an economic evaluation tool for flexible strategies that consist of a portfolio of options. It is noteworthy that neither method makes it easy to communicate with people not involved in the process. However, with its extensive collaboration process that engages with different stakeholders and an intuitive visual presentation, APP has more potential for information dissemination than the 'black-box', technical/computational-driven ROA processes.

These ideas will be unpacked in this section as follows:

1. The concepts and applications of the tools from the literature

2. Analysis and discussion based on interviewees' interpretations of the tools

3. A qualitative assessment of the capacity of the tools to deal with the complex issues identified in section 6.4

7.2.1 An overview of Adaptive Pathways Planning and Real Options Analysis

As reviewed in detail in chapter 2 (section 2.4) and chapter 3 (section 3.2), the Adaptive pathways planning (APP) approach has recently become the most popular planning tool to deal with future uncertainties among water planners. The tool provides a framework with elaborated principles and steps to guide sequences of decisions over time (pathways) based on potential changes in the system through monitoring triggers (adaptation tipping points) while maintaining the flexibility to switch pathways. APP has been praised for increasing the robustness of the short-term measures and flexibility as future alternative options can be employed or delayed or pathways switched (Brotchie & Williams, 2017; Haasnoot et al., 2013).

Due to advances in the financial options field of research, ROA offers a way to appraise the economic value of flexible strategies under uncertainty (Kwakkel, 2020). In other words, ROA can evaluate future options while considering any information that emerges as conditions change (P Watkiss et al., 2013). ROA gives the planning process optionality by evaluating various options of investing or not investing. It can invest now or later, or not invest at all. It can invest a little now and secure the chance to invest more in the future as conditions unfold. It can switch the investment between alternatives or delay investing. This optionality is comparable to 'managerial flexibility' (Slade, 2001). Kwakkel (2020) compiled a list of different interpretations of ROA from multiple perspectives (see Table 7.1).

Table 7. 1: Some interpretations of ROA (Kwakkel, 2020)

Authors	Definitions of ROA
(Woodward et al., 2011))	The economic evaluation of flexibility, for which the value of flexibility is the difference between the expected performance with the flexibility and the performance when the options are implemented deterministically
(Jeuland & Whittington, 2014))	The option to defer a capital investment
(Paul Watkiss et al., 2015))	Economic analysis method for assigning value to waiting for future information
(Dittrich et al., 2016))	Real options as flexibility, conditional on how uncertainty resolves over time

ROA has been picked up in natural resources management and climate change adaptation under the framework of the adaptive management approach. It is because ROA can evaluate flexible strategies under conditions of uncertainty, a task that existing economic evaluation tools, such as cost-benefit analysis (CBA), cannot accommodate (Dittrich et al., 2016; Yzer et al., 2014). To answer the question of 'Why flexibility?', the APP and ROA approaches share similar ideas, which indicates that the path-dependency characterised by significant capital investments on potential 'lock-in' options, such as building a dam, impedes the ability of the system to adapt to future changes (Marjolijn Haasnoot et al., 2020). Thus, flexibility is decreased by the commitment to long-term investments for long-lived infrastructure with specific trajectories, leading to limited adaptation choices for future unexpected changes. More specifically, urban water infrastructure with a long life and is susceptible to changes in environmental, climatic, and socio-economic conditions over time (e.g. a dam or a large water treatment plant) might not perform as intended or be left unused (as stranded assets). In such cases, adjusting these options, maintaining the unused assets in working condition, or switching to others is expensive. Further, conventional cost-benefit and cost-effectiveness analysis methods rely on the likely outcomes for individual decisions and not on multiple scenarios (Haasnoot et al., 2020; Hallegatte, 2009; White et al., 2006). Therefore, the underlying theory behind APP and ROA is to achieve flexibility and robustness in planning and management under conditions of uncertainty.

In the urban water context, ROA has gained support from Government agencies and water utilities; however, it has not been used widely in urban water planning in Australia. The tool was first introduced in 2006 in the review of the Metropolitan Water Plan to assess investment options within the adaptive management framework (White et al., 2006). Since then, Australian Government agencies such as the Productivity Commission (Productivity Commission, 2008; Productivity Commission, 2011) and other academic and industry researchers such as Mukheibir and Mitchell (2011) have endorsed it as a method for dealing with investment uncertainty. The most notable reference for ROA in urban water planning in Australia was captured in Borison and Ham (2008). ROA in supporting the decision-making process was dissected and then demonstrated through a hypothetical case study (Borison & Hamm, 2008).

Recently, a real options analysis approach has been applied to evaluate the value of 'keeping options open' by adopting incremental measures carried out by Hunter Water for the Lower Hunter region (Rust et al., 2020). This study was submitted to the pricing regulator, the Independent Pricing and Regulatory Tribunal (IPART) of New South Wales, in 2019. Basically, urban water supply and wastewater systems can be more resilient by using incremental measures such as stormwater harvesting, industrial wastewater recycling, demand management, water tanks, leakage reduction and better building practices to maintain 'substitutability in investment choices'. The study calculated the avoided costs induced by keeping options open based on scenarios of past events called shifts/shocks (accepted by IPART) and hypothetical source scenarios, including a dam and a desalination plant. The results suggested that using an incremental approach can reduce the region's total water supply cost.

Later on, in the 2020 adaptive water cycle plan for Greater Parramatta and Olympic Peninsula, ROA was also used to 'consider uncertainties around the acceptance of purified recycled water for drinking and also to sensitivity test assumptions about the capacities of existing trunk water and wastewater assets' (Sydney Water, 2020a).

7.2.2 What interviewees say about APP and ROA

Regarding interviewees' perceptions of APP and ROA, the APP approach was recommended by most interviewees (C1, C2, and W2) in the second round of data collection when it came to dealing with uncertainty in the urban water sector. Interviewee W2 described ROA as a tool that 'allows you to take things from complex and move them into a complicated realm so that you can actually make informed decisions'. W2 saw ROA as an economic evaluation tool — 'a variation of that [cost–benefits analysis]' — 'in the context of water supply and drought planning'.

ROA was described further by interviewee C1:

> We used an options assessment on Metropolitan Water Plan for bulk water supply for Sydney, for growth and drought. And that includes a multi-criteria analysis and it included real options for future desalination plants, dam enlargements, recycled water options … that kind of thing, they are all real options.

In practice, the APP approach, especially Dynamic Adaptive Policy Pathway (a variation of APP), has been adopted only recently by urban water utilities in Melbourne and Sydney. Despite the lack of empirical evidence, several interviewees stated that APP was useful for long-term planning because it could also account for short-term interventions and changes. ROA is also an approach that has been taken up by water utilities very recently, even though it has been advocated for by organisations for a long time.

APP and ROA appeared together for the first time in the Greater Parramatta and Olympic Peninsula (GPOP) planning document (Sydney Water, 2020a). The ROA and APP approaches were complementary in this document (the planning for GPOP). ROA was used to appraise the economic value of different sequencing of options (pathways) by considering multiple scenarios with various triggering points under uncertainties related to the implementation of purified water for drinking and the timing and extent of capacity constraints on assets (Sydney Water, 2020a). How the approaches were combined resonates with the work of (Gersonius et al., 2015) and (Buurman & Babovic, 2016), who argued that despite their significantly different objectives and starting points, they should be applied simultaneously. Also, ROA was used to help the DAPP process discover the 'occurrence probability threshold, a particular climate/flood scenario would have to attain, that would justify choosing one pathway or another' when managing flooding in the Hutt River region in New Zealand (J. Lawrence et al., 2019).

Interviewees in this round believed that the things that made APP and ROA appealing to the urban water context were twofold:

1. the need for a practical approach to tackle the high levels of uncertainty that water planners and strategists can experience first-hand, such as during the recent severe drought in NSW
2. the conventional planning approach in today's planning frameworks is no longer fit for purpose. Researchers in the field, (Farrelly & Brown, 2011; J. Lawrence & Haasnoot, 2017)), support this notion.

The interviewees realised that there is a need to change the current approaches to planning and management and adopt a practical methodology like APP and ROA to deal with future uncertainty.

> 'Making dynamic adaptive policy pathways is really important because if you find yourself in a different situation outside of the planning envelope for that assumption, then you can adjust early in terms of rerunning the model. Because you've got adaptive processes that review your assumptions on say, a year-to-year basis, then you quickly adapt the models that you've used to account for the changes they are seeing, that are different to what you've assumed in the first instance.' (C2)

> 'I think it should be in the complex realm because the other point is that you do not know the different relationships and connections, and multiple pathways that you could take up, but you have to adapt as you go, depending on how things change in the system.' (C1)

Several APP and ROA principles attracted particular attention from the interviewees. Some of them pointed out the general idea of how these approaches work, such as:

> 'Constantly learning by doing.' (G1)

> 'When we found ourselves outside the planning envelope, rerunning the models and redoing the portfolio of options and then gradually updating the data for each of the options in terms of getting more certainty around the costs and construction lead times.' (C2)

> ‘So you identify different planning pathways, but then the idea is you can adapt them as you go … you adapt your planning as you go to whatever environment you find yourself in over time.’ (C1)

Moreover, the key idea of ROA is about avoiding path-dependency and lock-in’ as a result of ‘leaving options open and ready’, together with the crucial principles of ‘not committing to big infrastructure projects if you didn't have to’ (G1) and ‘you leave your options open as long as you can, rather than choosing a pathway and then being stuck with it’ (C1). Finally, the flexibility of switching between options and pathways of APP that comes from a rigorous analysis of determining factors such as tipping points, the triggers and lead times of options, were highlighted: ‘building in adaptation in drought management by putting in triggers for when additional studies or things were happening or where capacity would be ramped up’ (G1). Also, the flexibility of ROA in dealing with unforeseen futures: ‘gradually updating the data for each of the options in terms of getting more certainty around the costs and construction lead time’ (C2).

While there was limited intensive discussion in the interviews on the details of the APP approach or how to implement it in the context of Sydney, the interviewees expressed frustration with the current urban water planning and management regime, describing it as under-prepared for uncertainty:

> ‘preparedness … I think what we have found out is once you are thrown into the chaotic realm, if you haven’t prepared at all it is very hard to manage effectively.’ (W2)

> ‘Nobody thought that Shoalhaven would have no flow … It does not make sense. Just six years later, it stops flowing.’ (C2)

7.2.3 Limitations of APP and ROA

As pointed out above, while the literature shows that APP has various promising features for dealing with uncertainty, there is little experience in the actual implementation of the approach (Abel et al., 2016; Bloemen et al., 2017; Jeuken et al., 2015) and three main drawbacks have been diagnosed.

The first drawback is its *inability to easily accommodate multiple objectives,* a significant weakness for integrated urban water management. A review of the literature on APP reveals that, in most cases, the ultimate objective is to adaptively plan for long-term flood risks while considering a range of plausible future scenarios (M. Haasnoot et al., 2015; J. Lawrence & Haasnoot, 2017; Reeder & Ranger, 2010), or, in rarer cases, to plan for water supply and demand in the urban context (Kingsborough et al., 2016b).

The second drawback, which might be one of the contributing factors to the first one, is that APP *relies on highly detailed data for its extensive analytical power* (Lin et al., 2017; Veelen & Jeuken, 2015). To determine tipping points for different strategies and lead times for portfolios of options within a range of plausible futures, the technical capacity required is high (Barnett et al., 2014). Much of the research into adopting APP so far has focused on modelling efforts and applying probabilistic approaches to develop assumptions and projections about the future that rely on data and inputs from biophysical, hydrological and economic models (Bloemen et al., 2017; Cradock-Henry et al., 2020; Jeuken et al., 2015).

This leads to the third drawback, which is *the lack of public engagement during the planning process*, a lack that constrains knowledge and value sharing from diverse perspectives (Barnett et al., 2014; Bosomworth & Gaillard, 2019; Cradock-Henry et al., 2020; Lin et al., 2017). In projects ranging from the large to the small (e.g. well-funded ones like the Dutch Delta Programme or the Thames Estuary protection to smaller ones like water supply and demand planning for London), the common practice is for there to be 'little input from affected stakeholders or end users' even though the government organisations involved collaborate (Cradock-Henry et al., 2020).

From the author's point of view, the way probabilities are assigned to different scenarios based on assumptions about future conditions for a referred pathway might provide a false sense of security in case of 'deep uncertainty' where unanticipated events outside the planning envelope take place.

The literature also identifies drawbacks for ROA, despite its ability to estimate the economic value for options under multiple uncertainties, which could add great value to the decision-making process. Kwakkel (2020) suggests that the *assumptions that rely on the assignment of probabilities under different scenarios would not hold*, as uncertainties related to climate change unfold over lengthy periods, and these uncertainties will 'coevolve' with the decisions made over time. In addition, he contends that the idea of *expected value over a range of scenarios does not capture the expected value of an option in the real future*. Also, Kwakkel believes that ROA induces a *data-intensive and technically driven dimension* to the planning process. This dimension limits its accessibility and transparency for stakeholders, decision-makers, and especially the wider public, reducing their ability to understand the merits of different options. Furthermore, Mukheibir and Mitchell (2011a) indicate that it is the associated 'significant analytical complexity and ultimately cost which can lead to shortcuts in the application and communication of the method and results'.

7.2.4 How do APP and ROA address complex issues?

From a CF perspective

The research and application of the APP approach are still under development, and there are limitations along the way, as discussed above. Arguably, from a CF (Cynefin framework) perspective, the APP approach could currently be positioned in-between the complex and complicated domains. Specifically, APP does not just seek to analyse the apparent cause-and-effect relationship of events and variables within the system; it systemically considers and explores uncertainty.

The complex domain elements are summarised as follows (Snowden & Kurtz, 2003):

- Complex issues are unpredictable.
- Cause and effect can only be understood in retrospect, which means that the causal relationship can be revealed only after the events.
- The suitable practice is ‘emergent practice’, as opposed to ‘good practices’ in the complicated domain and ‘best practice’ in the simple domain.
- The strategy to cope with complexity is ‘probe – sense – respond’.

This chapter argues that, regarding APP as a strategy to address uncertainty, it conceptually fits with the recommended ‘probe – sense – respond’ sequence. The APP approach is a descendant of adaptive management in environmental management (Holling et al., 1978), in which the essence is to adapt to changing conditions as the future unfolds. APP resembles a passive adaptive management approach innovatively because it explores historically informed projections of plausible futures to determine preferred ‘pathways’, followed by the assessment of those over time (Pahl-Wostl et al., 2008). It embraces the fact that the currently available evidence of urban water issues is not determinative, so the best approach is to ‘probe’ to uncover emergent solutions by monitoring and evaluating options implemented in the preferred pathways. In other words, the process considers the portfolios of options according to the preferred pathways, and then it gains insights by monitoring various signposts and triggers. APP produces flexible strategies in which low or no-regret options are preferred over lock-in infrastructural solutions. This avoids maladaptation (Sadr et al., 2020) while still ‘leaving options open’ by preparing for those unexpected events as they emerge. So, in so far as it considers the how changes in various parameters are observed over time to evaluate the policy adjustments according to a flexible framework, APP resembles ‘retrospect coherence’ to a certain level and might have the capacity to formulate emergent response strategies.

However, due to the deterministic modelling practice that characterises the analytical prowess of numerous APP applications, APP embodies the attributes from the complicated domain. To operate in a complex context, decision-supporting tools are recognised as strategic ones that come from qualitative sense-making rather than well-laid-out technical analysis of variables (French, 2015). This is due to not knowing or understanding the interconnectedness of these variables for predicting a future condition with a level of certainty. Thus, if taking this point into account, the materialisation of assumptions about future uncertainties based on models and calculations sets APP apart from operating in the complex domain and indicates a more explicit connection with the 'sense – analyse – respond' strategy that signifies the complicated domain.

Moreover, the application of APP has dealt with individual objectives, one at a time, making it harder for it to take advantage of emerging patterns or gains that might not be associated with the primary objective. Also, it narrows its capacity to explore uncertainty creatively since the scope is bound by one objective and by how far the modelling practice can accommodate it.

This chapter argues that ROA, like APP, is located on the borderline of complicated and complex domains. However, the author believes that ROA should sit more in the complicated domain than in the complex one, as only a few features suggest that it could fall within the complex domain.

Overall, this decision-supporting tool focuses on how best to use the sequence of future investments/interventions that respond to changes over time. ROA uses different probabilistic modelling techniques, such as decision trees, Monte Carlo analysis, and lattices, to account for the implications of future uncertainty (Erfani et al., 2018). As a result, the practice can be seen as an attempt to probe future conditions with an unclear discernible causal relationship to provide insight into flexible decisions that are likely to reinforce the desired future patterns of the system. This emphasis on a flexible range of alternatives over time to shape 'emergent practice' makes ROA stand out from other linear predictive economic approaches such as CBA (cost–benefit analysis).

However, the intensive modelling and analytical requirement at the core of the ROA method also suggest a deterministic approach to decision-making and planning. The value of the options' flexibility in ROA is 'predicted' based on probabilities and the expected values assigned to scenarios. It attempts to pull complexity into the complicated domain by making many assumptions about the probabilities of outcomes in the future. Theoretically, in the complex domain, the definition of 'retrospective coherence' (more in section 6.2.2) has disparities with the stochastic predictive approach of ROA.

While ROA offers a foundation to evaluate the value of flexibility within future strategies, it might be more useful as an economic evaluation module within a holistic, adaptive approach for dealing with problems in the complex domain.

How useful is it to solve complexity issues?

As a long-term planning approach, APP has mainly focused on the impacts of future changes in climate conditions. These considerations can be found in adaptation projects in the Netherlands. Time series data offers information on temperature, precipitation and evaporation, and sea-level rise constructed for the 'pathways' based on climate change scenarios (Haasnoot et al., 2015). The APP considers various plausible scenarios instead of one best-case scenario; and prepares for future conditions, so it is said to be more robust and flexible than the predictive planning approach. On the other hand, recent extreme events in Australia and elsewhere suggested that climate change uncertainty contains unknown unknowns. Hence, the 'plausible scenarios' might not be plausible anymore when the events exceed expectations, such as the severe dryness from 2017 to 2020 that led to the 'black summer' in Australia. As a result, extensive efforts have been made to understand future climate conditions within an APP framework, climate change uncertainty should be acknowledged beyond the planning scope.

In addition, APP might provide a prospective platform and stimuli for shifting rigid mindsets on planning and management to more innovative ones. Lawrence and Haasnoot (2017) report the results of 'simulation games' and 'knowledge broking' in applying APP:

> Uptake of new knowledge occurred, shifting the decision-making focus from the short term to decisions that were robust and flexible over at least 100 years … A shift from linear knowledge building to a learning style based on doing adaptive planning using the DAPP and sharing the learning across agencies was achieved.

The game stimulated the process of social learning as described by Baird et al. (2014) and Van der Wal et al. (2016) and catalysed the uptake of DAPP.

While there is not a lot of research on how to change water professionals' mindsets, and while the APP approach was not designed with that in mind, its iterative nature and the consideration of multiple plausible scenarios can be a foundation for challenging 'comfort zones' in thinking exercises. This, in turn, fosters social learning and bridges the gap between theory and practice (Malekpour et al., 2016). Further, intuitive representation of the transient pathways in the form of 'route-maps' or 'metro-maps' might potentially be of use for introducing and explaining complexity and uncertainty to actors in organisations, as well as engaging them in the decision-making process (Marjolijn Haasnoot et al., 2013; J. Lawrence et al., 2019).

Although there is not, as yet, evidence of APP and ROA contributing to the evaluation of non-market benefits, these two methods have the potential to do so based on their characteristics. As noted in section 7.2.2, ROA, combined with APP, has advantages over traditional economic evaluation tools because its long-term vision offers more opportunities to consider longitudinal economic values instead of solely focusing on short-term financial ones. Also, by building on a platform consisting of multiple plausible scenarios to avoid path dependency, the methods open access to diverse possible outcomes that eventually characterise future economic values.

However, there are issues that APP and ROA are not likely to address or could even make worse. While APP might help improve technical understanding for stakeholders and the community, it might not be suitable for addressing the technical complexity of an integrated system. APP has the potential to simplify the complexity of the matter at hand by providing a comprehensible presentation for communication purposes. Hence, this method improves technical understanding for a wider audience and might even create chances for people to increase their hands-on experience with the methods and tools. However, from a modelling angle, it is not necessarily suited to addressing the technical complexity of the integrated approach. The number of variables and their associated relationships might introduce a computational burden. Also, it might pose a threat by forming endless cycles of modelling and re-modelling to achieve 'perfect' simulations, as Walter (2007) indicated in his work on the drawback of the adaptive management approach in natural resource management.

Further, keeping options open by avoiding lock-in or path-dependency interventions is one key feature of both the APP and ROA approaches. Hence, an incremental approach to decision-making is favoured. Some options, such as wastewater recycling for portable uses or stormwater harvesting and reuse, face numerous institutional arrangement challenges (Productivity Commission, 2020) (more detail can be found in section 3.3). Therefore, the expected outcomes of APP and ROA applications from the author's perspective could impose more issues with the current Governance Arrangement.

Moreover, the author argues that the advantage of ROA accounting for long-term economic evaluation using a probabilistic approach could also be its significant drawback. ROA can also potentially give a false sense of security by minimising the value of 'fat-tail' events by placing a low probability on them (fat-tail probability distribution implies a greater probability of extreme events). Thus, ROA might not be able to evaluate the actual cost of catastrophic outcomes. In the author's opinion, this shortcoming overweights its potential to evaluate non-market benefits. Table 7.2 gives an outline of the challenges APP and ROA could potentially address.

Table 7. 2: Challenges that APP and ROA can potentially address;

↑ : helpful | ↓ : unhelpful | — : no impact

CHALLENGES	ADAPTIVE PATHWAY PLANNING/REAL OPTIONS ANALYSIS
Technical complexity	↓
Governance and institutional arrangement	↓
Climate change uncertainty	—
Worldview	↑
Communication methods	↑
Economic evaluation for non-market benefits	↓
Scale of planning/implementation	—
Complexity of the concepts	—

From a combined approach perspective

As mentioned above, APP was predominantly used as a single-objective approach, and its implementation has already revealed extensive input data requirements and analytical power. Therefore, it is illogical to employ it in the context of IUWM, where multiple social, environmental, and economic objectives are embedded, as it would only lead to more complex modelling tasks. On the other hand, while there is hardly any example of ROA applications in urban water sector, ROA has been used as an economic evaluation tool to assess performance of options in integrated water management in coastal area (Ramm et al., 2017).

An application of a participatory approach is needed to carry out APP (Haasnoot et al., 2013), and also, there is evidence that APP can offer a simple representation of the pathways for communication purposes (J. Lawrence et al., 2019). It could be perceived as APP is compatible with participatory approach. However, the level of engagement is limited due to the complex calculations and simulations. The case is more chanllenging when it comes to Real options as an analytical approach. Estimating the expected value of options in the future under multiple scenarios based on assigned probabilities involves many assumptions and calculations that can be considered a Blackbox model. There is a minimal window for the community to engage in that process. Besides, there are hardly any examples of cases where the community is involved in developing a ROA.

There are prominent cases where APP and ROA have adopted together a single purpose, such as adaptive pathways for urban flood management in Singapore (Manocha & Babovic, 2018) or regional flood risks management in the Hutt river catchment, New Zealand (J. Lawrence et al., 2019). In the former one, there were no signs of community engagement, and in the latter one the community was consulted about their preferences for options.

7.3 Multi-criteria decision analysis

7.3.1 An overview of MCDA and interviewees' perspectives

The multi-criteria decision analysis (MCDA) provides a systematic way for decision-makers, stakeholders and the wider public to reach consensus about objectives, consider various options, and assess trade-offs between options or portfolios of options (Hyde, 2006; Mukheibir, Cole, et al., 2015). Also, it offers a platform for integrating qualitative information (e.g. an expert judgment or opinion or stakeholders' perspectives) and quantitative data (e.g. technical information or cost–benefit analyses) throughout the process to gain a better understanding of the system (Huang et al., 2011). At its simplest, the performances of alternative options are scored against various criteria derived from those analyses and then summed based on criteria weightings. There are many MCDA methods — see (Huang et al., 2011; Elizabeth Lai, 2011). However, an extensive review of the tool is not the focus of this section. The aim is to critically analyse it in the context of the research areas and based on the concepts of the Cynefin framework.

Interviewees' views on MCDA

The interviewees reported that MCDA as an analytical decision-making support tool had been used for various applications such as 'prioritising projects' (C1) or 'choosing between options to augment water supply' (W2). The interviewees were quite familiar with the tool. Four out of five interviewees cited MCDA as used in collaborative processes with either stakeholders or the community. Most considered MCDA to be a complicated tool associated with the IUWM approach. One of them suggested that it might:

> 'give you a way to try and make sense of a situation that is complex; it is like you are trying to simplify complexity.' (C1)

The reason for this comment is that MCDA can potentially be adopted in complementary ways with other tools when dealing with complex issues.

7.3.2 How MCDA deals with complex issues

From a CF perspective

Based on the characteristics of the CF domains (see section 6.2.2), this thesis leans towards considering MCDA as a useful method for the 'ordered' space spanning from simple to complicated domains. The reason for this is that, while MCDA offers a good platform for incorporating mixed data (qualitative and quantitative) into decision analysis, it is essentially linear and deterministic, at least in its simple (and commonly used) forms. The statement aligns with (Stewart et al., 2013)). The criteria for MCDA are usually selected by experts based on a well-developed understanding of the cause and effect of the problem. The alternatives are assessed and weighted against qualitative and quantitative indicators informed by stakeholders' engagement processes, which are also based on an established analysis of the data and other information.

In general, the way MCDA as a methodology aids decision-making fits with the strategy recommended for the complicated domain (sense – analyse – respond). The application usually starts with a problem-structuring process that requires sufficient data to identify aspects of issues at hand, to 'sense' the current situation. Then qualitative and quantitative data from expert opinions and stakeholders' perspectives of option performance against criteria are extensively analysed to inform final decisions. Further, while some MCDA techniques like outranking and Analytic Hierarchy Process attempt to move away from linear scoring and deterministic approaches, the majority of MCDA only accounts for the uncertainty of outcomes through sensitivity analysis (Moglia et al., 2012).

However, while MCDA is best suited to address complicated problems, this does not mean it cannot address complex ones. From the original perspective of this research, MCDA offers a method that might play a crucial role in combining integrated, adaptive, and participatory approaches.

Owing to its ability to assess the performance of alternatives, it was initially seen as useful in 'optioneering' practices for water-sensitive urban design within the IUWM framework. Nevertheless, MCDA is versatile in that it is compatible with other methods and capable of incorporating different data-analysis approaches and techniques to reveal insights into the performance of options. Hence, it potentially has value to help tools associated with the adaptive management approach to enhance future resilience of the water system. The author's view aligns with those cited in (Mukheibir & Mitchell, 2011)— which suggest MCDA could and should combine with CBA and scenario planning in an approach that 'goes beyond financial and economic interpretations of the impacts of decisions' in the attempt to address complexity of the system and unforeseen future events.

Also, (Stewart et al., 2013) point out that some MCDA tools can support the evaluation of potential strategies in scenario planning. As a result, the methodology can be useful as an additional analytical approach for the adaptive pathway approach, which can be considered an improved scenario-planning technique (more detail unpacked in section 7.4). Moreover, MCDA might be functional in combination with ROA for understanding optionality in cases where iterative assessment needs to be carried out once new data emerge. Thus, it might support the APP approach.

From a combined approach perspective

Literature suggests that MCDA can help reinforce the collaboration between stakeholders and the public, in turn, fostering knowledge sharing among actors. MCDA offers a range of flexible methods to elicit and include qualitative data from expert opinions and various actors' perspectives in the decision-making process. These methods, or to be more exact, this family of methods, builds on coordination and collaboration, which signify the inclusive approach to urban water planning and management. And for that, it paves the way for the more creative design of both collaboration and analytical processes. The process of applying MCDA strives for the goal of reaching consensus among stakeholders; thus, the method might be able to mediate disputes that arise due to the different objectives of participating organisations. Moreover, the inclusive process holds a potential platform for sharing knowledge, opinions, and values among partners and with the community, which might allow for shared learning and understanding — thus, offering a possibility for changing the rigid mindset of professionals whose primary focus is on technical compatibility.

Therefore, the author believes that MCDA is not only compatible with public engagement practices, but also can support an IUWM approach by fostering collaboration and coordination between involved parties. In practice, there is no examples showing how MCDA could play a role within an adaptive management framework.

Table 7. 3: Challenges that MCDA can potentially address;
↑ : helpful | ↓ : unhelpful | — : no impact

CHALLENGES	MULTI-CRITERIA DECISION ANALYSIS
Technical complexity	—
Governance and institutional arrangement	↑
Climate change uncertainty	—
Worldview	↑
Communication methods	↑
Economic evaluation for non-market benefits	—
Scale of planning/implementation	—
Complexity of the concepts	—

7.4 Scenario planning

7.4.1 An overview of scenario planning and interviewees' perspectives

The traditional predict and control approach to planning, in which a single 'most likely' scenario for a particular objective with fixed growth rate and static climate/hydrological condition, has been proven to be unfit in dealing with uncertain future conditions (Mukheibir, Howe, et al., 2015; Skinner & Satur, 2020). The statement was also reiterated by multiple interviewees (G1, C1, W1, W2).

Scenario planning offers a framework for exploring the complexity and uncertainty of water systems to develop more resilient responses by analysing and comparing multiple futures. A scenario comprises a set of assumptions about a possible future state and scenario planning aims to clarify the consequences of decision points toward that future and alternative possible futures. Various quantitative and qualitative data types can be comprehended within scenario planning throughout the decision-making process. Ideally, a diverse group of participants engage in a systemic way to develop the scenarios. Decisions can be made to achieve multiple desired outcomes, under a range of future trends and shocks, whether they are predictable or not, to ensure the water system is resilient to changes in the initial assumptions. As a result, scenario planning should involve long-term and complex thinking, multiple objectives accompanied by multiple variables, adaptability (combining flexibility and robustness), and rigorous stakeholder and public participation.

Interviewee G1 referred to scenario planning as a useful tool in both the complex and complicated domains. It was observed to help foster better collaboration between stakeholders and community engagement processes. Respondent G1 asserted that:

> 'We used it with the community to get them to think about the city in 50 years and what it would look like and what that would mean for the water supply and the water system.'

Scenario planning provides a framework for catalysing conversations around future resilience and creating creative alternatives for those plausible scenarios by improving shared knowledge on key uncertainties and shared understanding with others' perspectives and values. Besides, the method is versatile. By robustly picturing multiple scenarios of how the future will play out, a range of quantitative and qualitative information can be incorporated into the decision-making process.

7.4.2 How do Scenarios Planning address complex issues

From a CF perspective

This thesis considers the scenario planning (SP) tool with embedded resilient thinking positions on the boundary of the complicated and complex domains. However, in comparison to APP and ROA, SP could be placed further into the complex domain. The argument is that the tool can be used as a thought experiment which can be more open to possibility and more experimental than APP and ROA. For example, back casting SP where the future conditions are determined at the beginning, then planning back to the present, along the way there will be more potential for future uncertainty in the assumptions to be exposed. In theory, the way SP and its outputs are used can determine whether it is useful in either of the two domains. For SP to operate in the complex domain, there is a need for advancements or supplementary modules to be added to the traditional SP. Deciding which of the two domains the tool suits would depend on the way its outcomes contribute to the overall objectives of the plan or projects.

In the complicated context, SP can be used to provide deterministic evidence as a basis for choosing between well-established or researched interventions. This is the case where scenario plans are outputs for decision-making. Decision-making in this domain relies on rigorous quantitative analytical approaches and modelling techniques to get close to certainty for patterns and well-rehearsed actions (Stewart et al., 2013). The basis for those strategies is developed from the 'knowable' cause and effects that use the analytical approaches carried out by experts.

In the complex decision-making context, due to the overwhelming number of moving objects, there is rarely sufficient information on causes and effects for deterministic models to calculate and predict system behaviours. Thus, actions and their consequences cannot be evaluated and projected in the same way as in the complicated domain. Instead, decision analysis should be based on more strategic qualitative approaches that emphasise broader experimental and exploratory perspectives that use subjective judgment and tacit knowledge of actors in the system. And this is where scenario planning is an input to assist the decision-making process (foresighting methods). To plan for resilience, the tool could offer a platform for engaging various stakeholders in quantitatively exploring various possible scenarios. As a result, the creative inputs from multiple individuals, together with the collective knowledge sharing, might allow for broader and more flexible strategies that accommodate changes and different uncertainties as the system evolves. Nevertheless, it is also a risk that participants might be over enthusiastic with deterministic analytical practices to justify their assumptions about future conditions and interventions. Applying the tool in that fashion will narrow the flexibility and exploratory nature to accommodate uncertainty, which is essential to operating in a complex context. The use of scenario planning is currently popular in urban water planning in Australia; it forms the methodological basis for exploring uncertainties whether they relate to climate change (such as drought and flood), population growth, or urbanisation (Furlong et al., 2017; Mukheibir & Mitchell, 2011). However, at the same time, SP is usually used in a predict-and-control manner, where the system is tested against a 2*2 scenario matrix and assessed for its resilience under those four scenarios only. Only in a few rare cases has SP evolved to address deep uncertainty.

From a combined approach perspective

SP will be discussed through a lens of a combined approach to analyse how good it can be used to address issues from chapter 6. The results are compiled in table 7.4.

SP is a valuable tool for the combined approach (IUWM, PP and AM). As the tool is relevant to the informal qualitative approach, sense-making technique, soft system or problem-structuring methods (Stewart et al., 2013), engagement with stakeholders and the community can be embedded into the processes. As a result, deliberative processes in both scenarios and strategy development might stimulate innovative future thinking and social learning among stakeholders and the public. Engagement programs are like those seen in cases such as the development of the Lower Hunter Water Plan (Metropolitan Water Directorate, 2014), and the draft Lower Hunter Water Security Plan (NSW DPIE, 2021b) or the Sydney Metropolitan Water Plan (Metropolitan Water, 2017) (which will be discussed in section 7.7). The flexible framework that scenario planning offers for actors' collaboration and community engagement might help shift people's worldviews to accommodate uncertainty through a shared perspective. By shifting the focus from details and technical analysis to structured exploration of judgment and tacit knowledge on aspects of possible futures, various types of uncertainty can be communicated more effectively to the people involved.

Scenario planning for resilience can be understood as a way to carry out experiments with collective mental models to explore possible responses to unforeseen circumstances such as climate change uncertainty. This is also a vital pillar within the adaptive management approach. Arguably, the APP methodology might be an extension of the traditional SP tools, judging by how the strategies are formulated. APP assists decision-making by testing portfolios of interventions against multiple plausible future scenarios while considering uncertainties such as climate change and population growth. The result is a possible sequence or 'pathway' that is flexible regarding upcoming changes and robust enough to deal with possible problems in the future. Pathways and actions are generated and tested based on scenarios using suites of analytical tools, including modelling and CBA (J. Lawrence & Haasnoot, 2017). In a similar fashion, SP is also the primary tool in any IUWM project, as assessing options' performance in multiple scenarios lies at the core of IUWM practices.

Table 7. 4: How scenario planning addresses the identified issues;

↑ : helpful | ↓ : unhelpful | — : no impact

CHALLENGES	SCENARIO PLANNING
Technical complexity	—
Governance and institutional arrangement	—
Climate change uncertainty	↑
Worldview	↑
Communication methods	↑
Economic evaluation for non-market benefits	—
Scale of planning/implementation	—
Complexity of the concepts	↑

7.5 Pilots and learning experiments

7.5.1 An overview of pilots and learning experiment

Adapting to climate uncertainties, or any kind of uncertainties for that matter, requires trialling unconventional alternatives regarding governance or technologies and establishing a process to learn from those experiments, whether they are successes or failures. The employment of experimental approaches in which learning from the implementation process is emphasised as one of the main objectives and is critical to transforming the current water paradigm into an integrative and adaptive one. The notion is not only advocated in many publications such as (Ananda et al., 2020; Farrelly & Brown, 2011; Hoffmann et al., 2020) but also by the multiple interviewees who participated in this study.

Discussions around pilot studies, experiments, or demonstration projects are generally engaged in a broader learning perspective involving concepts such as social learning and organisational learning (single, double, and triple-loop). Moreover, experimental approaches have been considered the backbone of the 'active adaptive management' approach, which was theoretically referred to as one of the most effective ways to accumulate knowledge and experience to address uncertainties (Hasselman, 2016; Walters & Holling, 1990; Williams, 2011b).

From the early 2000s, when the urban water sector in Australia was forced to find innovative solutions to cope with the prolonged drought (also called the Millennium Drought), there have been niche experiment projects/pilot studies/demonstration projects documented. Since then, the concept has further developed to not only have interventions in response to the crisis at hand but also to think about upcoming uncertainty and plan for sustainable and resilient futures. Therefore, demonstration projects and experiments have been recognised and taken up as critical instruments to foster the transition to sustainability in practice through the learning process. In the Australian urban water sector, those trials have ranged from water-efficiency options (like retrofitting or swapping water-saving appliances and fixtures and labelling water consumption) to green infrastructure (such as open park space, constructed wetlands and rain gardens or bioretention facilities) to recycling water for non-potable purposes at different scales.

Within the scope of this study, it would be unrealistic to attempt to come up with and evaluate an exhaustive list of all the experiments/pilots and demonstration projects in south-eastern Australia. Thus, this section briefly discusses some of the prominent cases that have either provided meaningful lessons or contributed to the transition to a more sustainable paradigm as a whole. The examples are the water-recycling practice in the Aurora development in the city of Whittlesea, Victoria; the sustainable innovations in the Aquarevo residential development in Melbourne, Victoria; and the integrated innovative solutions in Sydney's Central Park precinct.

Aurora (Victoria)

The Aurora water-recycling scheme was launched in 2006 and was the first large-scale third-pipe system in Victoria. It will serve 8500 homes when completed in around 2025–2030. The development is a demonstration project to test the viability of the Urban and Regional Land Corporation's (URLC) sustainable development agenda. The scheme aims to treat all wastewater from the development and provide the treated water for non-potable purposes, such as toilet flushing, laundry, garden watering and public open space irrigation. Building on the concept of 'learning by doing', the project has provided useful learnings for the different actors involved, especially Yarra Valley Water (YVW). According to the evaluation report from the (Institute for Sustainable Futures, 2013), while Aurora contributes little to the overall water-recycling landscape in the Melbourne metropolitan area, it has triggered a fundamental shift in the way Yarra Valley Water views and adopts sustainable supply options. Moreover, the development of Aurora Estate has unveiled regulatory uncertainty around recycling water. This uncertainty has led to the 2003 *Guidelines for Environmental Management: Use of Reclaimed Water* and the 2005 *Guidelines for Environmental Management: Dual Pipe Water Recycling Schemes – Health and Environmental Risk Management* which were published by Environmental Protection Authority (Institute for Sustainable Futures, 2013).

Unexpected events encountered, explored, and overcome during the trial urged the organisation to change its operational approach. The shift in organisational philosophy halfway into the implementation phase, together with the slowdown in real estate market conditions, led to an increase in costs and a decrease in revenue for YVW (Institute for Sustainable Futures, 2013). To be more specific, the key stakeholder valued the commercial imperative more and the sustainable one less, which resulted in the redesign of the development's layout for higher returns by reducing the number of lots. As a result, the demand for recycled water fell, along with the revenue for YVW. Furthermore, the 12-month delay for replanning incurred operational costs and the mothballing of the Recycled Water Plant. Plus, the market slowed, leading to a slower rate of sales. As analysed in the 2013 report of the Institution for Sustainable Futures, unforeseen incidents like those helped trigger the transformation of YVW into a pioneer as a learning organisation as it offers an opportunity for the organisation, who is well prepared to changes, to learn as the plan goes.

Aquarevo (Victoria)

Since 2013, South East Water has collaborated with Villawood Properties (a property developer) and CRC Water Sensitive Cities to create the Aquarevo urban residential development, which serves as a 'ready-made demonstration site' for unprecedented water-saving innovations on a precinct scale. Those innovations included:

- a high-tech system to screen, filter and UV-treat rainwater for bathing and showering;
- a water-recycling facility that treats the water to Class A standard (suitable for garden watering, toilet flushing and washing machines), leading to a reduction of approximately 70% in drinking-water use;

- rainwater tanks that release water before heavy rainfall to avoid overflow by integrating with weather forecast data;
- a OneBox® smart metering device that remotely monitors the pressure sewer and reads each house's water and energy use in real time.

Other sustainable initiatives included installing rooftop solar panels in each house, constructing wetlands and waterways to connect them, applying various water-sensitive urban design and greening landscape options, and launching community education and engagement programs.

The development has been proceeding smoothly due to support from the former Office of Living Victoria (in the early years), the collaboration between various actors, and the commitment of South East Water to change their 'business as usual' approach. The early successful outcomes suggest that urban residential development can be sustainable without compromising any economic benefits.

However, the experiment also exposed complexity and uncertainty that pushed the organisation in charge to adapt. There were unexpected delays during the implementation due to potential health risks from Legionnaire's disease via water vapour — caused by an increase in microbial hazards when incorporating rainwater into hot water systems. While ultraviolet treatment and heat treatment were included in the system, there was a need to collaborate continuously with the Department of Health and Human Services to monitor and explore any potential exposure.

Moreover, the project employed an unconventional practice that led to hesitancy from the builders. As a result, extra effort, time and money had to be invested in facilitated conversations with the builders to help them understand the concepts and be confident enough to sell them.

Central Park (New South Wales)

Although Central Park was not an intended demonstration project, nor did it embody the full range of available innovations, it is a distinctive model of how the planning, design and implementation processes for a sustainable, regenerative urban renewal should look like at precinct scale (Ruming, 2018). The purpose was not only to achieve commercial success but also to differentiate the project from others via future thinking on sustainability, community engagement and advanced technological applications. To that end, the development committed to goals such as net-zero carbon emissions and water consumption. Thus, the two-billion-dollar staged development (progressing from 2005 until 2018) showcased a visionary sustainable strategy in which a long list of innovative ideas materialised as integrated energy and water management.

In terms of water management, water-efficiency measures and water recycling came into play. Best-practice water-efficient cooling towers, plumbing fixtures, appliances, irrigation systems, infra-red tap controllers and showerheads were installed. Further, the wastewater, harvested rainwater, stormwater, irrigation runoff, and car-park drainage from across the precinct were recycled on site for irrigation, toilet washing, washing machines (cold water use), and cooling towers. Also, the facility takes wastewater from and supplies recycled water to the University of Technology, Sydney (across the road). The four basement levels of the vertical water-recycling plant make it the world's largest water-recycling facility built within a residential building basement (Ruming, 2018).

In terms of energy, a trigeneration central thermal and electrical plant was used to produce electricity, including hot and cold water, with low-carbon emissions due to the recycling of heat. In general, the waste heat from the gas-powered generator and the exhaust gases were used to heat recycled water and rainwater; then part of the hot water could be used to produce chilled water by an absorption chiller. The plant is also the first one applied on a precinct scale that supplies multiple buildings owned by different people.

Besides these innovations, there were also many sustainable initiatives and features such as:

- the prioritisation of car-share, bicycle, and pedestrian services around the precinct;
- recycling and reusing of building demolition waste (from the former brewery);
- green roofs and walls to reduce heating and cooling loads naturally;
- green-star compliant building material;
- sustainability strategy for art and culture dimensions.

All in all, many useful lessons were learnt along the way, from the planning and design stage through to implementation, and from the different components of the project, such as community engagement and institutional arrangements.

The complexity at the beginning of the project concerned differences with the local community and developer over what the floor-to-space ratio (FSR) of the development essentially was. On the one hand, to secure sufficient profits, the NSW Minister for Planning approved plans to raise the density of the proposed buildings (floor plans). A levy was imposed to raise funds for affordable housing in the area. Since the site was deemed ‘state significant’, there were fewer restrictions to the height limit and the FSR. On the other hand, the local community’s view did not align with the proposal and the minister since the community believed that the green space was inadequately designed and the shadow cast by high-rise towers was too much. This conflict led to a case in the NSW Land and Environment Court where the final verdict went in favour of the minister.

After that, Frasers Australia (which bought the site from the previous developer) committed to staying true to a sustainable vision that focused on investing in the future with unique design and high-quality architecture (Nouvel & Beissel, 2014). Frasers realised the role that the adjacent community played in that vision. Thus, it acknowledged the community’s concern and put effort into working towards mutual agreements. Accordingly, it substantially modified the concept design of the urban renewal site by having the Institution for Sustainable Futures from the University of Technology Sydney develop a sustainability strategy that included environmental, social, and cultural dimensions. The strategy served as the backbone to integrate all the planning and design components of the site. It relied on significant engagement with the local community and other stakeholders through workshops and open days, as well as information exchange and communication via the development's website (Ruming, 2018).The outcomes of the collaborative re-configuration were:

- The development was lowered on the south side to avoid overshadowing the neighbourhood.
- A vertical garden along the tower's façade was established to signify a 'green' presence and help reduce the heat island.
- Heliostats were added to bring greater light onto One Central Park (the mixed-use duel towers) and boost the solar energy supply.
- The public park/open green space was given green pockets, public artwork, and small waterways for recreation and for paying symbolic tribute to the overall sustainable goal of the development.

Although it was a long process, intensive public engagement and a holistic sustainability strategy significantly reshaped and improved the initial proposal. As a result, the concept re-design successfully came to life with many exemplars of sustainable features and lessons for the world to study.

It is also important to note that complications regarding institutional arrangements were exposed because the on-site water and energy management innovations were novelties.

Regarding energy supply, Central Park is the first of its kind in which a central thermal power plant with a trigeneration facility supplies multiple buildings owned by different people on a precinct scale. Aiming for a six-green-star rating, at first Frasers wanted to run its own decentralised central thermal and electrical plant for its low carbon emissions and efficiency and also to avoid expensive connection fees. But, according to a regulatory requirement, the development had to be connected to the grid. As a result, Frasers had to downsize the power plant and the supply for commercial buildings close to the power plant.

As for the 'world's largest water-recycling facility in the basement of a residential building' (White et al., 2018), Flow Systems, which is the private utility that constructs and operates the facility, needs to have two licenses (for suppling seaware, recycled, and drinking water services, and for operating the system) issued by the NSW Independent Pricing and Regulatory Tribunal (IPART). IPART also audits the plant to ensure water quality and the reliability of the process are up to standard.

Across the three examples, learning occurred throughout the implementation of pilots and demonstration projects in multiple aspects. Whether it is around regulations and the market's behaviours in the Aurora case, economic benefits from sustainable options in the Aquarevo case or approval processes, community engagement, or technological advances in Central Park Precinct, the author believes that the lessons learnt from those projects are essential. The significance of those projects comes from the knowledge gained and what they can contribute to the changes in how urban water should be planned and managed in the future.

It is noteworthy that there are innovative projects underway by which valuable knowledge and lessons can potentially be generated. One major project is Aura development on Queensland's Sunshine Coast, a large-scale master-planned community (McAlister et al., 2017). The project utilized WSUD innovations to plan sustainable water infrastructure for the future growth of the local community, including rainwater tanks in all households, rain gardens, constructed wetlands and bioretention basins throughout the development. The 'main course' of Aura development might be the stormwater harvesting scheme, a potential indirect water reuse scheme, which can potentially capture 2 GL/year of urban stormwater (collecting through site WSUD devices) to augment SEQ's Ewen Maddock Dam

(Hamlyn-Harris et al., 2018). The project is innovative in the sense that 1) it adopted state-of-the-art technologies in WSUD and water treatment, 2) it employed a risk-based approach to stormwater quality (instead of prescriptive regulations) with the close and transparent collaboration between the developer (Stockland), consulting/ research team (Water Tech), and water utility (South East Queensland Water) 3) it has the ongoing monitoring procedures in place for various water quality parameters to assess the impacts of WSUD implementations(Hamlyn-Harris et al., 2018; McAlister et al., 2018). However, the project is still in the developing phase for the stormwater harvesting scheme, and there is little up-to-date information on the current situation of the development.

7.5.2 How the interviewees perceived 'pilots and learning experiments'

The interviewees mentioned that 'pilots and learning experiments' can hypothetically operate in the complex domain to address uncertainty and complexity. Essentially, the concept is to use pilots and design experiments to learn about how systems behave and then to improve the actions and processes based on what has been learnt, to the point where the system reaches the desired state or objective. Then, the knowledge obtained through this process about the key factors that made it successful can be 'replicated and amplified, scaling up to tackle larger and complex issues' (C2).

Pilots and learning experiments are more like an overarching approach to understanding the system rather than a specific tool. In fact, a set of tools would be needed to implement the learnings from these experiments. Interviewee G1 and C2 believed that the Water Smart Cities program (in New South Wales) might have the potential to explore and gain insights from experimenting in the 'different ways of approaching the uncertainties in water, wastewater, stormwater delivery when aligning that with the land-use planning at subregional scale' (as mentioned in more detail in section 6.3). The overall aim was to maximise multiple environmental, social, and economic benefits. According to interviewee C2, the program was designed to investigate the enabling regulations when trialling best practices and innovations learnt from other greenfield developments and urban renewal projects. The aims were to have the benefits realised, gain a better understanding of the conditions for successful implementation, and make business cases for future high-rated green developments in Sydney.

However, while experimentation is a crucial tool, two main impediments to its employability are the risk-averse attitude of decision-makers and investors and the lack of mechanisms for learning, as suggested by respondents C2 and W1, respectively.

Firstly, C2 shared the reason that the funding for 'pilots and learning experiments' in the context of the Water Smart Cities program was withdrawn as:

> 'The organisation that traditionally did that [the planning] wanted to do it themselves, and they wanted to do it the same way it had always been done. So, it was resistant to a new way of doing things.'

There was no further articulation from interviewee C2, so the 'resistance' can be interpreted as the responsible organisation retaining a rigid mindset causing doubt over the long-term benefits of the sustainability principles and goals. However, a statement from interviewee G1, who also had insights into the program, shed more light on the 'why'.

> 'And then it [Water Smart Cities program] got cancelled, Sydney Water was very upset that money came from them. They did not agree with it. They wanted to be in charge of water supply and delivery and that one [Water Smart Cities program] cut across their particular programs.'

The above comment does not only signify the need for technical control over the process but also implies an unwillingness to take risks and embrace uncertainty. If the risk of failure and the loss of initial capital investment or the risk of having to 'clean up' after the experiments cannot be offset by the realised benefits in the long term, then the risk-averse decision-makers will prevent an experimental approach from being taken up. While the experimental approach embedded in this program has the qualities needed to operate in the complex domain, given that it inherently adopts the underlying ideas and principles of adaptive management, it is not considered to have any merit in practice. Besides the fact that the program was stopped, there are no documents related to it in the public domain. So, it remains unclear how this experiment for integrated urban water management was designed or what aspects of the system would have resulted in lessons learned.

Secondly, interviewee W1 shared that doing pilots (in general) has been recognised for quite a while, but it has not yet been developed into mainstream practices since pilots have always been carried out in a set-and-forget manner: 'We've been doing pilots for 20 years. Everyone's done a pilot and they don't go anywhere, no one does anything with it' (W1). With no learning mechanisms and evaluation programs to distil the emerging knowledge, replication or scaling up occurred elsewhere. Hence, there has not been much progress in method development.

7.5.3 How do pilots and learning experiments address the complex issues

From a CF perspective

From this study's point of view, doing pilot studies and design experiments for learning and adjusting plans and interventions accordingly over time are fundamental to tackling multiple types of uncertainty. This method can help test the performance of options against desired objectives and to explore uncertainty in implementing alternatives or novel approaches. However, for the experimental approach to urban water management to be mainstreamed, at least the hindrances mentioned above should be paid more attention to and addressed by all key stakeholders.

The concept of this method aligned with the theoretical basis of complex domain. As the main purpose of carrying out pilot studies and demonstration programme as learning experiments is to explore the response of the system against experimental policies or interventions. In other words, it is to 'probe' the system to obtain insights on the unpredictable causal relationships among variables as well as events. As a result, it forms a basis for retrospectively making sense of the reactions, to then provides evidence-based analysis for emerging practices upon which the responses can be decided. This reinforces the desired pattern or diminishes the unwanted ones. The experimental approach represents the 'probe – sense – respond' strategy neatly.

From a combined approach perspective

The experimental method is not only one of the main pillars of the adaptive approach, but it also plays a vital role in IUWM and the participatory approach. It has the potential to cover different grounds within different approaches. When used to adapt to unknown external conditions such as climate change, the experimental approach is a way to 'test the water' (so to speak) to see how options stack up against system responses and improve the knowledge of such a system. Pilots and learning experiments might also offer a way to explore uncertainties in implementing the IUWM approach — like what interviewee C2 and G1 were hoping for with the Water Smart Cities program (section 7.5.2). Furthermore, community engagement is beneficial for the experimental approach to be successful. For example, in the development of the Central Park precinct, early and ongoing conversations, as well as negotiations between key stakeholders, developers and the community, played a decisive role in the sustainable vision becoming reality. While it has not been implemented yet, the development of demonstration plants for purified recycled water using for drinking purpose were proposed in both the Draft of the Lower Hunter Water Security Plan and Draft of Greater Sydney Water Plan (NSW DPIE, 2021b, 2021a). It could potentially be a prime example of the tool applied within the framework of the combined approach since:

- Purified recycled water is an integrated solution
- The plant was proposed as a readiness improvement measure against future climate uncertainty for the drought response strategy

- The use of purified recycled wastewater for drinking is controversial and it is crucial to educate the community and to understand the community's perspectives.

Regarding how well this methodology can be used to solve the identified issues, it has potential to gather information on the technical difficulties with experimentation and offers an opportunity for different actors to learn more about the overall approach of the project and the specific interventions that are being tested (summarised in Table 7.5). Thus, as stakeholders get involved in the process and improve their understanding of the subject, they might gain practical experience as a by-product. This by-product might be handy to ignite the shift in participants' perceptions, as well as boost their knowledge of and insights into the complexity of IUWM and AM. Further, different examples of how various actors obtain new knowledge during the process through problems and uncertainties raised along the way (related to design and construction, monitoring and maintenance, institutional barriers and approval processes) can be found in case studies compiled from South East Queensland (Farrelly & Davis, 2009b) and Perth (Farrelly & Davis, 2009a). Those case studies also revealed that the knowledge about Governance and Institutional arrangement issues can also emerge during the process, providing valuable cues for improvement. Also, according to respondent C2, the Water Smart Cities program was designed with that in mind — that is, to learn how implementing the practices associated with the integrated water management approach could improve the situation and what to amplify at a broader scale. Besides, while it is not explicitly manifested, the complexity that comes with the implementation of similar project at different scales might be revealed through follow-up research. Thus, it is likely that the experimental approach is among the best ways to study more about coordinating the overlapping planning and authorities.

Table 7. 5: How 'pilots and learning experiments' might address the identified issues

↑ : helpful | ↓ : unhelpful | — : no impact

CHALLENGES	PILOTS AND EXPERIMENTS
Technical complexity	↑
Governance and institutional arrangement	↑
Climate change uncertainty	—
Worldview	↑
Communication methods	↑
Economic evaluation for non-market benefits	—
Scale of planning/implementation	↑
Complexity of the concepts	↑

7.6 Community engagement tools

7.6.1 An overview of community engagement practices

As mentioned in section 7.1.2, there is an issue with community engagement that primarily relates to how challenging it is for the community to comprehend complexity, and how difficult it is to communicate uncertainty and complexity to laypeople. It is noticeable that while this was a concern that interested practitioners in the second round of interviews, there was not much elaboration on the possible tools or methods to improve approaches for engagement. Developing tools for engaging the public should be among the most critical focuses when dealing with complex problems since many of the unconventional sustainable initiatives cannot be progressed without getting the community on board first, in terms of both vision and commitment. That statement is especially true in examples where there is a need to increase the initial capital investment in a project, or planning to keep options open when preparing for future unknowns, something that is usually seen when approaches such as APP or ROA are employed. In other cases, unconventional options need to have the support of customers to be feasible, such as the use of recycled water for potable supply or the willingness to pay for additional costs of sustainable options compared to BAU (e.g. renewable energy, constructed wetlands, rain garden, nutrient recovery).

From the 'level of engagement' perspective (see Figure 7.1), it is good to 'inform' or 'consult' the community because this will increase their awareness, build their knowledge, promote behavioural changes, and increase compliance with policies. However, public engagement is only beneficial when there are lasting partnerships with active conversations formed between stakeholders and actors in the community. Involving the public in decision-making processes and considering their voices and values in aspects of decision-making does the following:

- fosters learning cycles among stakeholders;
- engenders long-term relationships;

- builds up trust and knowledge;
- potentially makes those involved more self-sufficient.

So, the level of engagement on the IAP2 continuum (IAP2, 2014) should preferably be to 'collaborate' and ideally, where the conditions are met, to 'empower'.

7.6.2 Review of good practices from the study areas

Among the various engagement practices in the metropolitan areas of South Eastern Australia, several programs stood out in terms of fostering interactive conversations, learning, and partnerships with the community.

One of the highlights was a community consultation program consisting of four workshops over a 10-month period that contributed to the Lower Hunter Water Plan (LWHP) in 2014 (Metropolitan Water Directorate, 2014). The consultation workshops were designed to share knowledge about water planning and to learn about community values, priority preferences on supply, demand options, the cost, drought management, and environmental trade-offs. The outcomes of each workshop were incorporated into the planning and decision-making process and fed into the next workshop. What makes this engagement program stand out is that community participation was not just a case of 'set and forget' after the plan was published. It was an ongoing process where deliberative forums were held in 2018 to update the conversations. These forums explored community values and perspectives on long-term sustainable and resilient water systems. Then, from November 2020 to February 2021, the community online survey attracted 1100 participants, who shared their views and gave feedback on water security, environmental goals, and their preferences across seven portfolios of supply-and-demand options. In this way, they contributed to the review of the 2014 Lower Hunter Water Plan and provided input into the recent Draft Water Plan (NSW DPIE, 2021b) . In addition to those initiatives, customers also have a chance to make online comments and suggestions through the 'Your voice' portal. Besides, a few active community groups have been formed out of the program and regularly meet, such as Hunter Water's Customer and Community Advisory Group and the Lower Hunter Water Security Plan Community Liaison Group. The engagement level of the community involved in LWH planning and implementation is close to 'collaborate', where the utility partners up with groups of customers and takes their feedback into the decision-making process, even though the utility initiated and led the whole process.

In Melbourne, there was a deliberative community panel within Sunbury's water future project (five full days over May to June in 2019) and a Citizen Jury to assist Yarra Valley Water (YVW) (five meetings from May to July 2017) determine water services and pricing. The methods used in the two cases were different, and so were the objectives.

Community engagement and the panel's recommendations have played a vital role in developing the Integrated Water Management Plan for Sunbury. The engagement 'roadmap' includes six phases spanning from 2018 until 2024, from initial value scoping to plan implementation, as outlined in Figure 7.2 The program was designed to be highly educational and interactive. Phase 1 captured the diverse views and preferences of community members on seven topics related to integrated water management in general. An online survey was used to scope the interest and general ideas on the topics. Then face-to-face engagement further explored the questions in the survey in the three main categories of Benefits of IWM, Elements of the Water System, and Other Creative Ideas. Four discussion groups were formed to participate in two open community workshops and two individual conversations. The outcomes of phase 1 were also communicated to participants of phase 2. The spotlight of the process was the deliberative engagement in phase 2 where the panel met for five full intensive days over a month to share their views and priorities for portfolios of IWM options. The good practice of this phase is that the stakeholders did not jump right into the conversations and exchange ideas. Instead, knowledge sharing and education sessions were held for the first few days where experts in multiple fields, such as stormwater management, urban design, law, and policy experts, were invited from different organisations to not only explain the various aspects of IWM planning and sustainable measures but also facilitate a Q&A session in break-out community groups.

To make a meaningful and informed contribution to such specific IWM portfolios of options, the community needs training in how each of them works. Another plus point is that while Melbourne Water collaborated with Western Water to initiate the process, the design of the program and the techniques applied were developed with the support of a third-party organisation, Mosaic Lab. The company also took the lead in implementing the 'engagement side' of the program, while Melbourne Water and Western Water provided overall purposes, objectives, knowledge, and technical expertise. The program should be rated at the peak of 'collaborate', according to IAP2's spectrum of engagement, where not only the conversations between stakeholders are engaging but there is also a commitment to incorporate the panel's recommendations into the final decision-making process. This was shown in the 'Response to Community Panel's recommendations' report prepared by both water utilities.

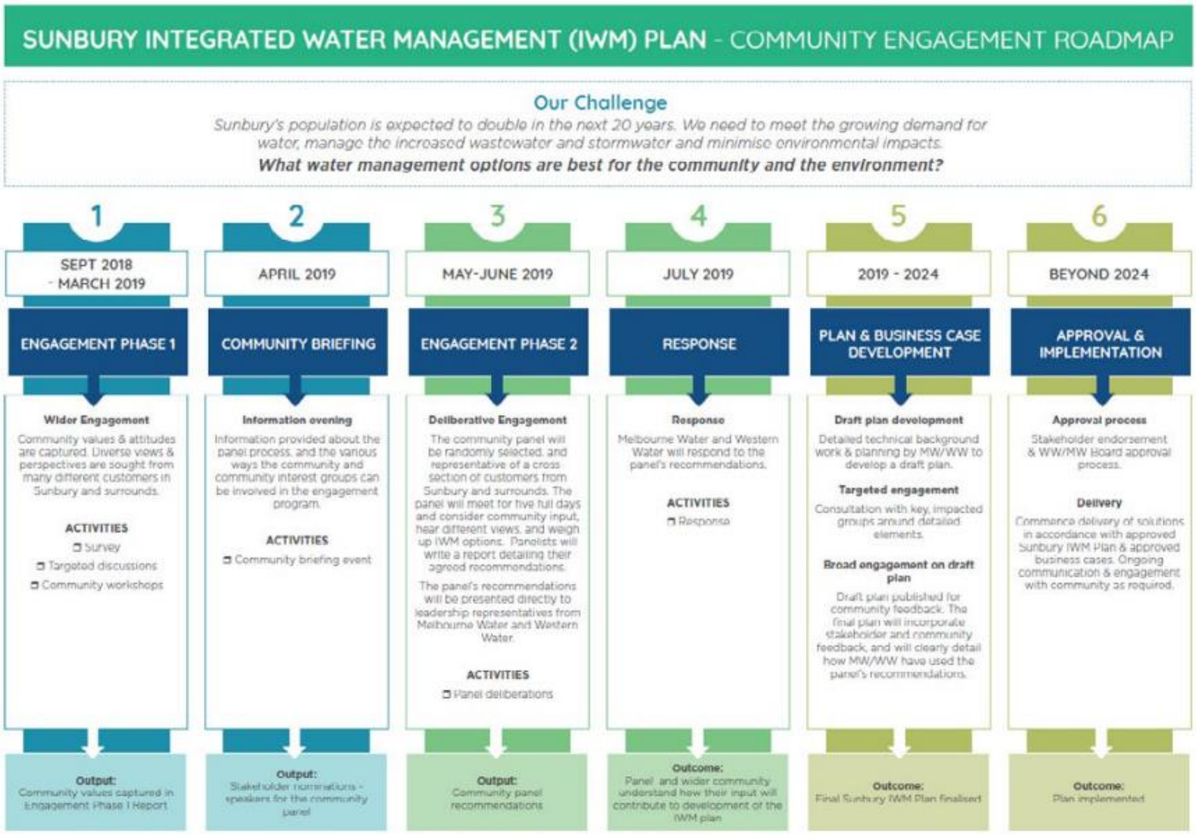


Figure 7. 4: Sunbury Integrated Water Management Plan — Community engagement roadmap

Another example of a comprehensive deliberative community engagement process is the Citizen Jury that was formed in 2017 by a group of 30 customers to assist with Yarra Valley Water's five-year regulatory pricing submission (2018–2023) to the Essential Service Commission (ESC). The term 'jury' refers to the jury in a court case where the members thoroughly consider and contemplate all evidence to make a collective decision. The aim was not only to understand customers' thoughts on determining how best to retain fairness in balancing prices and services but also to incorporate their recommendations into the report that guides priorities over the five-year period. The engagement process spanned approximately 800 working hours over six months. The jury deliberated on a key question based on their collective understanding of the evidence-based challenges regarding water quality and sanitation service delivery, as well as the YVW operational settings and impacts of changes. All the materials, information and expertise required to make informed feedback were provided and interpreted by the YVW team and multiple experts throughout the participation process. Basically, by exploring broad thinking and concentrating on priority trade-offs, the deliberation was able to produce potential solutions that reflected broader customer values and perspectives on the final submission.

The Citizen Jury method has been used in a wide range of contexts but this application by YVW is unique to the Australian urban water sector in the sense that it steps into the uncharted territory of 'empower' (IAP2 2014). The method challenges the usual idea of community engagement by introducing a process for sharing decision-making with the community via informed public judgment and recommendations.

7.6.3 How useful are the tools in addressing complexity and uncertainty?

From a CF perspective

Based on the interviews within this research, as well as reflections on the literature review, the participatory approach must be embedded in any strategies to respond to problems in any of the domains of the Cynefin framework. It is observed from the literature that public engagement has never been used as a standalone methodology for solving any particular problem, even if it concerns a conflict of interests between actors. Rather, it has always been associated with other approaches, whether carried out as part of an integrated approach (in Sunbury or Lower Hunter water cases) or as a component of an integrated solutions implementation or experimental/demonstration project such as the development of the Central Park precinct or the Aquarevo residential area case. Besides, community's perspectives on adaptive or integrated interventions are also perceived as one kind of uncertainty (Kochskämper et al., 2021; Tyre & Michaels, 2011). Further, the notion of 'social learning' where collective knowledge gathers from sharing views, values, and understandings among stakeholders and the community about uncertainty and complexity hold promising chance to trigger ‘double loop learning’ (Argyris, 1977; Kochskämper et al., 2021; McLoughlin & Thoms, 2015). As a result, while there were issues with the community comprehending complexity and with communication about complexity and uncertainty, as mentioned above, the author believes that a set of tools for public engagement should still be a crucial component of an adaptive and integrated strategy against complex issues

From a combined approach perspective

A range of methods to engage with the community during the decision-making process is critical and useful in many cases, especially to (as summarized in table 7.6):

- gain a better grasp of climate change uncertainty;
- help transform people’s worldview;
- communicate uncertainty;
- have a better understanding of the abstract concepts related to IUWM and AM.

Public engagement programs might not be helpful to improving the uncertainty related to climate modelling, but ongoing engagement is crucial to improve the understanding of the uncertainty and increase adaptive capacity of the urban water system. There are two main interactive principles of adaptive planning that need to have support from the community. The first one is the *adoption of an experimental approach*. The role of experimentation with technology or policy interventions is important, as elaborated in section 7.5. The main pillar of the experimental approach is the learning practices that inform the changes of the interventions and methods (single loop) or changes in the assumptions and objectives of the planning (double loop), or changes in how one learns about the changes (triple loop) (Johannessen et al., 2019; Medema et al., 2014) . Engaging with the community formally or informally with informative two-way conversations, combined with ongoing partnerships, might foster social learning and create holistic solutions.

The second one is *proactive preparedness*. Planning for future uncertainty always needs to be flexible and robust. The flexibility is presented by 'leave all options open' and avoiding lock-in so that options can be switched on, adjusted, or delayed once there is more information over time. Robustness means that alternatives and contingency plans should be prepared and ready to be implemented whenever the system reaches a trigger point. So, to be able to lay that foundation, the community needs to be informed and have a say in how all the options and processes are prepared. Further, proactive preparedness usually comes with some initial capital investment and the sustainable measures are in some cases more expensive than usual practice. Therefore, it is imperative to get the customers on board to share those risks using the knowledge gained through the engagement program.

A highly engaged process can potentially stimulate a shift in worldviews and help make up for any lack of knowledge and experience regarding the complexity of IUWM and AM approaches. The rationale is that involvement throughout the program will expose key actors to informative, up-to-date discussions. These discussions can be on such subjects as climate change uncertainty or the background, processes and feasibility related to multiple aspects of IUWM or AM, as partially pointed out in the case of Sunbury's water future and YVW above. Methods like a deliberative community panel or Citizen Jury, with the support of comprehensive training and educational sessions, are among the best ways to help the community collectively learn about the matter at hand in a social context. Then the generated knowledge can be built up and strengthened by forming long-term partnerships with the community.

Table 7. 6: How public engagement tools might address identified issues

↑ : helpful | ↓ : unhelpful | — : no impact

CHALLENGES	ENGAGEMENT TOOLS
Technical complexity	—
Governance and institutional arrangement	—
Climate change uncertainty	↑
Worldview	↑
Communication methods	↑
Economic evaluation for non-market benefits	—
Scale of planning/implementation	—
Complexity of the concepts	↑

While it is essential to improve the engagement program, it is also essential to develop more robust evaluation processes or tools that allow for assessing process outputs, social outcomes, and desired outcomes. The literature review on natural resources management and water resources management elsewhere has shown that there is little understanding of the relationship between public engagement practices and environmental outcomes, especially when it comes to evaluating such relationships (Drazkiewicz et al., 2015; Koontz & Newig, 2014; Koontz & Thomas, 2006; Mandarano, 2008b).

As an aside, while there are many engagement programs launched for different purposes at different scales in Australia, it is currently challenging to access information on these. Therefore, it would be beneficial to have a platform or a learning hub for organisations to share materials, such as documented case studies or research papers.

7.7 Bringing the tools together

The way forward for dealing with the multiple objectives currently being addressed by water planning and the uncertainty associated with a changing future lies in using the tools in combination — drawing on the aspects of the tools that are useful for the job at hand. A recent example of this is the Lower Hunter Water Security Plan (LHWSP).

The LHWSP, released for public comment in August 2021 (NSW DPIE, 2021b), emerges as a balanced example that embeds various elements of the combined approach within its planning approaches and practices.

The overall aim of the plan is water security for the Lower Hunter for the next 40 years. For the goal of a resilient and sustainable water future, water security and social and economic objectives are considered.

The IUWM approach has been applied systematically to consider water supply and demand for domestic and business usage, ground and surface water, wastewater, stormwater, recycled water and waterway health, as well as external social and environmental factors. Further, for options related to water conservation, leakage reduction, the circular economy principle for the 'interconnections between water services, energy, carbon emissions, ecological health and economic productivity', alternative sources such as recycled water and desalination plants are on the table.

In this iteration of LHWSP, the role of adaptive management in securing water supply against drought is especially emphasised because new modelling methods (incorporating paleoclimate data) suggest longer and more severe droughts than witnessed in the past 120 years. Therefore, the strategy stresses a no-regrets action over time, an incremental investment approach to avoid lock-in options, and readiness activities (contingency plans) such as land acquisition, concept design, planning, and funding approvals for a new desalination plant.

The ongoing monitoring, reviewing, and reporting processes have been briefly mentioned, but no detail is available yet. Besides, the plan was said to be adopting an adaptable approach with flexibility and robustness by which changes in future circumstances are sure to be responded to. However, there is also no further clarification on how and when the situation will be reviewed or the plan will be adapted. The 'adaptive pathways modelling' was mentioned to assess the performance of alternatives against different uncertainties within various future scenarios. It is worth noting that while clear actions have already been named, following the establishment of four main priorities, no action has yet been taken to evaluate their efficacy and robustness. Moreover, the document also set out a readiness strategy of developing a pilot plan for purified recycled water (wastewater) for drinking in which a demonstration plants and community education and engagement facility will be built. The purpose is to update how technology for treating wastewater works in a practical exhibition, to explain to the community why the water is safe and suitable to go back into the drinking water supply system, and to capture community's perspectives on the matter.

Further, the fact that the previous LHWP (2014) was developed with a rigorous community engagement program (see section 7.2.2), and the review process to develop the updated version was also guided by a 'collaborative, system approach', suggests Hunter Water has a consistent view on adopting a participatory approach to planning. From 2018 to 2021, various techniques such as deliberative forums, online surveys and community groups have been used in different sessions to engage the community's views and enhance their knowledge of the plan. Moreover, participants' perspectives and needs will be incorporated into the decision-making process later in the implementation phase. The commitment to the participatory approach has been shown also by including the values and knowledge of marginal stakeholders such as First Nations people in the development of the plan and decision-making process.

The plan clearly established a foundation for experimental approach and has demonstrated a promising use of the combined approach (IUWM, AM & PA) in dealing with a complex future. The development framework (Figure 7.5) is simple and precise yet provides a structure for applying various tools and techniques at different stages of the process and potentially provides a good example of how the various tools can be used in collaboration to complement each other. This approach is, in itself, an experiment. The proof of the adaptability and flexibility of the plan will be in its application over time and in response to changing assumptions.

Figure 7. 5: Plan development framework (the 2021 Lower Hunter Water Security Plan)

The plan development framework (figure 7.3) can be a good exemplar structure in which various tools are incorporated into the processes.

The participatory approach element has already been planned to incorporate community values to underpin the goals and objectives, gain their perspectives on the range of options and their trade-offs and the actions associated with the strategies. Community engagement tools in this plan, such as deliberative forums with the community, focus groups with local businesses and councils, engagement websites, and online surveys, have been established and launched since 2018.

MCDA is another tool that was adopted in this plan repeatedly. It is unknown which specific tools under the MCDA umbrella were chosen to consider both qualitative and quantitative. However, it was used to evaluate the options for shortlisting and evaluate the program of actions that developed put those options in place. .

Scenario planning was used to develop a range of plausible futures considering future social, environmental, economic conditions. Those scenarios laid a foundation for assessing the alternatives in terms of technical (hydrological models) and financial (cost and benefits analysis) aspects.

Then, Adaptive pathways planning was elected as a modelling approach to stress test the programs of actions against future uncertainty, to evaluate the trade-offs and ensure the goal and visions are realised.

According to the plan, pilots and learning experiments will be manifested through a purified recycled water demonstration plant that aims to show the technology and reliability of water quality and services.

The author thinks that ROA can also be helpful as an economic evaluation tool when paired with adaptive pathways modelling to evaluate the trade-offs.

7.8 Summary and conclusion

This chapter analysed and assessed the current use and the potential application of the highlighted tools from various points of view. Those tools/methods that stand out from this study as having the potential to deal with uncertainty and complexity were discussed in the context of the different domains in the Cynefin framework. They were discussed from the perspective of the combined approach (including IUWM, AM and participatory approaches) and in terms of how they potentially address the issues identified in previous chapters.

7.8.1 From the Cynefin framework point of view

The chapter first assessed the potential of the proposed tools by demonstrating how the Cynefin sense-making framework can be used as a heuristic device to determine the most suitable contexts for the methods. This was done by comparing and contrasting interviewees' insights into how those methods fit within the complex domain and an interpretation of domain characteristics in the urban water context. The result is compiled in Figure 7.4.

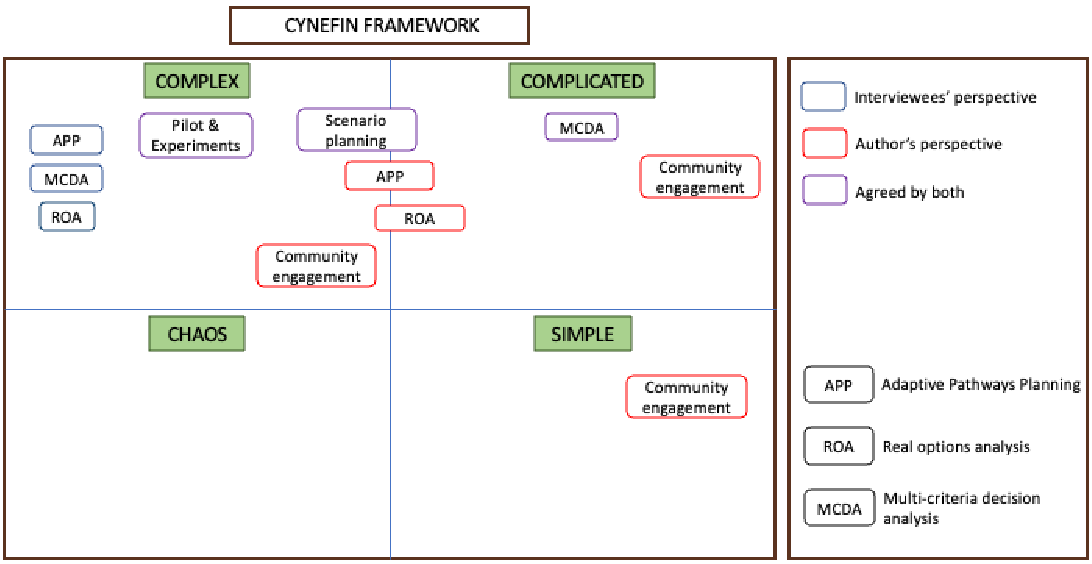


Figure 7. 6: Tools assigned in different domains of the Cynefin framework

Overall, some of the tools or methods that the interviewees suggested might not be suitable for the complex domain. However, this thesis agrees with those interviewees who trust that 'pilots and learning experiments' have the potential to operate well in the complex domain and should be considered when dealing with uncertainties.

Various approaches to the design and implementation of pilots or experiments were developed to create a set of 'what-if' alternatives. This opened a path to investigate the uncertainty associated with either the implementation processes or the performance (or impacts) of the options on the whole system and signifies the essence of the 'probe – sense – respond' strategy in the complex domain.

The flexible strategies encapsulated in APP make it a potential tool to address uncertainty and adapt to changes over time (i.e. in the complex domain). However, its associated deterministic modelling approach, as well as the limitation of the analytical requirement to one objective at a time, potentially limits it to the characteristics of the complicated domain. Furthermore, the capacity of APP to address uncertainty would also be limited by what planners perceive to be plausible scenarios. Recent extreme incidents outside of the planning envelope prove that unless the 'unknown unknowns' are being considered in planning, there is still a long way for APP to excel in the complex domain. Therefore, the APP method at this point of its development and application means that it should be situated at the boundary between the complicated and complex domains.

While ROA can be useful as an economic evaluation tool for trade-offs between different sequences of alternatives across future plausible scenarios while considering multiple uncertainties, it can be positioned in the middle of the two domains — possibly more within the complicated than the complex context — owing to the way ROA carries out 'optioneering'. The way probabilities and expected values are assigned to the options suggests predetermined causal relationships about a set of future events. While the underlying goal is to achieve flexible response strategies, ROA is deterministic and mechanical since the method demands and relies on outcomes of mathematical modelling practice for calculation and predictions based on many assumptions. Where uncertainty is high, and there are many variables and scenarios involved, it can become overwhelming for the computational capacity of the models. The way ROA is often done in practice is that it relies on the Black box/mathematical models that calculate many possibilities for various outcomes based on deterministic inputs for variables and risks. Further, the assigned probabilities to scenarios might not reflect actual situations as catastrophic events usually were assigned lower probabilities. As a result, options' value and associated financial costs might be misjudged in extreme instances.

Multi-criteria decision analysis is a powerful and versatile analytical method in the complicated domain. It offers a framework to engage with both qualitative and quantitative information, and it encourages dynamic cooperative stakeholders and community interactions. However, the criteria and indicators are usually developed from well-understood events and actions and their consequences. Further, uncertainty in MCDA is dealt with using sensitivity analysis. In its simplest and most commonly used form, the method is linear and deterministic and fit-for-purpose with the 'sense – analyse – respond' strategy.

SP (scenario planning) falls between the complicated and complex domains, however, compared to APP and ROA, the author realises that SP holds more potential to deal with issues in the complex domain. It is popularly used in planning as an analytical framework for testing alternatives against different well-understood conditions to predict possible future outcomes. This use aligns with the characteristics, as well as the strategy, to respond to issues in a complicated context. From a different angle, SP also has the potential to operate in the complex domain when the goal is to explore or carry out experiments with possible ideas on future uncertainty, adopting a qualitative approach at the strategic level. However, to be at that level, an innovative approach to the traditional SP is needed.

7.8.2 How the tools address identified issues

In this section, the tools or methods suggested by the interviewees, based on the analysis of their potential to address issues aggregated from two rounds of interviews, were discussed, and the outcomes are summarised in Table 7.7. The chapter evaluated their potential based on an interpretation of the literature.

Table 7. 7: Summary of how the tools address the identified issues

↑ : helpful | ↓ : unhelpful | — : no impact

Tools / Challenges	APP & ROA	MCDA	Scenario Planning	Pilots/ experiments	Engagement tools
Technical complexity	↓	—	—	↑	—
Governance and institution arrangement	↓	↑	—	↑	—
Climate change uncertainty	—	—	↑	—	↑
Worldview	↑	↑	↑	↑	↑
Communication methods	↑	↑	↑	↑	↑
Economic evaluation for non-market benefits	↓	—	—	—	—
Scale	—	—	—	↑	—
Complexity of the concepts	—	—	↑	↑	↑

It is interesting that rigid worldviews on the new approach in general, and a lack of communication methods, can be improved by all the mentioned methods.

Those methods respond differently with each issue, but overall, no one tool can address all the issues. It can be observed that pilots and learning experiments holds the best potential to deal with complex issues, especially with issues related to the overlapping scales which no other tools/methods demonstrates the potential to tackle. Also, it is noteworthy that many of these methods are compatible with and complement other techniques or tools to support decision-making. As each tool is led by a different discipline, it potentially covers only a part/component of the whole process. Therefore, it might be a better approach for the tools to be applied together in a framework guided by a combined approach (see recommendation in the Conclusion chapter 8).

7.8.3 The current status of the 'combined approach'

Finally, the tools were regarded through the lens of the combined approach (IUWM, AM and PP), which is the initial perspective and goal of this research, to see where they currently reside. See Figure 7.5.

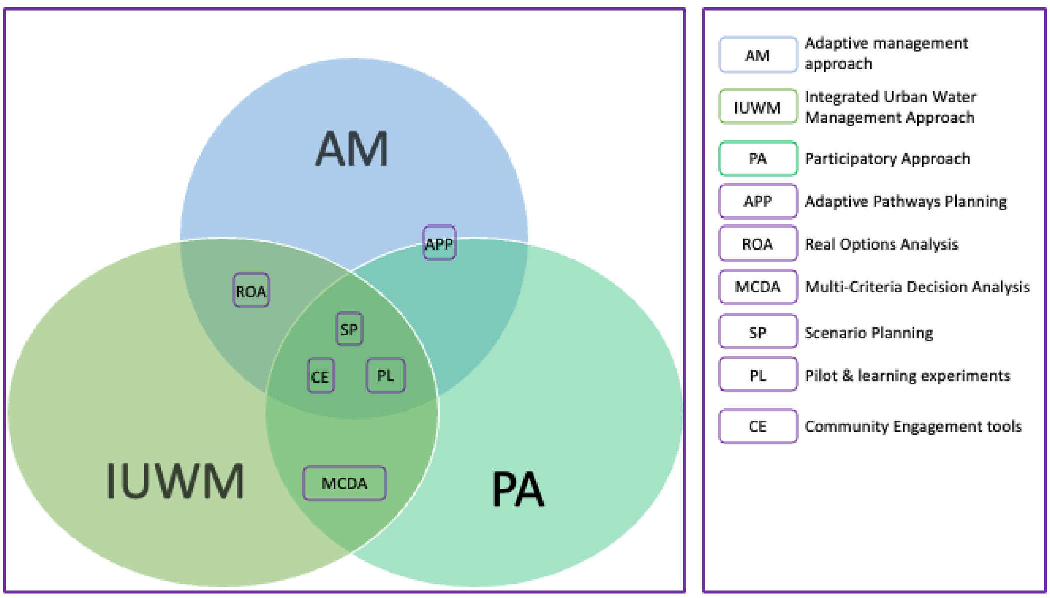


Figure 7. 7: How the tools fit within the combined framework in practice

Among those methods, it is observed that some originated in either one or two approaches and very few were used across all three. While APP was strictly designed for adaptive management practice with the help of a participatory approach, ROA can be found helpful with both IUWM and AM. Methods associated with MCDA (multi-criteria decision analysis) were reported to contribute to disciplines of both IUWM and PA. Overall, SP (scenario planning), PL (pilots and learning experiments), and CE (community engagement) are used to a certain extent within all three approaches. This diagram of where the tools are positioned is derived from a literature review and documents analysis on how they have been applied in urban water planning and management practice in the study area.

APP, the methodology that relies on modelling practices to materialise future uncertainty, has been seen so far to be too complex to accommodate multiple objectives. Also, while stakeholder collaboration plays a vital role throughout the process, there is no evidence of the engagement of the broader community. Since it does have some application for engaging with planning stakeholders, it has been located on the border of AM and PA.

Regarding ROA, its analytical prowess in 'optioneering' has been proven to be useful for the IUWM and AM approaches. In fact, Australian practitioners have even been encouraged to adopt ROA as 'business as usual' (Department of the Environment, 2015). The method has reportedly been used in various IUWM projects and in evaluating adaptation options (Ramm et al., 2017). However, the computational and analytical complexity poses challenges in terms of communicating and reporting the underlying technical concepts and the uncertainties considered by the method. Therefore, it might not be the best tool to support a participatory approach or even for collaboration between multiple actors from different disciplines and backgrounds.

So far, different uses of MCDA have been adopted together with IUWM projects seeking community engagement. Some of the examples described in section 7.6.1

show that the lessons and experience learnt during the implementation of integrated and sustainable solutions contribute largely to the common pool of knowledge about the subject. Further, the perspectives and values of the community affected by the intervention are some of the most seminal practices learnt from the applications, as illustrated from the case of the Central Park precinct.

Likewise, different MCDA processes currently play vital roles in balancing the multiple objectives of stakeholders and the community and assessing the performance of alternatives (for shortlisting) following an integrated approach, as described in publications such as (Mukheibir, Howe, et al., 2015; Mukheibir & Mitchell, 2011; Skinner & Satur, 2020)).

The current practice of SP and CE suggests a well-rounded and widespread use in urban water planning. Traces of their adoption following the principles of the three approaches can be found in various planning documents such as the Metropolitan Water Plan for AM and PA approaches (Metropolitan Water, 2017) or the Lower Hunter Water Plan for aspects of the three approaches altogether (NSW DPIE, 2021b). While being less prevalent than SP or CE in the uptake, the recent application of demonstration projects can be found in the planning documents. In both draft versions of the Lower Hunter Water Security Plan and Greater Sydney Water Strategy (NSW DPIE, 2021a, 2021b), the pilot plant for purified recycled water for drinking as a readiness measure to address drought uncertainty was proposed to demonstrate the technology and find any issues in treatment, educate and capture community's preferences.

8 Chapter 8 – Conclusions and way forward

8.1 Introduction

The Australian urban water sector has witnessed rapid changes in recent years, resulting in a high level of complexity and uncertainty when ensuring safe and reliable water services. The conventional linear and deterministic management paradigm has proven to be ill-suited for planning under these conditions. Therefore, to increase the resilience of the urban water systems, there is a call for a transformation to a more sustainable paradigm that consists of characteristics and qualities from participatory practice (PP), integrated urban water management (IUWM), and adaptive management (AM) approaches.

This thesis aimed to inform this transition by identifying and investigating the challenges and issues of complexity and uncertainty that might arise. Four research questions were investigated within the scope of this research by adopting an exploratory nested case study approach focused on the metropolitan areas of the South Eastern seaboard of Australia and utilising semi-structured interviews.

In this introductory section, the exploratory literature review process that led up to the final version of research questions is presented to provide the overall summary of the context for the research. The narrative can be constructed based on three main influencing factors:

- the research gaps identified
- the rationale behind the changes in research focus as the research evolved
- the impacts of the COVID-19 pandemic on data collection and analysis processes

Research gaps

The analysis of the literature revealed that the current state of knowledge and trend is focused on planning and managing in an adaptive, integrated, and participatory manner. The transition calls for planning strategies to be flexible and robust enough to cope with unpredictable future conditions. However, this transformation remains a theoretical one. Current practices continue to demonstrate the predominance of top-down management models, where the focus is on the positivist approach of traditional engineers, economists, and policymakers. When considering an integrated approach, decision-makers focus more on centralised recycling than also considering a broader range of integrated options such as demand management and localised solutions (based on a systems approach), and fail to consider multiple and often competing objectives adequately. Public engagement practices that go beyond merely 'informing' have not been well captured in the literature. Finally, uncertainty has been considered through a 'predict and control' planning lens. An adaptive management approach has only recently gained attention by some water utilities through adaptive pathways planning.

While the literature on the three separate approaches (IUWM, PP, and AM) is vast and, to some extent, in the case of IUWM and PP, is well-documented, it was observed from the literature review that no frameworks that explicitly combine these three approaches exist. There is an absence of cases that demonstrate the extent to which the approaches might be combined. This leaves a gap in terms of the analysis of the practices based on the combination of the three approaches. While documented analyses of the individual challenges confronting these approaches can be found and, in some cases, limited overlapping binary challenges are described, the specific analysis of the root causes for the complexity that arises when delivering these frameworks in combination has *not been reported* in the literature to date

Rationale for the shift in the research focus

Based on the research gaps identified, research questions were articulated in a way that helped contribute to filling this gap in the published literature. It is noteworthy that this study's research approach allowed the research design to evolve and adapt to new knowledge throughout the process, taking an exploratory approach.

Firstly, Research Question 1 asked: *To what extent are there examples in which all the three approaches have been combined*?. Any examples that exhibits characteristics of the three approaches combined would be new to this area of research and placed at the forefront of developing urban water planning and management knowledge. While the theoretical basis can be developed regardless of location, there are only a small number of places that this knowledge finds expression on the ground. Literature suggested that practices associated with the paradigms upon which this research is built were emerging in the metropolitan areas of the South Eastern seaboard of Australia. Document analysis and semi-structural interviews with senior professionals in the Australian urban water sector were, therefore, utilised to answer this question.

In response to the lack of analysis or a framework that exhibited qualities of the three approaches, Research Question 2 proposed: *What tensions/challenges might arise when adopting the three approaches?* The examples of tensions/challenges were extracted from the semi-structured interviews that were prepared to elicit practical experience and knowledge from urban water planning and management experts.

As the research evolved, some changes needed to be made regarding the focus, objectives and thus, research methods to address this question due to several reasons. The initial plan was to identify and analyse the challenges, and then explore the solutions through deliberative workshops and focus groups with a wider group of industry professionals. However, the turning point came after the findings from the document analysis and the first round of interviews were scrutinised. It surfaced from the interviews that the current practices have been struggling to deal with the complexity and uncertainty that would accompany the adoption of sustainable practices (within the frameworks of IUWM, PP, and AM). Interviewees revealed that there is a high level of complexity and uncertainty associated with the issues in enacting new/innovative practices. Through the conversations with interviewees, this level of complexity and uncertainty associated with currently planning environment was difficult to fully comprehend by industry practitioners at the moment, which currently creates confusion and a lower level of confidence in investment plans. Consequently, the situation might force decision-makers to resort to the business as usual or 'secure' infrastructural solutions. The findings from the first round of data collection underlined the issues of "complexity" as a fundamental problem that needs to be addressed to inform the desirable transition.

To that end, this research focus evolved from purely identifying and analysing tensions arising when integrating the three approaches (IUWM, AM & PP) to more closely investigate the questions of complexity and uncertainty. As a result, the Cynefin framework (CF), a sense-making framework from the realm of complexity theory, was introduced and adopted in the second round of interviews to further unpack the concept of complexity and the root causes of the related challenges. This part of the research focused on the Greater Sydney case study, especially in relation to the 2017 Metropolitan Water Plan (MWP).

Research questions 3 and 4 were modified to accommodate the shift in focus better. Question 3 was drafted to focus on further exploring the underlying issues related to complexity. Question 4 shifted from assessing the practicality of the analytical framework used in the first round of data collection to examining the available tools and methods that have the potential to deal with complex issues identified in the second round of semi-structured interviews.

All research questions are summarised in the following table.

Table 8. 1: The refinement of the Research Questions

	The initial research questions	The evolved research questions
1	To what extent are there examples in which all the three approaches have been combined?	no change
2	What tensions are evident when planning water services using the three approaches?	What tensions and broader challenges are evident when planning water services using the three approaches?
3	How can these tensions be avoided or overcome?	What are the underlining causes of the tensions and challenges?
4	Is the analytical framework a practically relevant tool?	Are the current available tools appropriate for dealing with complex problems?

The impact of COVID-19 pandemic on research process

Regarding changes in the research design, the shift in the focus was not the only influencing factor. During the past two years, the COVID-19 outbreak imposed critical hurdles on data collection and analysis processes.

In early 2020, the Government issued a social distancing policy and multiple month lockdowns in Sydney. Those interventions led to significant changes in the way people socialised and communicate with others, altering the data collection methods for this thesis. Initially, the second round of data collection, which was designed to seek solutions, consisted of a series of deliberative workshops with various professionals across the urban water industry. The workshops were initially developed to allow participants to deliberate over the questions of complexity and 'socially construct' the meaning of CF domains and their boundaries in the context of urban water planning and management in Greater Sydney. However, the COVID-19 pandemic escalated right after the invitations were sent out for the first workshop and made a deliberative discussion physically impossible. Hence, it delayed the research progress since the researcher required an alternative data collection technique in an online medium. Due to the limitations of time and resources available for the PhD program and the difficulties of data collection in lockdown, online semi-structured interview based on a CF perspective were chosen as the primary data collection approach for the second round. The method was chosen due to its ability to foster in-depth discussions and its feasibility regarding logistics in coordinating and implementing compared to an online workshop.

Structure of the chapter

This chapter provides a summary of the findings, reflection, and evaluation of the research process. To that end, it is divided into three main parts. First, how the findings answer research questions and meet the overall research aim are summarised. Afterwards, the potential ways to deal with future complexity and uncertainty are discussed.

8.2 Addressing the research questions

The broad aim of the thesis is to answer the overarching question: *How can urban water service planning and management simultaneously incorporate adaptive, integrated and participatory approaches when dealing with complexity in the Australian context?* Therefore, the research investigated four sub-questions by adopting an exploratory nested case study approach that utilised semi-structured interviews as qualitative data collection technique and thematic coding, and provisional and grounded theory coding techniques for analysing data with the help of NVIVO12. This section is dedicated to a summary of the findings that assemble the answer to those four research questions.

8.2.1 Research Question 1

To what extent are there examples in which all the three approaches have been combined?

This research question was designed to investigate the overall applicability of the approaches from interviewees' perspectives and experiences and reflect on it with reviewed literature. It was reported that the IUWM, AM and PP approaches are highly intertwined and should be considered together. Currently, the IUWM approach and the adaptive pathways planning approach seem to have received the most attention recently.

The pervading view was that the current practice of IUWM and PP has been carried out in a sub-optimal manner as several associated issues with the design and implementation were revealed. While the concept of IUWM has been around for many years, the execution and the idea is 'not business as usual' (N2).

Engagement with the community has been regarded as a critical element of IUWM by the interviewees. While it is also not usual practice, attempts reportedly resulted in high-level engagement ('consult' and 'involve', according to the spectrum of engagement from IAP2) and a number of examples have been cited in this thesis. This finding partly contradicts the common outcome from the literature that indicates that public participation has not been well adopted and incorporated into the decision-making process.

Also, the AM approach has only been considered in the urban water sector recently when adaptive pathway planning appeared on official documents as a response strategy to uncertainty. Varying perception have been found of the AM approach with unclear definitions and unclear methods to implement it in general.

No case on the ground could be found that exhibits the principles and qualities of the three approaches in combination, and this was supported by the reviewed literature, and systemic changes required to mainstream IUWM approach in practice are rare. So far, the most elaborate effort to popularise the integrated approach is the development and implementation of the 2017 Integrated Water Management Framework for Victoria. Within this framework, the unified platforms for collaborations between involved stakeholders at different levels, and the commitment of the Government to support the mainstreaming of IWM financially and institutionally are making the most changes to the landscape of urban water sector in Victoria.

A number of implications can be drawn from the research in this thesis regarding how the approaches are integrating together. Firstly, designing and carrying out public participation processes when engaging IUWM and AM is costly and time-consuming. It is perceived to be challenging to nurture meaningful engagement and contribution within the framework of IUWM and AM approach as the community needs to be well communicated and educated. Thus, this imposes a high investment and long timeframes to bring experts to explain to the community such as was found in the examples of Sunbury Water Future or Yarra Valley Water's citizen jury. Furthermore, while incorporating various perspectives can help overcome conflicts and misunderstandings, it might also lead to raising unresolved ones, and thus, have the potential to drive the process 'off track'. Besides, it was found that it might be problematic to maintain continuous community engagement as the AM approach is based on ongoing monitoring, evaluation, and adaptation over a long time. Further, it is reported that water professionals still struggle to define when should be the appropriate timing for the engagement program to be carried out in relation to the whole plan.

Secondly, the inherent complexity of IUWM and AM was highlighted as one of the main hurdles for stakeholders' collaboration and community engagement. This complexity was suggested to be comprised of several issues: i) so far, no method was proven to be effective against communicating complexity to laypeople and even stakeholders; ii) people discussed the problem of assigning responsibilities and actions with cross-jurisdictional cooperation and the conflict of interest as organisations have different priorities when implementing plans; iii) there are people in parts of the industry whose mindset imposes high resistance to the whole idea of collaboration within a holistic multidisciplinary framework to explore future uncertainty. These obstacles limit the extent to which those approaches are integrated.

8.2.2 Research Question 2

What tensions and broader challenges are evident when planning water services using the three approaches?

In seeking the answer to this question, this research focused on gaining insights from the knowledge and experience of senior urban water professionals through a semi-structural interview as a qualitative data collecting technique. From the outset, the professionals reflected from their experience on the kinds of issues that exist with applying each approach separately in the urban water planning and management process. There were intersected discussions on the difficulties when it comes to adopting IUWM as well as Participatory approaches. Thus, the related issues with the two approaches will be outlined together within this segment.

Several notions about difficulties that made organisational collaboration and community engagement process sub-optimal were reported. The intertwining issues concerning the *overlaps of responsibilities and authorities*, *the lack of leadership* with high commitment to an integrated approach, and the *entrenched culture of the organisation* were identified as obstacles in establishing effective and successful collaborations between involved organisations.

Furthermore, on the topic of community engagement, which was seen as one of the main pillars of the IUWM approach, the *strain on resources when carrying out community engagement programs,* and the *challenging complexity of planning and management concepts* which in this case was the IUWM approach, were found to be key challenges. For a 'true' public engagement, it was reported that a considerable amount of money, time and human resources are required to improve participants' knowledge and understanding of the objectives and processes of the matters at hand. Moreover, the time-consuming aspect of the community involvement program is reported to slow down the overall timeline of a project or plan. Further, the timing of when public engagement program commences in the context of the plan development or project implementation is important as it can potentially enhance or diminish 'people's buy-in'. The final concern was that the complex nature of the IUWM approach led to difficulties in communicating with laypeople. The complexity here can be interpreted as considering multiple dimensions interconnecting with others, such as the integrated system's social-political and social-technical components.

Regarding the adaptive management approach, the ongoing attribute of *long-term nature of projects*, *the understanding of the involved parties about the adaptive planning concepts (or lack thereof)*, and the *lack of confidence due to uncertainty* were raised as inherent problems to implement. The challenge of maintaining ongoing collaboration and consistency of institutional arrangement over an extended period were identified in association with changes in personnel and management level officers. Also, as there have been no documented cases of the implementation of the AM approach in the urban water sector, there is some concern that some concepts such as the 'soft' approach to flexible solutions in dealing with uncertainty are hard to convey to the stakeholders and the community. Although the most critical objective of employing an adaptive approach is addressing uncertainty, this can be a problematic idea to convey to the public and stakeholders, and thus, it generates doubt in the investment decisions.

Besides capturing the perceptions of water professionals on the three approaches individually, the research also explored the challenges when it comes to *combining* all three. Among those, the four of most interest related to i) *community engagement*, ii) *the difficulties in comprehending the concepts of IUWM and AM*, iii) *the challenge of taking up the three approaches given the rigid mindset of professionals in the water industry*, and iv) *the complications of planning and implementation at a range of scales*. It is difficult for laypeople to understand and embrace uncertainty regarding public engagement. This difficulty might erode their trust and confidence in the decision-makers or the decision-making process. Plus, when complexity and uncertainty need to be communicated to the public, in many cases it costs a lot of money and time to allow 'true participation'. Concerning the complexity of the IUWM and AM concepts. Further, it was reported that the responsible organisations lack the necessary knowledge and experience regarding these approaches and the lack of communication tools to get the messages across to their peers and the community. In addition, the Newtonian/mechanistic mindset and risk-averse attitude associated with some professionals working in the sector might cause them to resist innovative thinking or a methodology that resided in uncharted territory. Lastly, the overlapping nature and complexity of the different planning and implementation scales for IUWM was repeatedly raised during the data collection phase.

Overall, those findings uncovered fundamental problems related to *complexity and uncertainty* that need to be dealt with to move forward with the transformation of the planning and management paradigm. Thus, questions around the complexity and uncertainty needed to be explored to address the process of marrying the three approaches. The results of that exploration are captured in answering the subsequent research questions.

8.2.3 Research Question 3

What are the underlining causes of the tensions and challenges?

This question seeks to unpack the complexity and uncertainty that were referred to in the first-round interviews. Thus, a complexity theory perspective was adopted as a new lens to gain better insights into planning and management for future urban water. Accordingly, the research deliberately employed CF, a conceptual sense-making tool, to explore underlying issues related to the highlighted complexity and uncertainty. To be more specific, the concepts and principles of the four main domains within CF, namely simple, complicated, complex, and chaotic (figure 4.5), were used as a guide and a theoretical standpoint to reflect on the literature and the previous findings, to develop interview questions, and to structure the analysis of the transcripts for emerging issues and potential solutions. The findings using this approach are reported in two parts.

8.2.3.1 Urban water planning responses through CF lens

The first part captured the current context of urban water planning and management in the study areas by breaking down and making sense of it through the lens of CF. Data from the first round of interviews and information from an analysis of relevant planning documents and reports were scrutinised to gain better insights on high-level case studies by examining urban water practices regarding their respective operating domains according to CF. The analysis exploited the exploratory and explanatory power of CF to understand approaches to urban water planning including historic examples at different complexity levels.

Regarding the simple domain, the thesis argues that parts of the current system still rely on a conventional technocratic approach to manage urban water streams. The analysis of the interview transcripts and documents pointed out that there are practices that fit with characteristic in simple domain, such as:

- The reliance on linear deterministic models to mimic a simplified and controlled system
- The 'right' decision on infrastructural solutions based on modelling the most preferred scenario
- The tendency to employ a discipline-specific approach where water supply and demand, stormwater, and wastewater management are considered separately in planning.
- The confidence in best practice management approach drawn from different guidelines and designs for standardised services. The 'integrated water cycle management (IWCM) check list' can be an example.

- The reliance on technical experts in decision-making process means that there is minimal room for laypeople to join the conversation. Thus, community engagement remains at the 'inform' level.
- Business as usual valuing certainty of outcomes

The author believes that the current development state of IUWM in the study areas is operating within a complicated domain for a few reasons. First of all, while analytical processes within an IUWM project have been considered more perspectives and multi-disciplinary knowledge to understand the integrated system, it does not account for uncertainty, as confirmed by the interviewees. Secondly, deviating from the principle of the simple domain, outcomes of the IUWM process usually consist of multiple options associated with multiple plausible scenarios. Those features align with the principle that causes and effects in the complicated domain are not always visible to laypeople and require analysis from experts.

Regarding public participation practices, examples where there were better established and coordinated programmes that bring the level of engagement up to 'consult' (according to the IAP2 spectrum, Figure 2.8) include the citizen jury used by Yarra Valley Water, the deliberative forums in Sunbury Water Future, or the fact that marginal groups of the public such as farmers or Aboriginal community. These examples would suggest that the approach is evolving.

From the author's perspective, the evolution to perceive urban water problems as complex issues and embrace uncertainty should be the overall goal of the sector, given how fast the changes can impose damage to society (examples on catastrophic events in Chapter 3). In practice, there are parts of the industry that are trying to engage with uncertainty by picking up elements of adaptive management in a planning. Overall, the current trend toward sustainable urban water planning is conceptualised as the commitment to a flexible strategy in long term where all options are considered while avoiding lock-in interventions and endorse the use of adaptive pathway planning. Several examples of this in recent years were discussed in depth in Chapter 3, section 3.2. Further, the experimental approach which is among the most critical elements to probe the system can be found in cases such as the 2021 Lower Hunter Water Security Plan and the initiated but never fully implemented NSW WaterSmart Cities program.

While, the chaotic domain is not the focus of this study, the author perceives it as a state of emergency that the system is pushed into. The situation urgently needs to be moved into another domain rather than remain in that operational context. So, the presence of the chaotic domain adjacent to the simple domain helps explain how the simple approach such as 'predict and control' can accelerate the system into chaos when unexpected events happen such as the prolonged dry spell that contributed to severe bushfire in late 2019.

8.2.3.2 Emerging issues of complexity

In the second part, root causes and underlying issues of the seeming complexity and uncertainty that emerged from the second round of interviews, guided by the CF lens, were analysed and synthesised into six key topics.

i) The technical complexity of implementing IUWM and AM.

It was found that a lack of technical understanding and hands-on experience the high computational burden required for the simulation models was required. The modelling and thorough quantitative analysis of an integrated system requires substantial advancement in terms modelling approaches and tools. Further, the challenges were also related to the scale of application which significantly influence the number of variables, scenarios, possibilities and calculations. This thesis argues that the uncertainties of 'imperfect knowledge' and 'incomplete knowledge' contributes largely to the technical complexity. Basically, it is the situation where the modellers, planners and decision makers do not have sufficient knowledge and perspectives (of multiple agents functioning within the system) about the system which is being modelled.

ii) The complex governance and institutional arrangements.

Several problems constituted this group of issues. The prominent is the fragmentation of current governance and institutional arrangements, which is more commonly known as the 'silo effect'.. These are areas where the responsibilities are 'split' between organisations, such as stormwater management in Sydney (by local Government and Sydney Water). The unclear authorities, obligations, and benefits has led to the conflicts that stood in the way of a combined approach. Moreover, a unified framework, a guideline, and a vision is needed. So that organisations can interact with each other, share understanding, and jointly plan for and manage an integrated system. As a result, their organisational views, objectives, and priorities might not align with the IUWM approach and might clash with others. Therefore, there is a need for more policy support and incentivising to create a flexible yet structured environment for organisations representing different components of the urban water system to collaborate.

iii) The uncertainty of climate change owing to the unpredictability of the climate variables.

It has been reported that there is a disparity in outcomes from different modelling approaches when it comes to precipitation and drought projections in the context of climate change. Moreover, the predictive capacity, which is based on the current state of knowledge, has been criticised for holding low credibility. Besides the fact that recent catastrophes, such as the 2017-2020 severe drought, black summer in the late 2019, and 'recent emergency' flooding in 2022 (more detail in chapter 3), were outside of the planning envelope. The concern about the current observed data as an inadequate source of input to generate reliable projections has also been raised as a significant issue.

iv) Professional mind sets

The fourth difficulty that stemmed from the complexity was again the rigid mindset of some professionals regarding accommodating complexity and uncertainty. This is manifest through the technical/infrastructural focus on interventions, which might be due to an underlying conventional approach to problem-solving. This focus seemed to foster the risk-averse nature of investment decisions when accounting for uncertainty in the process.

v) Poor communication

Poor communication is the fifth difficulty. The lack of communication methods can impede everyone's understanding of complexity and uncertainty — the public, practitioners, and decision-makers alike. In practice, complexity and uncertainty tended to be oversimplified, so that it is easier for stakeholders to understand the integrated system, which results in higher level of certainty to make decisions upon.

vi) Lack on externality estimates

Finally, the lack of economic evaluation for non-market value is a barrier to realising the full range of benefits that sustainable alternatives might offer.

Studies have shown that economic and even financial benefits might be generated in an integrated urban water system that adopts an adaptive management approach to increase its resilience, such as Mukheibir & Mitchell (2014) and Rust et al. (2020). However, the trade-offs between higher capital investment and higher system resilience are still unevaluatable. It appeared that the initial cost of sustainable measures is higher than BAU if the intangible long-term social and ecological benefits could not be factored into the evaluation.

8.2.4 Research Question 4

Are the current available tools appropriate for dealing with complex problems?

Built on the findings from the first round of interviews, the author presumed there was a lack of methods and tools that can operate well within the complex domain to deal with complexity and uncertainty. Hence, the second round of interviews aimed to obtain further insights on that supposition from the CF point of view. The outcomes suggested that interviewees believed several current methods and tools could operate in the complex domain. Nevertheless, this research has argued (chapter 7) that some of those methods and tools are only useful in the 'ordered' contexts (the simple and complicated domains), and only a few showed potential in the complex domain. In response to this research question, the findings have been analysed and discussed through different perspectives, including a CF point of view, an assessment of how those tools can address the identified issues, and a combined approach (IUWM, AM and PP) perspective.

8.2.4.1 From a Cyenfin framework perspective

Overall, the interviewees proposed five tools that can be used to deal with complex issues. The author recommended the sixth tool (or group of tools to be exact) related to community engagement (CE) since it is essential to many other methods and can work well within all contexts, except the chaos domain. It can be observed from figure 7.3 (from chapter 7) that only the methods for 'pilots and learning experiments' (PL) have the potential to engage with the complex domain. While scenarios Planning (SP), Adaptive Pathway Planning (APP), and Real Options Analysis (ROA) should be positioned on the boundary between complicated and complex domains, there is a subtle difference in their placements. The last one, Multi-Criteria Decision Analysis (MCDA), operates well in the complicated domain. The context matching exercise was carried out by drawing and reflecting on interviewees' insights and the author's understanding and interpretation of CF domains in the urban water context.

In detail, PL offers an effective means to 'probe' the system so that the desirable patterns can emerge during the 'testing' process. Also, PL was invented to tackle uncertainty head-on and seek reasoning behind events in retrospect. In other words, it offers a learning cycle as the experiments progress. An experimental approach has always been a vital component of an adaptive management approach to exploring future uncertainty. Hence, PL holds the most merit among the tools for dealing with complex issues.

While APP embodies the development of flexible strategies to adapt to changes over time and embraces uncertainty within the planning process, the analysis relies on a deterministic modelling approach. Moreover, the APP method at this point of development can only accommodate a single objective at a time. Further, coming up with a preferred pathway in planning means that assumptions on plausible scenarios must have been made. Thus, the downside would be the under-preparedness of pathways when unexpected extreme events occur. For that reason, the author believes that APP sits on the boundary between complex and complicated domains.

ROA is valid as an economic evaluation tool for 'optioneering'. ROA assists decision making by proposing flexible responses to the matter after considering multiple uncertainties. However, in practice, ROA relies heavily on black-box models that use deterministic inputs for variables and risks to calculate the likelihood of potential outcomes. Further, similar to how plausible scenarios were made in APP, in ROA, assigned possibilities based on assumptions about future conditions might provide a false sense of security and mislead financial evaluation of costs of water supply by decreasing the probability of catastrophic events. Therefore, according to the author's opinion, ROA should also be positioned between complex and complicated domains but lean more toward the complicated realm than the other one.

Regarding SP, it has already been used regularly in planning as an analytical tool to investigate options against different future conditions. The current use fits well with the complicated domain principle. However, the method is believed to hold the potential to push planning practices to the complex domain. SP can potentially be used as a thought experiment to explore different futures trajectories and uncertainty by adopting a qualitative approach at the strategic level. Moreover, it could be used as a means for back-casting planning. As a result, in the author's opinion, SP can become more useful in dealing with uncertainty compared to APP. Thus, SP should be more into the complex domain (as shown in Figure 8.1).

MCDA offers a range of powerful analytical tools to engage with both quantitative and qualitative data. However, the criteria and indicators are usually developed from well-understood actions and their consequences. The method is linear and deterministic in its simplest and most commonly used form. Hence, it is a powerful tool in the complicated domain.

Community engagement methods and the associated tools and techniques have been seen as crucial components in any plans and strategies by interviewees and commentators in urban water planning and management. A variety of methods and techniques representing the different levels of engagement can be tailored to solve issues that reside in either simple or complicated or complex domains. Literature has shown a glimpse of that versatility. For example, the continuous public engagement program within the Lower Hunter Water Security Plan (LHWSP) revealed a 'involve' or even 'consult' level of engagement through focus-group and multiple deliberative forums held over the years. The view of the community has been factored in the holistic discussions about water systems that helped shape integrated response strategies to drought and other uncertainties. So, in theory, this example can be perceived as an attempt to use public engagement tools to tackle complex problems. Moreover, the decisive role of community participation in supporting and contributing to the implementation of pilot studies or experiments in real-life settings has been learnt from several instances (section 7.5).

8.2.4.2 From an assessment of how the tools can address identified issues

The analysis that sought to answer this research question has also considered the proposed capacity of the tools to address issues identified from two rounds of interviews, as captured in table 7.7. (from Chapter 7). The proposed use of the tools was conceptually based on what the literature documented about their applications and what the interviewees shared about their uses. Some highlights from the table are discussed in the following paragraphs.

Overall, the tools appeared to respond to different challenges, but none can be considered suitable for all the challenges. As summarised in table 7.7, in different ways, all the tools/methods can contribute to addressing the problems either related to a rigid worldview or the lack of communication tools. The collaboration component is the crucial feature that contributes significantly to the ability to change one's worldview and help form communication mediums shared by multiple methods. The applications of those methods all offer opportunities and platforms for the stakeholders and the community to engage in activities that encourage knowledge and perspective sharing. For instance, stakeholders and community engagement programs in scenarios and strategies development consist of educational and deliberative processes found in such cases as Lower Hunter Water Plan (2014) and Sunbury Water Future (2019). In both instances, the community's view has been reported to align with the overall goal of maximising social, environmental, and economic benefits and supporting a range of sustainable options, including fit-for-purpose recycling and reusing stormwater and wastewater water conservations and green infrastructures.

Interestingly on the two issues: technical complexity and the complexity from different planning and implementation scales, the applications of pilots and learning experiments were the only and the most appropriate ways to tackle these. The critical element of this method is the learning process from the experimental approach, by which both incomplete knowledge and imperfect knowledge could potentially be addressed. In general, pilots and learning experiments delivered information on uncertainties in various aspects of implementation processes, such as construction difficulties, technical feasibility, approval processes, and institutional arrangement. More details can be found from the review of the cases, such as the Aurora and Aquarevo residential developments and the Central Park precinct (undertaken in section 7.5).

8.2.4.3 From a combined approach perspective

Further, the effectiveness of the tools was assessed against how well they are used across multiple approaches. Diagram 7.4 (from chapter 7) should be referred to as it shows the locations of current applications of methods and tools against the three approaches, according to literature and information from the interviews.

The use of scenario planning and various tools associated with community engagement have been the backbone of integrated urban water management and planning for a long time. In recent years, from the author's point of view, in response to the numerous uncertainties primarily related to severe droughts, it has been observed that the Australian urban water sector has recently tended to adopt adaptive pathways planning in their plans. The method relies basically on developing a range of long term, flexible scenarios in which different alternatives can be switched to when new information is revealed. While documented implementation is rare, the signs of SP and CE have been selected to accommodate IUWM, AM, and PP principles can be found in cases such as the 2014 Lower Hunter Water Plan or the 2019 Sunbury Water Future plan (as discussed in chapter 7).

Moreover, there have been recent cases in which pilot and learning experiments might potentially be utilised within a combined approach (more information in section 7.5). Pilots and learning experiments have been used initially to test the technical feasibility and uncertainties of implementing integrated interventions, predominantly associated with the IUWM approach. Also, from the author's point of view, PL's underlying concept of learning retrospectively by doing plays a vital role in an adaptive management approach. Further, it has been revealed that the community engagement process, which fosters social learning and increases public compliance, is a decisive factor for the demonstration projects to be successfully implemented and learned from. The draft Lower Hunter Water Security Plan (NSW DPIE, 2021) is a typical example where pilot plans of purified recycled wastewater, an integrated solution, are proposed to demonstrate the technology, educate the public, and obtain their perspectives.

As mentioned above, APP has been recently picked up to target the uncertainty element of the planning. The method was born as a variation of the classic adaptive management approach, where the modelling approach is exploited extensively to materialise possibilities of unexpected future conditions. As a result, it has not accounted for multiple objectives associated with the IUWM approach. Furthermore, there is are limited examples of where APP has utilised a participatory approach, such as the long-term flood protection project for Hutt City, New Zealand. The author still believes it stands on the boundary of the participatory and AM approaches based on the possibility that metro-map-like transient pathways can be helpful in engagement programs.

ROA has been used in the IUWM, and AM approaches to evaluate options and support flexible strategies. However, as its analytical power comes from complex modelling practices and many assumptions, it is challenging to report and communicate the underlying technical concepts and results to decision-makers, let alone to the community and therefore is not ideal for engagement purposes.

MCDA has been primarily applied with an IUWM approach, where the tool contributes to evaluating and selecting alternatives. MCDA can integrate both quantitative and qualitative data, thus helping balance the objectives of stakeholders and the community. Therefore, it has been positioned in the overlap of IUWM and PA.

8.3 Proposed way forward

Finally, in answering the overarching question: *How can urban water service planning and management simultaneously incorporate adaptive, integrated, and participatory approaches when dealing with complexity in the Australian context?* the following lessons and recommendations are put forward to support the transition towards an integrated approach and to accommodate uncertainty in the planning.

1) Firstly, ***the methods and associated tools should be applied and coordinated together*** in a framework guided by a combined approach to better address complex problems.

There are several implications on the applications and potential of the tools/methods that can be interpreted from the above discussions. Among those tools identified in this research, some are not necessarily compatible to operate in the complex context of CF. Furthermore, they are not capable of addressing the challenges identified (in table 7.2 on their own. In addition, it has been argued above that a tool that encapsulates the principles of its original approach (AM or IUWM or PA) can only to a limited extent enhance certain aspects of the whole planning process.

Those implications bring more insights to the premise of the second round of interviews that focus on a mismatch between tools or methods to address problems in the complex domain. It has been observed that a shortage of tools in the complex domain hindered the undertaking of the identified group of issues. Furthermore, there is also a lack of tools that can be adopted across the three approaches (IUWM, AM & PA). In the author's opinion, a reason can be that the potential of the tools in combination has not been fully developed yet.

So, therefore, two intertwined directions for water industry are proposed. The first path is to continue researching, designing, and developing novel tools/methods to deal specifically with the high uncertainty of complex problems. This path requires ongoing and long-term commitment, as well as changes of a set of beliefs. Therefore, in parallel with that path, it would be better to try to develop the existing tools to their full potential and coordinate the uses of tools that are compatible with and complement well altogether within a framework guided by the combined approach. The author believes that it is possible for the tools to work collaboratively, supporting all three approaches, as shown in figure 8.1.

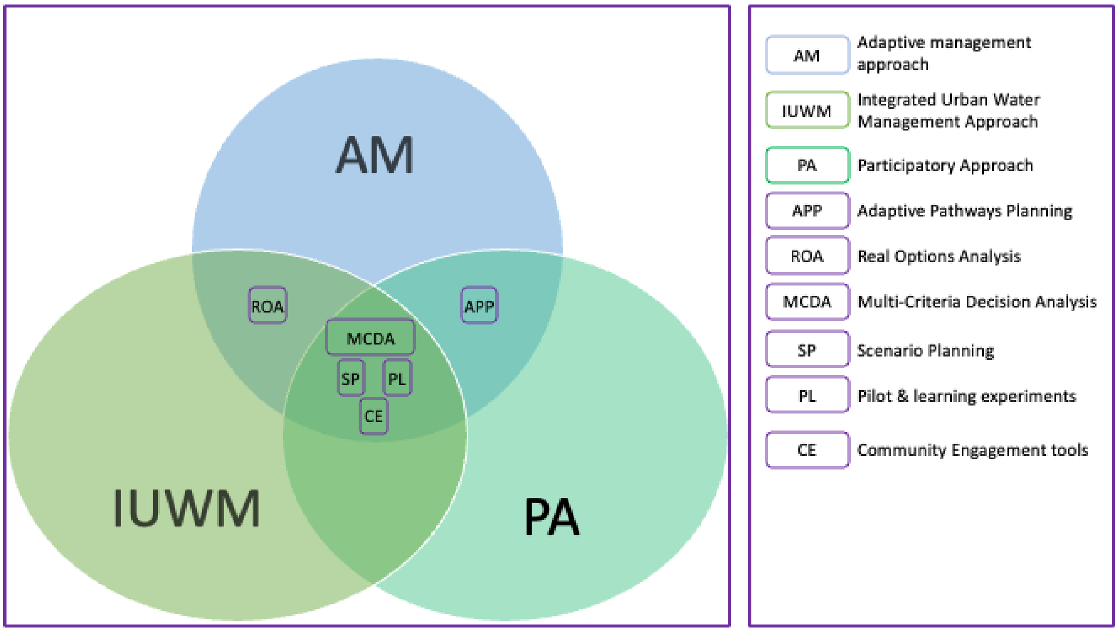


Figure 8. 1: how the tools could fit within the combined framework (potential)

The APP should be able to accommodate both AM and PA approaches. The intuitive visualisation of the APP can be utilised to communicate, educate, and engage the public throughout the decision-making process. The inherent technical complexity of APP creates the need for an approachable explanatory method for communication and rigorous attention paid to educating the community about water literacy and the planning approach prior to engagement. For APP to consider multiple objectives within the IUWM approach, more research is required to mobilise modelling complexity without trading-off robustness and transparency.

Besides the current practices in IUWM and PA, MCDA and SP are among the most versatile methods available that can be used in a combined approach. Both methods have currently been used within the integrated planning approach and community engagement thanks to their ability to complement each other to perform stress tests, options performance evaluations, conflicts mediation, etc., to support future strategies. Both have the potential to explore changes from unforeseen events with adaptive pathways planning as an updated version of scenario planning, and MCDA can provide a means to materialise the visions from strategically qualitative practice.

The PL is the main component of AM approach and plays a critical role in IUWM by trialling for the compatibility and versatility of integrated solutions. Moreover, in many examples mentioned here and elsewhere, community engagement is crucial for the experimental approach. The understanding and support of the public hold decisive power in whether pilots and demonstration programs have a chance to move forward.

As discussed in chapter 7, the 2021 Lower Hunter Water Security Plan is an excellent recent example of where the plan emphasised such an integrated approach and deployed many of these tools in a combined manner in response to a complex and uncertain future. Others can use the planning framework as a local example of how the proposed tools can potentially be combined within the whole planning and decision-making process. What remains to be seen is how the plan will be evaluated and be adapted to changes and as new information comes to hand.

2) The second recommendation is that more attention should be paid in the future to ***develop the techniques and practices for designing and implementing pilots and learning experiments***.

The learning element of this method holds unlimited potential when it comes to either improving knowledge on technical aspects in the future or acquiring insights on the barriers or impacts that the overlapping of planning and implementing scales might bring. Moreover, the method aligns with the principle of the complex domain, where the causal relationships are too complex to be investigated unless it is in a retrospective manner – i.e. a learning-by-doing approach.

3) Finally, it is necessary to ***provide capacity-building assistance*** for actors within urban water on IUWM and AP

It is noteworthy that the lack of knowledge and understanding about the IUWM and AM approach and the concept of uncertainties and its associated methods was a common thread throughout this research. This overarching issue is possibly the main reason for the rigid mindset that is resistant to collaborative, integrated and adaptive practices, and change in general. Therefore, following on from point 2 above, it is necessary to provide capacity-building assistance for actors within urban water systems including professionals, regulators, planners, investment decision makers, and the community. A possible way to move forward with this agenda could be to expose them to the knowledge and information of pilot studies, case studies and to engage them with more frequent detail educational participatory program on matters related to complexity and uncertainty.

In conclusion, to adequately plan for sustainable and resilient urban water servicing, this research has demonstrated that the sector needs to find a way to simultaneously incorporate adaptive, integrated, and participatory approaches, especially when dealing with complexity. A combined approach should be achieved through a process that draws on an understanding of the three approaches, employs available tools in a considered, appropriate, and effective way, and anticipates how deep uncertainty and complexity might interact with the systems in question. Such an approach is likely to invest in options that ensure adaptive decision-making. This proposed integrated adaptive and participatory planning approach is in itself an experiment. The proof of such adaptability and flexibility of any developed and proposed plan will be in its application over time and how its owners respond to changing assumptions.

Appendices

Appendix A: Consent form and information sheet

CONSENT FORM

PARTICIPATORY ADAPTIVE INTEGRATED URBAN WATER MANAGEMENT – POTENTIAL AND TENSIONS, HREC APPROVAL NUMBER ETH18-2548

I ____________________ agree to participate in the research project "Participatory adaptive integrated urban water management – potential and tensions", HREC approval number ETH18-2548 being conducted by Bao Anh Nong from Institute for Sustainable Futures, UTS +61 2 9514 4950.

I have read the Participant Information Sheet or someone has read it to me in a language that I understand.

I understand the purposes, procedures and risks of the research as described in the Participant Information Sheet.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to participate in this research project as described and understand that I am free to withdraw at any time without affecting my relationship with the researchers or the University of Technology Sydney.

I understand that I will be given a signed copy of this document to keep.

I agree to be:

☐ Audio recorded
☐ Video recorded
☐ Photographed

I agree that the research data gathered from this project may be published in a form that:

☐ Identifies me
☐ Does not identify me in any way
☐ May be used for future research purposes

I am aware that I can contact Bao Anh Nong if I have any concerns about the research.

____ ____/____/____

Name and Signature [participant] Date

____ ____/____/____

Name and Signature [researcher] Date

PARTICIPANT INFORMATION SHEET
PARTICIPATORY ADAPTIVE INTEGRATED URBAN WATER MANAGEMENT – POTENTIAL AND TENSIONS, HREC APPROVAL NUMBER ETH18-2548

WHO IS DOING THE RESEARCH?

My name is Bao Anh Nong, and I am a student at UTS. My supervisors are Prof. Pierre Mukheibir and Assoc. Prof. Simon Fane

WHAT IS THIS RESEARCH ABOUT?

This research is to investigate the potential and key possible tensions that might emerge when employing the three frameworks of Participatory approach, Adaptive Management and Integrated Urban Water Management simultaneously in strategic planning and managing urban water.

IF I SAY YES, WHAT WILL IT INVOLVE?

If you decide to participate, I will invite you to join in a 1 hour 30 minutes semi-structured interview.
The interview will be conducted online via Zoom a teleconferencing platform, and at the date and time that convenient for you.
Written notes will be taken, and the conversation will be recorded with your permission. Raw data such as notes, video, and audio will be store electronically; the hard copy will be destroyed right after. Only my supervisors and I will have access to the data. The data will be analysed and used to answer the research questions in my PhD dissertation, and probably in the journal papers or conference papers with your permission.

ARE THERE ANY RISKS/INCONVENIENCE?

Not really. However, the research aim is to improve understanding on current and future practices by eliciting the challenges and problems from a range of actors' perspectives. Therefore, it is likely that there will be conflicting opinions.

DO I HAVE TO SAY YES?

Participation in this study is voluntary. It is entirely up to you whether or not you decide to take part.

WHAT WILL HAPPEN IF I SAY NO?

If you decide not to participate, it will not affect your relationship with me or the University of Technology Sydney. If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason, by contacting Bao Anh Nong.

If you withdraw from the study, you are also provided with the option to have the audio and video records, the transcripts and written notes related to your interview destroyed physically and electronically.

CONFIDENTIALITY

By signing the consent form, you consent to me collecting and using personal information about you for the research project. All this information will be treated confidentially. You can choose to be named/credited along with the information you provide or de-identify or completely hidden your response.
All the information will be store electronically on ISF cloud server and in one personal hard driver with protected password, only my supervisors and I have access to the data.

We would like to store your information for future use in research projects that are an extension of this research project. In all instances your information will be treated confidentially.

We plan to publish the results in my PhD Dissertation/report and potentially journal papers or conference papers. In any publication, information will be provided in such a way that you cannot be identified.

WHAT IF I HAVE CONCERNS OR A COMPLAINT?

If you have concerns about the research that you think I or my supervisor can help you with, please feel free to contact me on anh.nong@uts.edu.au or +612 9514 4706 or +61 .
Alternatively you can contact my supervisors on Pierre.Mukheibir@uts.edu.au or Simon.Fane@uts.edu.au

You will be given a copy of this form to keep.

NOTE:
This study has been approved by the University of Technology Sydney Human Research Ethics Committee [UTS HREC]. If you have any concerns or complaints about any aspect of the conduct of this research, please contact the Ethics Secretariat on ph.: +61 2 9514 2478 or email: Research.Ethics@uts.edu.au], and quote the UTS HREC reference number. Any matter raised will be treated confidentially, investigated and you will be informed of the outcome.

Appendix B: First round of semi-structured interview guide

No.	Interview questions	Sub-questions/Descriptions	Timing
0.	Introduction to the study, and explanation of the three approaches.		5
1	What in your view are key characteristics of IUWM, PP, and AM?	The most significant elements of each approach.	5
2	What experience have you have integrating/combining any of those frameworks?	a. Which approaches are mostly applied? And why do you think that is? b. Are there any examples of where they have been integrated? c. Explore the examples (what? How? Why? So what?) d. What have been the benefits of these approaches working together/integrated?	10-15
3	What issues do you see as being common across these frameworks?	Exploratory discussions on the issues using the synthesised findings from literature review and document analyses as preferences	15
4	Can you shed some light on the possible challenges or trade-off when combining these approaches?	What were the challenges that you have encountered? Sub-questions might be structured based on elements of the framework (figure 3.5) (if the question cannot get them to share)	15
5	Are there any other examples? or Are there any other people that I can talk to in order to get further insights?		5

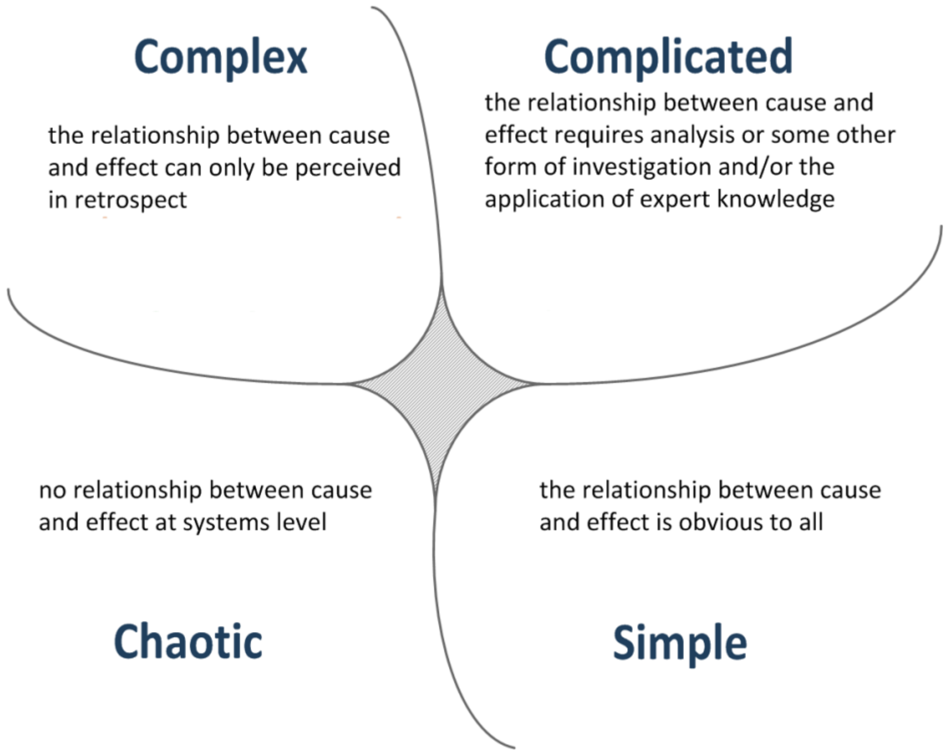
Appendix C: Second round of semi-structured interview guide

The second round was developed to engage the interviewer and interviewee in positioning exercises that determine how complex the matters of concern are. To that end, issues that might arise when combining the three approaches and the currently available tools and methods were deliberately discussed through the lens of the Cynefin framework. Therefore, the prerequisite condition was that the interviewees understood different concepts associated with the framework.

Cynefin framework was first introduced to the interviewees regarding the definitions and conceptualisation of the four primary contexts. Afterwards, overarching questions were asked and followed by exploratory sub-questions and discussions.

The table which provided a 'Cynefin map' and suggestive items on the left column was provided to utilise the exercises and facilitate discussions.

<u>The introduction</u>



The Cynefin framework

Simple domain	- Stable and predictable system - Clear, well understood causal relationships - There is always a right answer - Type of practice: best practice
Complicated domain	- System is stable and predictable by experts in the field - Cause and effect are not necessarily straight forward but definable with analysis - Multiple right answers - Type of practice: good practice that defined by expert skill and opinion
Complex domain	- Unordered and unpredictable system - Cause and effect can only be understood in retrospect - No right answer, only emergent practice
Chaotic domain	- Turbulent system - System is in an emergency emergency state, there is no need to understand causal relationships. - Type of practice: act to control the situation, then observe to response accordingly

<u>Interview guide</u>

<u>The first overarching question</u>: How complex the problems you encountered when doing water planning and management practice are from a CF perspective?

The interview questions:

What issues have you encountered?

Where would you place the issue into the Cynefin domains? And what would be the reason for that?

Other follow-up questions to any specific discussions were generated on spot to further explore interviewees' point of view.

<table>
<tr><th>Items</th><th>Complex</th><th>Complicated</th></tr>
<tr><td rowspan="3">1. Meeting 1 objective eg: stormwater mitigation
2. Meeting 2 objectives eg: supply demand balance and ensuring environmental flow
3. Meeting multiple objectives eg: supply demand balance, ensuring environmental flow, and flood control
4. Balancing resources and demand
5. Forecasting demand
6. Planning integrated services
7. Incorporating climate change impacts
8. Incorporating population growth</td><td>1. T1
2. T2</td><td>1. T1
2. T2</td></tr>
<tr><th>Chaotics</th><th>Simple</th></tr>
<tr><td>1. T1
2. T2</td><td>1. T1
2. T2
3.</td></tr>
</table>

9. Incorporating climate change impacts and population growth 10. Addressing multiple uncertainties 11. Addressing multiple objectives + uncertainties 12. Gaining community acceptance		

<u>The second overarching question</u>: How the tools or methods you used for urban water planning deal with issues of different complexity level?

The interview questions:

What tools or methods have you frequently use for planning and management?

Where would you place the tools/methods into the Cynefin domains? And what would be the reason for that?

Other follow-up questions to any specific discussions were generated on spot to further explore interviewees' point of view.

<table>
<tr><th>Items</th><th>Complex</th><th>Complicated</th></tr>
<tr><td rowspan="3">1. Approaches that built on the integration of water system components such as Integrated Water Cycle Management (IWCM); Water Sensitive Urban Designs (WSUDs); Integrated Urban Water Management (IUWM)
2. Economic evaluation methodologies such as Cost-Benefit Analysis (CBA), Cost-Effectiveness Analysis (CEA) - Least Cost Planning (LCP), etc.</td><td>1. T1
2. T2</td><td>1. T1
2. T2</td></tr>
<tr><td>Chaotics</td><td>Simple</td></tr>
<tr><td>1. T1
2. T2</td><td>1. T1
2. T2</td></tr>
</table>

3. Best practices guidelines for IWCM (in NSW) 4. Analytical tools/methods such as Multi-Criterial Analysis (MCA) or Multi Criteria Decision analysis (MCDA), Real Options Analysis (ROA), etc. 5. Numerical/ Simulation models such as hydrological models, end-use models, Agent-based modelling, etc 6. Decision supporting/ Planning tools or methods such as Risk assessment frameworks, Scenarios Planning, System thinking tools, etc 7. Dynamic Adaptive Policy Pathways 8. Resilience frameworks 9. Climate change impacts map 10. Pilots/Learning experiments		3.

Appendix D: Coding scheme for emerging issues related to complexity (second round of interview)

Name	Description	Cases	References
Climate change uncertainty		3	15
	Effect of soil moisture and CO2 in the atmosphere to bushfire.	1	1
	Importance of monitoring and evaluation	1	1
	models are conflict; uncertainty in drivers of low flow; unprecedented loss of river flow during drought	2	4
	Importance of data and its relationship with the scale of consideration	1	1
	Uncertainty of climate change related questions, variability or climate chagne	1	1
	Supporting examples for how uncertainty it is that climate change might bring	1	1
	The level of uncertainty that is unprecedented	3	8
	Impacts of climate change on supply options decision or planning	1	1
	The danger level of Uncertainty that outside of planning envelop in the case of severe drought in Sydney - unprepared	1	1
	the unexpected disappeared flow	1	1
	things far worse than what predicted happened, the response was unprepared	1	1
	Uncertainty vs certainty; challenge of factoring uncertainty in cost-benefits analysis and the certainty of desalination plants	1	1
	Unpredictability- modelling climate chang provide varied results	2	2

Name	Description	Cases	References
Communication challenge		3	15
	Lack of Methods to reflect understanding of the system	3	8
	A lof of variable data. No benchmark	1	3
	Communication of risks to realise opportunities and benefits	1	1
	Difficulty in communicating the complex of knowledge and expertise of models to DMs and community	1	1
	Too complex with all scenarios and variability	1	1
	Variability and complexity and uncertainty	1	1
	Suggestion for a communication tool that show the dynamic of the system considering uncertainty	1	2
	The need for certainty and simplification	1	5
	Certainty in black box options like building more infrastructure is appealing	1	1
	Certainty. communication. deterministic data. Simplification	1	1
	Resistance to new or complex info due to the lack of confidence	1	2
	What to simplify meaningfully	1	1
Difficulties in incorporating non-market benefit - social benefits - broader or wider benefit for the community, into C&B analysis		2	5
	It's hard because there is not much examples to learn from - lack of information-knowledge	1	1

Name	Description	Cases	References
	The notion of incorporating broader benefits to the community into cost and benefit analysis for water planning	1	1
	Tradeoff between the realistic, quantifiable benefit and vague, theoretical social value in C&B analysis	1	1
	Understanding social benefit as in externalities in economic evaluation is complex	1	1
Governance issues around water management		5	35
	Aside from split authorities, the funding mechanisms affects investment process	1	1
	Conflicting priorities - value proposition	4	16
	Conflict between views of organisations	2	2
	Conflicting priorities between organisations or part of the organisation	1	1
	Conflict of purposes investment return or social-wide benefit first	4	14
	Conflicting objectives or expected outcomes since the aims of DMs is generally about reducing cost rather than covering the risk appetite	1	1
	Conflicting perspectives on risk evaluation - public health = financial	1	5
	Long term interests of the society vs short-term interest of stakeholders and political parties that take advantages of the vulnerable side of the system	1	2
	Value proposition when viewing a problems - cost and benefit focused or broader environmental benefits	1	2
	DMs unable to deal with complexity due to time constrain	1	1
	Engineering and technology factors are not the main challenge but institutional barriers in applying IWCM	2	2

Name	Description	Cases	References
	Institutional arrangements	1	4
	Fragmented of institutional arrangement around Flood management in Sydney	0	0
	Fragmented institutional arrangements, different responsibilities in water Governnance	1	3
	No flood authority	1	4
	Split in institutional arrangement between sydney water and local governments over stormwater management	1	1
	Local councils-Government are only reinforce the floodplain guidelines	1	2
	No lead authority and responsibility in Metropolitan water space	1	1
	No one responsible for monitoring and evaluation in MWP 2017	1	1
	Lack of Gov Policies on incentives and pricing framework for IWCM make it hard	2	7
	Complexity around pricing process in Sydney	2	3
	Example of how the lack of Gov Policy can affect the uptake of integrated options	1	2
	Integrated options are expensive than BAU, than it always run into issues	1	1
	Political influences in MWP that hinderred its success	1	1
Oversimplification -	IWM or IWCM is too complex, often being simplify down to what people comfortable with, it then lose the nuance/opportunity of integrated approach and pull ppl back to BAU	2	6
	DMs like simple things so ppl tend to monetise environment or social costs and benefits	1	1
	Pricing authorities' capability to understand the industry	1	1
	Risk being simplified from complex straight to simple- lost of nuances	1	1

Name	Description	Cases	References
Philosophical point of view. World view		4	7
	DMs unable to deal with complexity due to time constrain	1	1
	Organisation want to do the same way as it always done	1	1
	Ppl worldview that does not want to think abou the systems in complex sense	2	2
	Strategic driver.phylosiphical point of view to change to integrated approach	1	1
	the framing is still C&B without realising the complexity of problems and how to deal with it	1	1
Requirement and Challenges for IWCM or in some case AM transitions		4	22
	Challenges to IWCM. lack of collaboration; community consultation; an understanding and valuing water cycle in context of climate change	1	1
	Collaboration across organisations is hard and uncertain	2	4
	Collaboration between organisations - regulators	2	2
	How mature the people are about having implemented them. IWCM, WSUD	1	1
	IWCM is not done well due to funding; how organisation is organised; people skills; and how systems are managed in non-integrated way	1	1
	Lack of Gov Policies on incentives and pricing framework for IWCM make it hard	1	1
	Integrated options are expensive than BAU, than it always run into issues	1	1
	Leadership - endorsement	1	3

Name	Description	Cases	References
	More attention to IWCM after extreme events - IWCM more resilience than BAU	1	1
	Spatial - locational - temporal scale issues in applying IWCM	1	3
	Team with high capability	1	1
	The importance of adaptive approach	1	2
	The need for a leader or higher ups to understand the work	1	1
	Uncertainty in implementation process	1	1
	The need for long term planning dealing with root cause of climate change	1	1

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